A Report on Field Research in Soils

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A Report on Field Research in Soil Science

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This 1990 edition of the soils "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 stations 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 appreciate the cooperation of the many farmers, agents, technical assistants, secretaries, and farm and business representatives who contribute time, land, machinery and materials which assist or enable the research this publication reports. Much of the research would not be possible without that support.

DISCLAIMERS

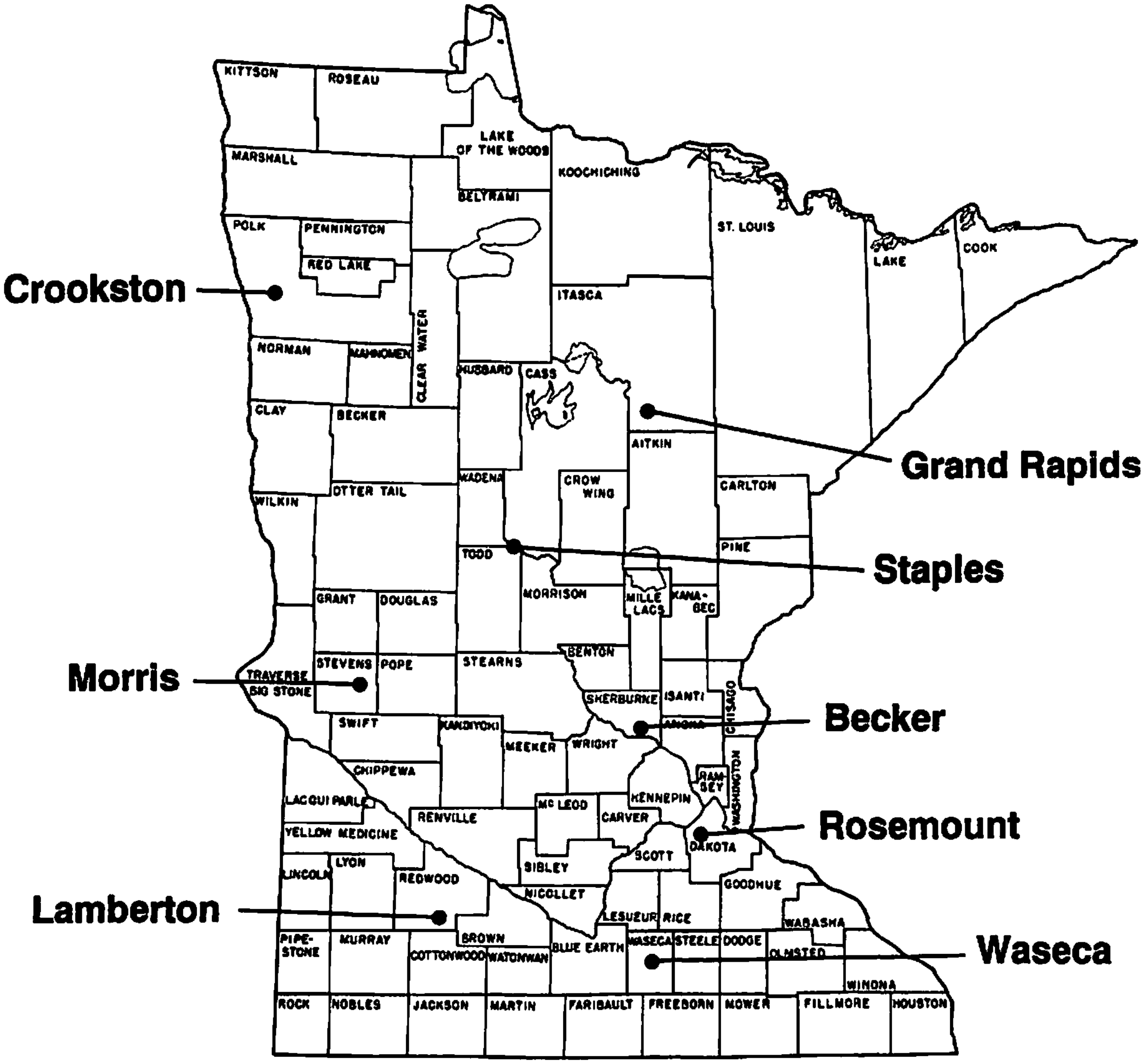
Some of the results reported in this publication are from 1989 experiments and should be regarded on this basis. Since most of the data is from 1989 studies only, stated conclusions may not be absolutely conclusive, and thus are not for further publication without the written consent of the individual researchers involved.

NOTE TO CATALOGERS AND LIBRARIANS

The numbering of this publication within the Miscellaneous Publication series changes with this edition of the soils "bluebook." To be consistent with other annual reports of ongoing research published by the Minnesota Agricultural Experiment Station, it will no longer be produced as an annually revised number "2" in the series. "Revised" implies that content, while updated and corrected, nevertheless parallels and otherwise covers the same territory found in earlier edition. By contrast, each of the last several editions of this publication has large amounts of new information and research. Each future edition will receive its own number current with the progress of titles in the series.

-- Series Editor

MINNESOTA AGRICULTURAL EXPERIMENT STATION BRANCH STATIONS AND RESEARCH FARMS



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CLIMATE AND CLIMATOLOGY, 1989

D. Baker, D. Ruschy, S. Evans, W.W. Nelson, J. Lamb, G. Randall, G. Spoden, and J. Zandlo[1]

ABSTRACT: At the time of writing, the drought that began in October, 1986 continues across much of the state. The drought is both hydrologic and agricultural in nature. The soil moisture remains low at many locations because of lack of the usual autumn recharge. Long-term Minnesota corn yields, from 1966-1989, are illustrated and discussed. Since about 1950, the mean increase has been 2.25 bushels per acre. As severe as 1988 was in terms of yield depression, it is shown that other years, particularly 1894, 1934, and 1936, were, relatively speaking, just as severe. Examples of the time change in the density of winter snowpacks is shown along with a density-time equation.

Our Ongoing Drought:

After public attention had been focused for nearly a decade on the abundance of precipitation, an abrupt reversal of the wet trend began in the fall of 1986 with rapid decline toward drought conditions. Drought is difficult to manage because it is a gradual phenomenon that has no well-defined beginning or end. While droughts are unpredictable, they are a normal feature of the North American climate. We're actually in the 40th consecutive month (as of February 1990) of drought conditions and this winter season, thus far, has done little to relieve apprehension for the coming growing season.

In 1989, Minnesota farmers harvested their best soybean crop and fifth largest corn crop. An indication of a return to "normal" weather? Unfortunately no. Minnesota's drought persists and it is now over three years old. Our agricultural good fortune can be attributed to well timed rainfalls and forgiving temperatures. However, as a whole, much of Minnesota received below normal precipitation for the past "hydrologic" year (October, 1988 - September, 1989). This comes on the heels of two extremely dry years, perpetuating the water deficit in Minnesota's overall hydrology. Many of Minnesota's wetlands, lakes, rivers, streams, and shallow aquifers require an abundant recharge to return to more desireable levels.

The climate Analysis Center of the National Weather Service quantifies the intensity of droughts by using a scheme called the Palmer Drought Severity Index. The Palmer index currently places northwestern and south central Minnesota in the "extreme" drought category, the worst case scenario. Most of the remaining agricultural regions fall in the moderate to severe category, whereas areas of north central Minnesota are near the neutral or "normal" class. While conditions in northwestern Minnesota are similar to last year at this time, there has been some improvement in the central tier of the state, with worsening conditions in the southern one-third of Minnesota.

Where do we stand as we enter 1990? Soil moisture in many areas is as short as it was entering the 1989 growing season. (See Fig. 1 which shows the cumulative departures of precipitation since 1987.). Extremely cold December temperatures and relatively little snow cover has caused a thorough and deep freezing of the ground. Over-winter precipitation will do little to add moisture to the rooting zone; therefore, growing season soil moisture levels will depend quite heavily on spring rain. Much of this winter's snowfall will likely run off along with frozen ground as it melts, causing an initial flush of water to the surface systems. This flush will be short lived however. True recovery of most of the hydrologic systems will occur only after moisture in the "unsaturated zone" (top few meters of the soil) is replenished.

Continuing precipitation shortages have reduced groundwater levels, reduced streamflows, and lowered lake levels. The length of time before these reduced water levels respond can vary greatly -- sometimes it is noticeable immediately, sometimes not until several months after the precipitation deficit occurs.

The 1989 Hydrologic Year Precipitation:

The hydrologic year, which extends from October to September, is often considered a better indicator of general conditions than the calendar year. This is true because the low point in stream flow normally occurs in October. It also closely approximates the agricultural season since precipitation in October and November is stored in the soil for use by plants in the succeeding growing season.

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The 1989 hydrologic year is shown in Figure 2. The total precipitation amounts received in the southern half of the state were generally below average and indicate why the 1989 crop was raised on "opportune" rains. In the extreme western part of the state, the amounts of some of the totals were quite marginal. This was accentuated in many soils, and not just in the extreme west, because there was little or no stored soil moisture from the previous season.

Soil Moisture:

Because soil moisture reserves in much of the state have not been recharged since September, 1986, the previous season's crop becomes very important when planning for the 1990 season. As a result, where small grains, for example, were grown in the 1989 season, the soil moisture is apt to be higher for the 1990 season than where sugarbeets or alfalfa, for example, were grown.

The change in the readily available soil moisture in the 1989 season is shown in Figure 3. It can be seen that at the end of the 1989 season the total water available in the 5-foot column of soil that was in corn was about 1.5 inches below the 1964-1988 average at the end of the season. The usual autumn recharge was missing in 1989, so the spring 1990 recharge becomes very important.

The 1989 growing season soil moisture changes at Crookston, Lamberton, Morris, and Waseca, are shown in Fig. 4. At all except Crookston, the crop was corn. The Crookston soil moisture is an average for three crops. The Morris data consist of two different soils -- the Hamerly silty clay loam, and the Tara silt loam.

Long-Term Corn Yields, 1866-1989:

It is a surprise for most of us to discover that statewide corn yields are available since 1866. They are shown in Fig. 5. The crosses represent the individual years and the solid lines the general trend for the indicated periods. It is apparent in Fig. 5 that although the yields varied from year to year due to the weather (and insects and diseases), there was no trend change between 1866 and 1938. That is, the overall yield for the 73 years between 1866 and 1938 was nearly constant at 30.1 bushels per acre with weather creating the difference between years. The severity of the drought and heat of 1934 and 1936 is made very evident by the low yields. The year 1894 was also a poor crop year.

Beginning with the year 1939, there appears to have been a marked change in corn yields. The 11-year period of 1939-1949 saw the mean state yield increase to 42.3 bushels per acre. This increase can probably be ascribed to the introduction of hybrid corn. The selection of the exact year to begin the next period is arbitrary, but beginning approximately in 1950, with the increasing adoption of new technology (such as commercial fertilizer, particularly nitrogen, denser plant populations, insecticides, herbicides, and improved machinery), the yield change was dramatic. The general trend for 1950-1987 was a phenomenal 2.24 bushels per acre increase. This includes the low yielding years of 1974, 1975, 1976, and 1983.

We all remember 1988 as such a devastating year, and indeed it was. However, when the departures of the mean annual yields from the general trends of the three periods are compared, Fig. 6, it is apparent that other years have been equally devastating. This figure shows the relative or percentage increase or decrease of each year's yield from the general trend line of that particular period. For example, the 1988 yield was nearly 40% below the expected yield. But, there have been other years in which the yield was as low or lower relative to the expectation for that period. In 1934 and 1936 the yields were even poorer, relatively speaking, than the 1988 yields. That is, the 1934 mean yield of 17 bushels per acre was a 43.5% departure from the expected yield of 30.1 bushels per acre. That size departure was obviously as serious in 1934 as the 1988 mean yield of 74 bushels per acre that was 39.9% below the expected yield.

Snowpack Densities:

A typical feature of snowpacks is the sharp drop in the density that occurs following each new snowfall as lower density fresh snow is added to the total, Fig. 7. The winters of 1984-1985 and 1987-1988 provide an example of the frequent variations that occur in the pack's density. In two of the four years, the density of the snowpack increased within three days after a snowfall to about 200 kg m^{-3}. Fresh snows, however, repeatedly reduced the density so that there was a relatively gradual and approximately linear increase with time to over 300 kg m^{-3} in the four winters at St. Paul, It was our experience that at a density of about 250 kg m^{-3} the snow reached a physical state that one observer labeled "corn snow". That is, the snow had undergone sufficient metamorphosis that it resembled kernels of corn (maize). Such snow can be difficult to sample because once a side is cut, it flows like corn and has a similar angle of repose. This kind of snow has apparently undergone a process which results in rounded or irregular grains of uniform size. The winter of 1984-1985 was one of a rapidly increasing density commencing at 97 kg m^{-3} with the first snow. The last sample, taken on March 8, was a very high density sample, with virtually no snow characteristics remaining. In the winter of 1985-1986, the density showed a far more gradual increase starting from a density of 110 kg m^{-3}, reaching a maximum of 396 kg m^{-3} in isolated drifts, but due to late season snowfalls, it ended at 301 kg m^{-3} with the last sample. In the third winter, 1987-1988, the density began at 90 kg m^{-3} and 72 days later reached a maximum of 326 kg m^{-3}.

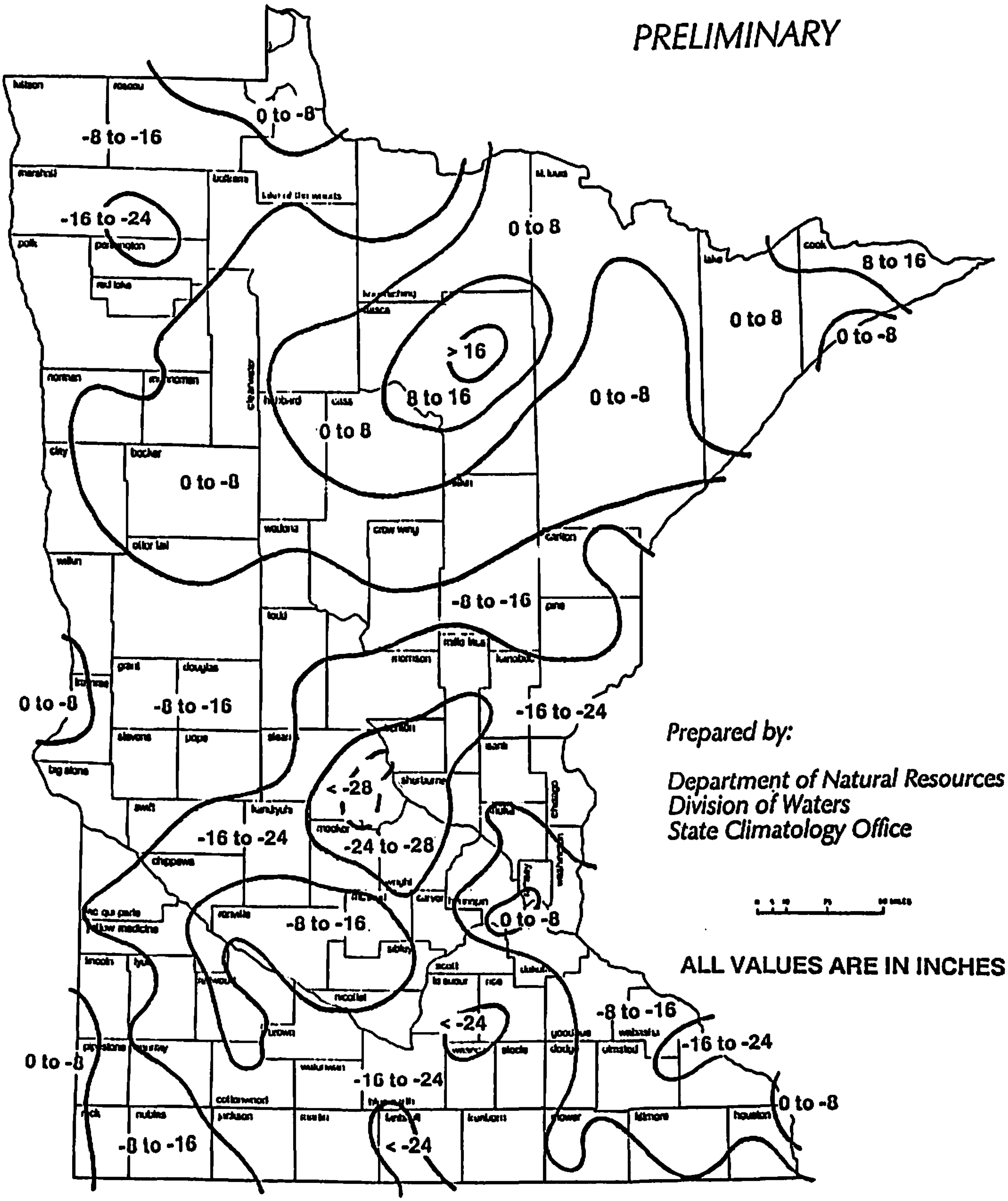
In the winter of 1988-1989, the density started at a relatively high level but showed little overall increase until late February when warm temperatures and a lack of fresh snows resulted in just scattered snow drifts in which the density reached 480 kg m^{-3}. Then, more normal winter conditions returned with several snows and lower air temperatures. The resulting snowpack densities ranged from 188-324 kg m^{-3} until 11 March. The last three densities were of the remaining snow drifts, with the last sample measuring 460 kg m^{-3} on 13 March.

During the 1984-85 winter, the average daily rate of density change from 1 November was 3.4 kg m^{-3}. This daily increase usually rapid as a result of the shallow snow cover of relatively brief duration. In 1985-1986 and 1987-1988, the density change was less, amounting to a daily average increase of 1.5 and 1.8 kg m^{-3}, respectively. The 1988-1989 mean daily change was only .01 kg m^{-3} day^{-1}. The four-year mean density increase form 1 November equaled about 1.7 kg m^{-3} day^{-1}.

The U.S. Dept. of Agriculture Forest Service personnel near Grand Rapids, MN, have been measuring snow depth and density at various forested and non-forested sites since 1962. Their "open" site field condition approximated that at St. Paul, although the surrounding countryside is forested. The density data from their initial to final measurements, usually February or early March to the disappearance of the snow cover in early to mid-April, were added to the St. Paul data, Fig. 8. However, because the Grand Rapids site is about 265 km north of St. Paul, an appreciable lag occurs in the seasons. For example, the 50% probability date of the last occurrence of 0°C at St. Paul is 29 April compared to 29 May at Grand Rapids. Therefore, in combining the Grand Rapids and St. Paul data, in order to determine a density versus time equation, the Grand Rapids data were advanced 30 days. As a result, the two sets of data are quite homogeneous, Fig. 8.

In spite of the irregularity of the density changes with time, as shown in Fig. 7, each of the years showed an overall increase from either 1 November, or from the first snowfall, that could be approximated by a curvilinear equation: $Y=163.78 - 0.49X + 0.01x^2$ where X is days from 1 November and Y is density in kg m^{-3}.

1987 - 1989 CUMULATIVE PRECIPITATION DEPARTURE



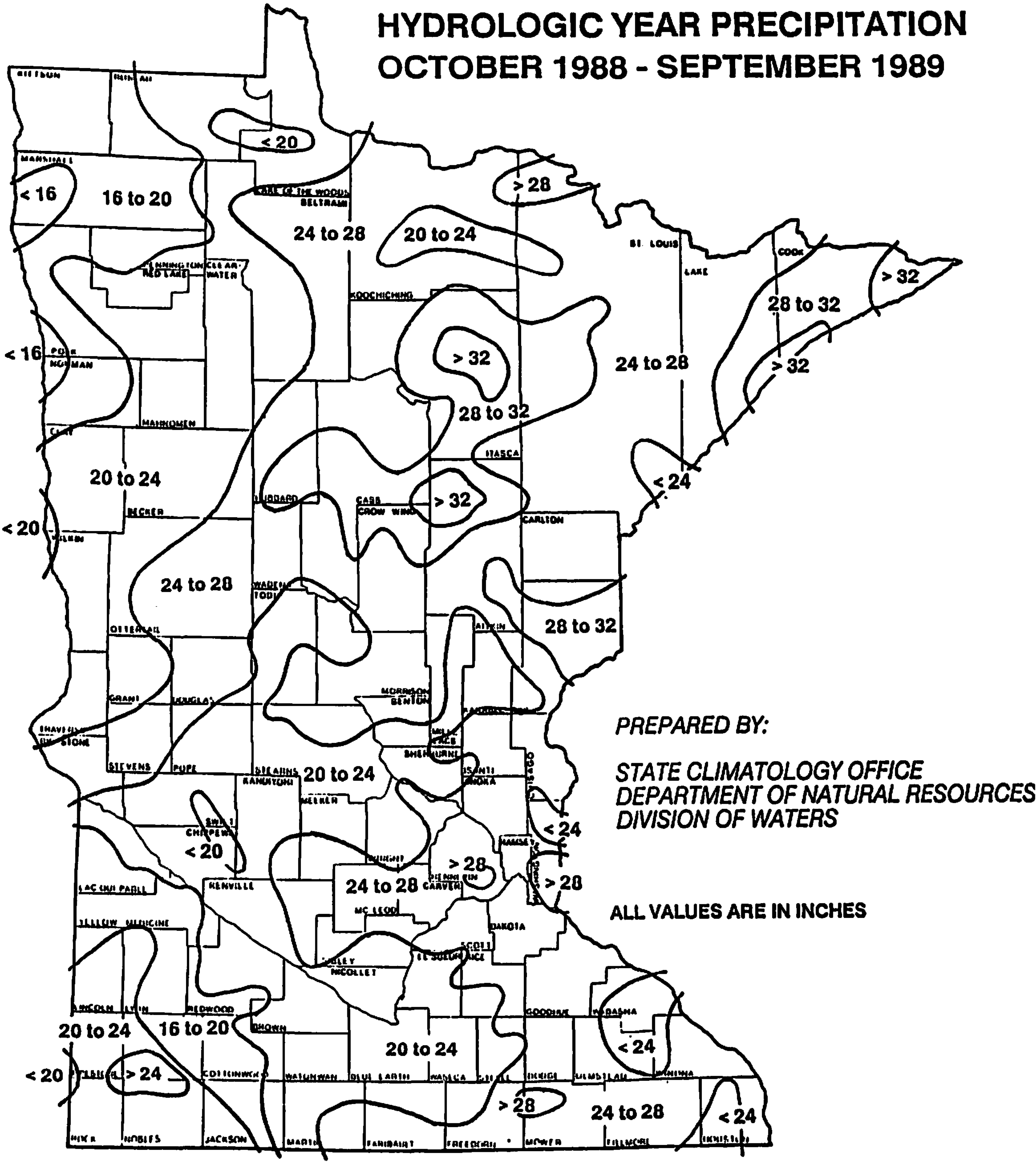
PRELIMINARY

Prepared by:

Department of Natural Resources
Division of Waters
State Climatology Office

ALL VALUES ARE IN INCHES

Fig. 1. The cumulative departure of precipitation between 1987-1989. All values are in inches.



HYDROLOGIC YEAR PRECIPITATION
OCTOBER 1988 - SEPTEMBER 1989

PREPARED BY:

STATE CLIMATOLOGY OFFICE
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS

ALL VALUES ARE IN INCHES

Fig. 2. The hydrologic year precipitation, October 1988 - September 1989. All values are in inches.

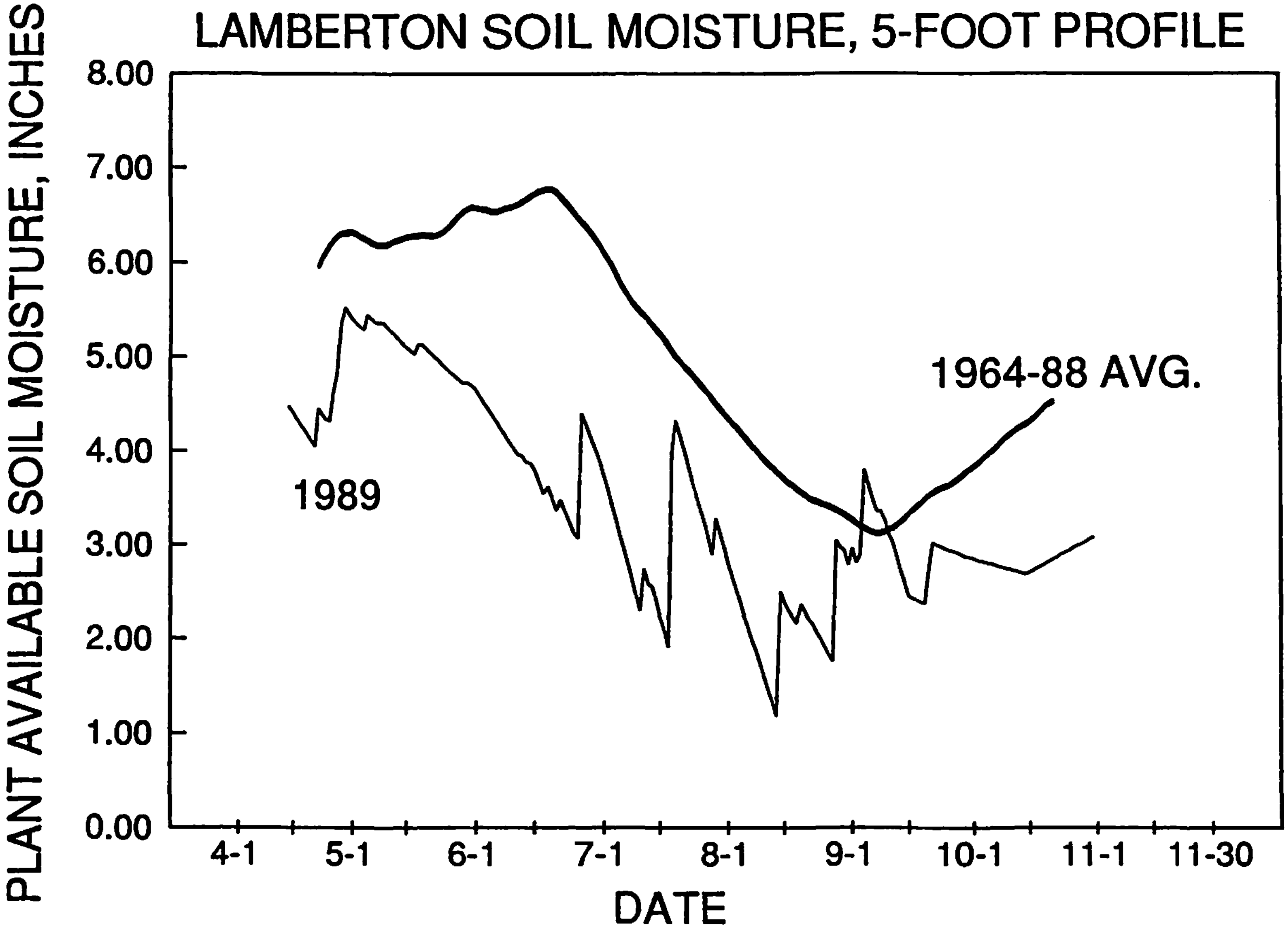


Fig. 3. Total plant available soil moisture in a 5-foot column of soil under corn during 1989 compared to the 1964-1988 mean, Lamberton.

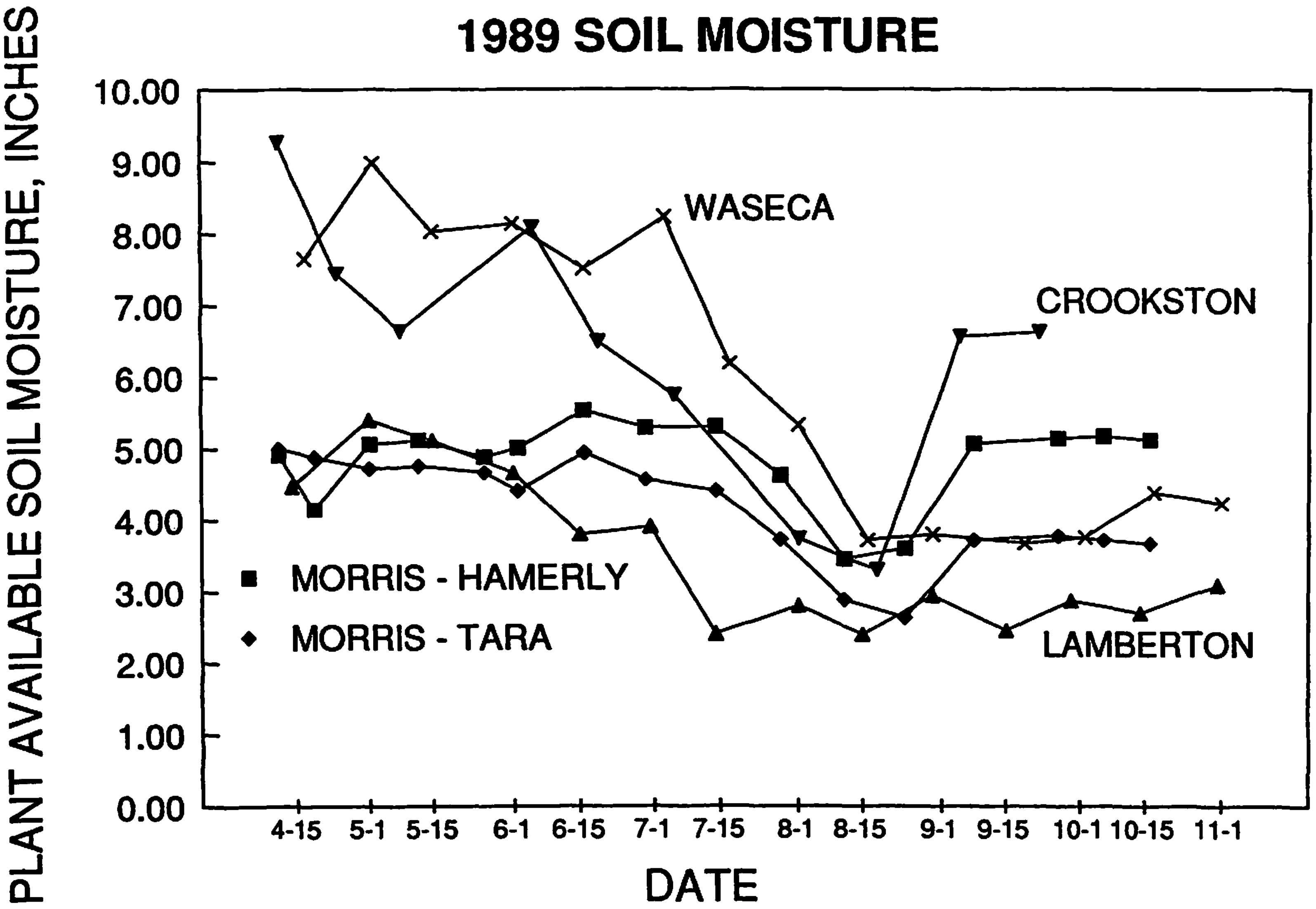


Fig. 4. Total plant available soil moisture in a 5-foot column of soil under corn at Lamberton, Morris, and Waseca, and under small grain at Crookston during the 1989 season.

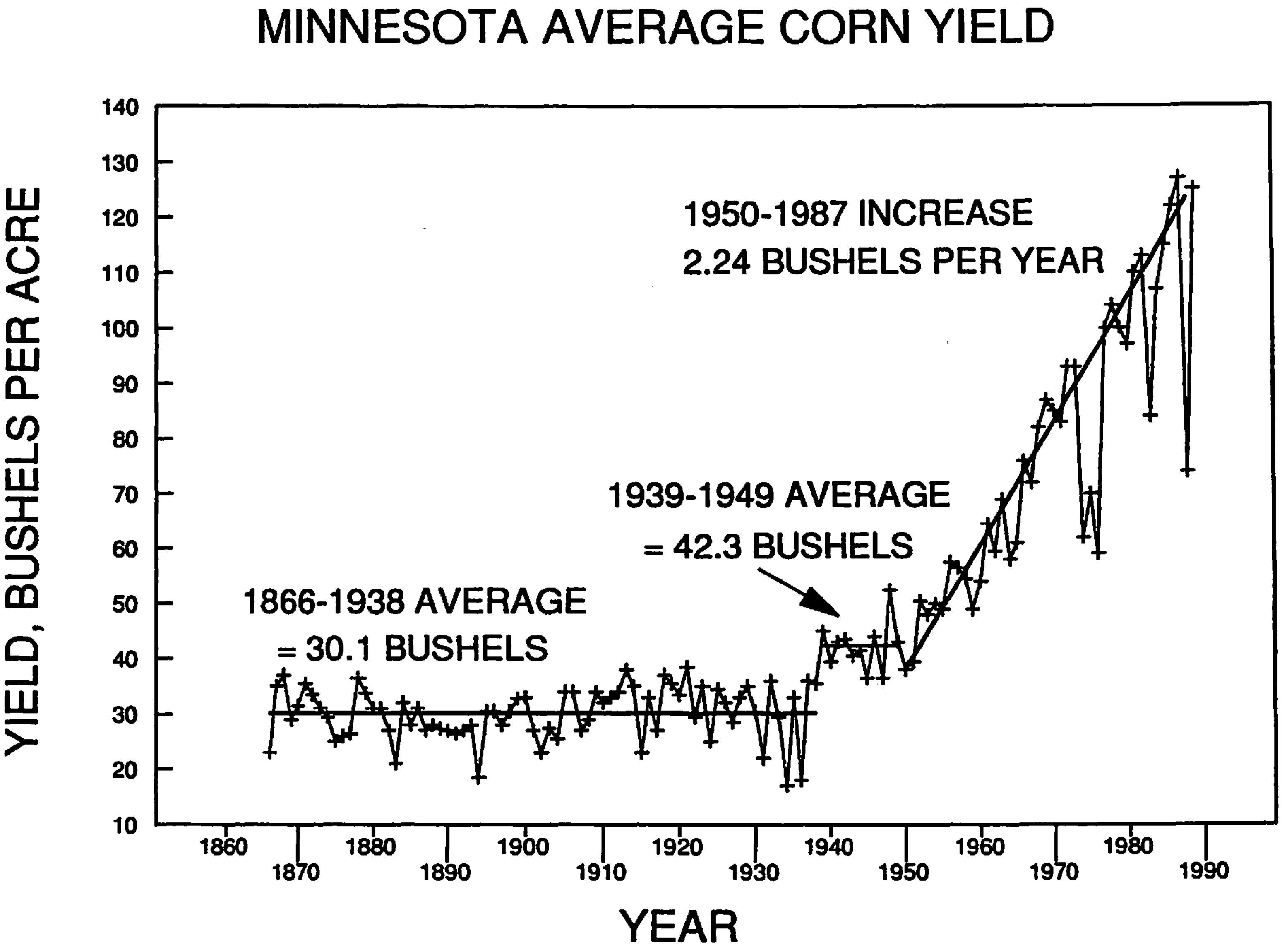


Fig. 5. State mean annual corn yields, 1866-1989. The general yield trend for these periods is shown by the solid lines. (Data source: Minnesota Crop and Livestock Reporting Service).

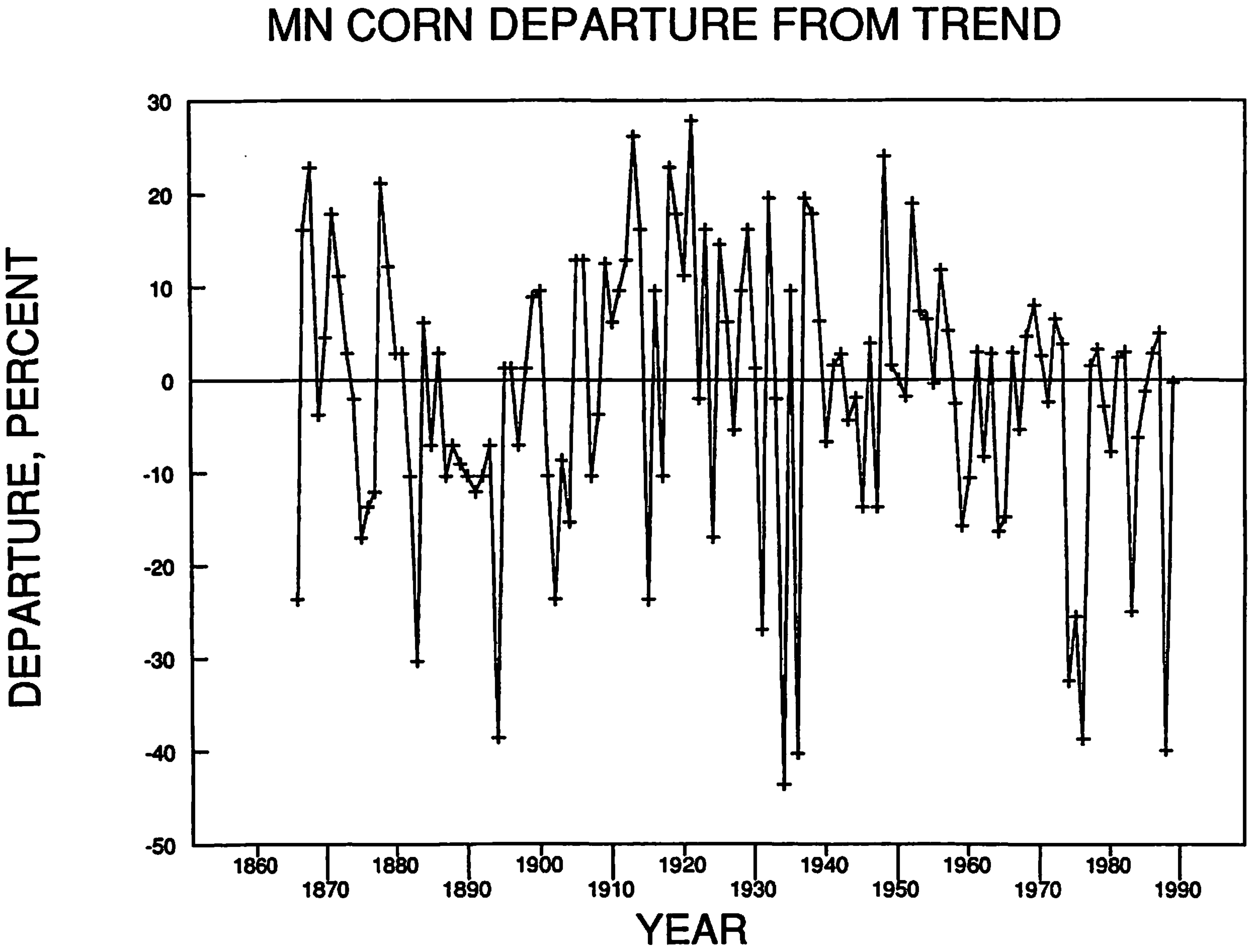


Fig. 6. Percent departure of the mean annual corn yields, 1866-1989, from the general trend lines shown in Fig. 5.

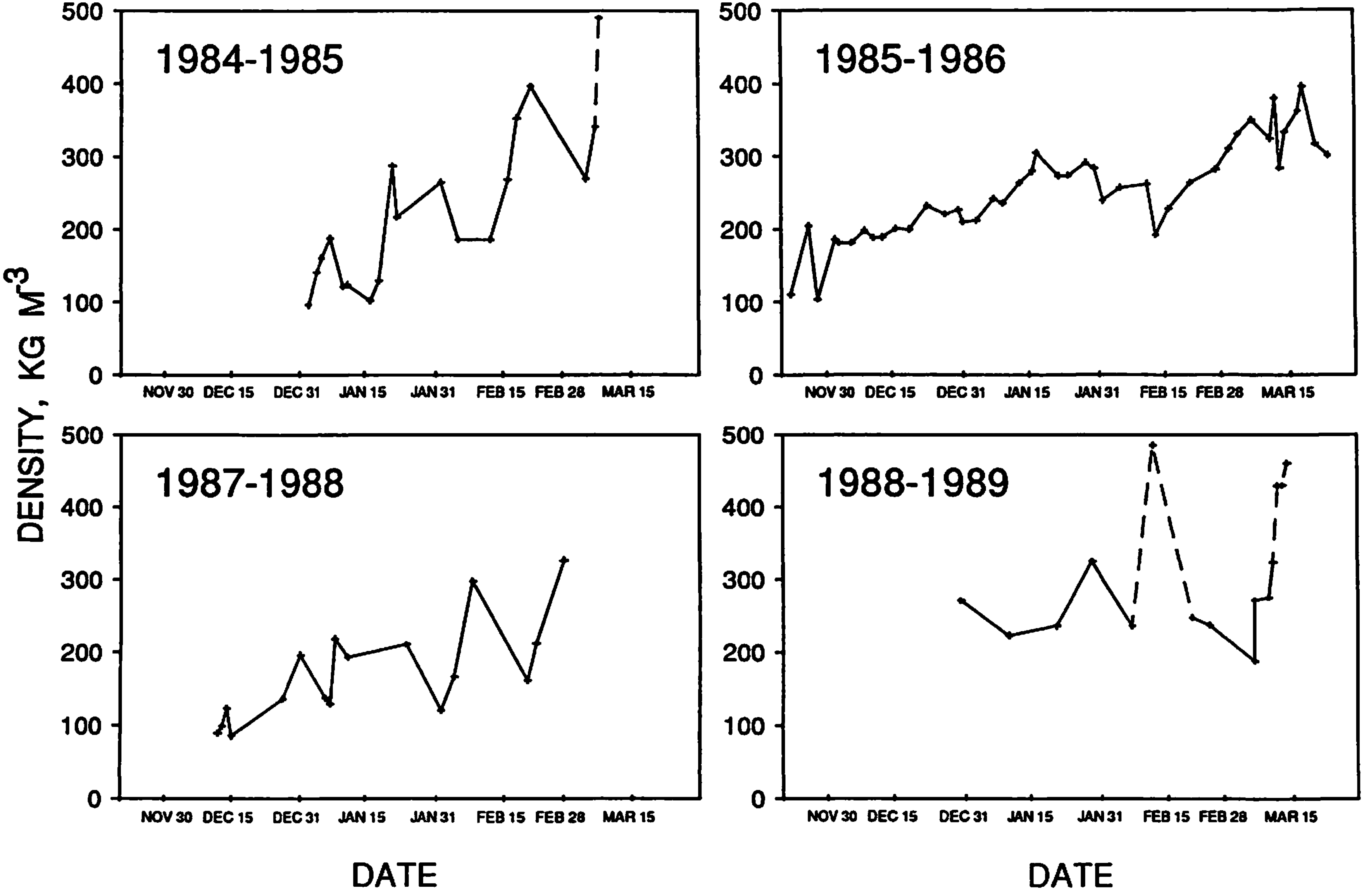


Fig. 7. Density changes of the snowpacks during four minutes at St. Paul. Samples representing isolated snow drifts rather than a continuous snowpack are noted by dashed lines.

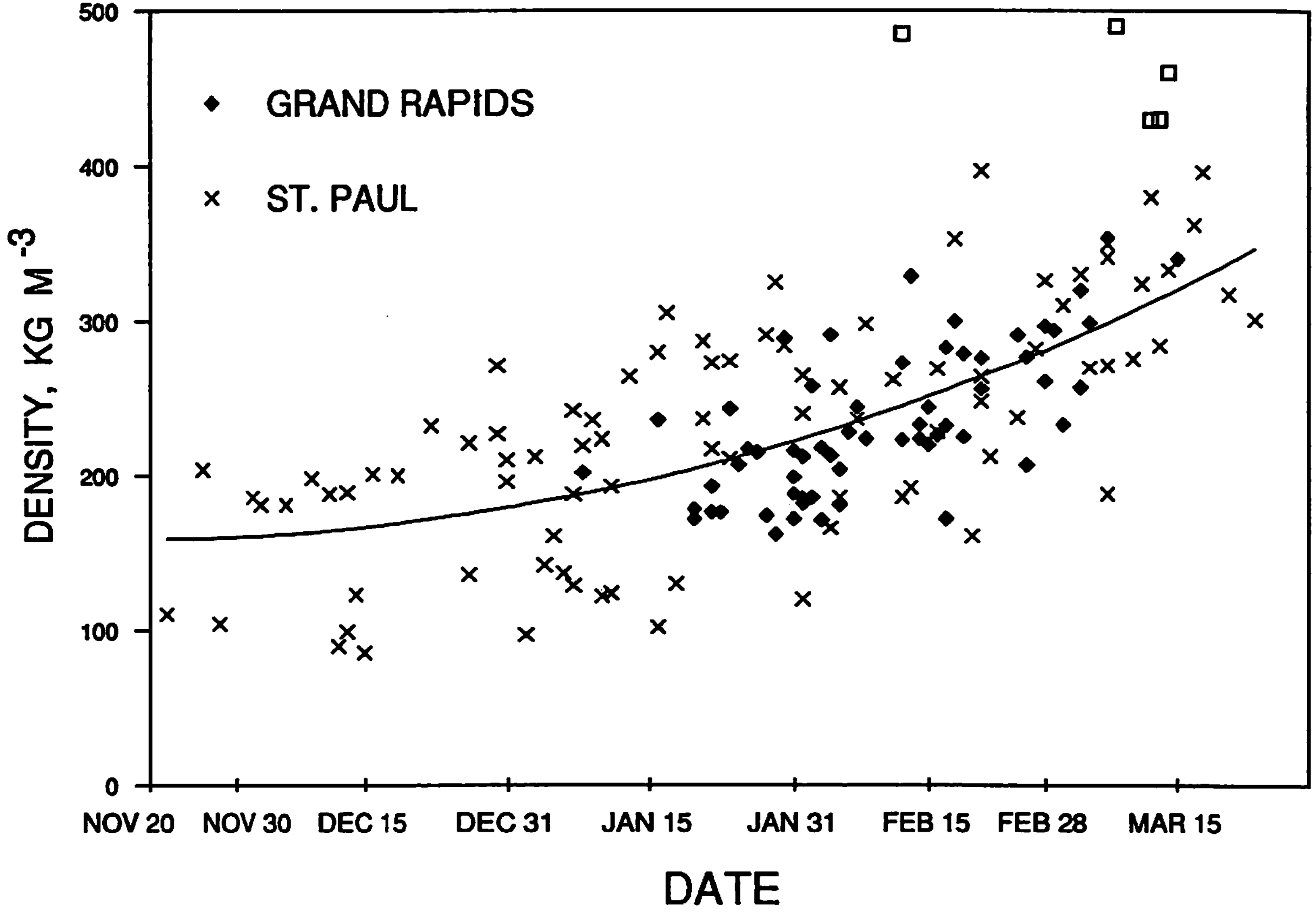


Fig. 8. Density change of the snowpacks at Grand Rapids and St. Paul. The five boxes represent the densities of isolated snow drifts and were not used to obtain the best-fit line. Grand Rapids data courtesy of Forest Service, USDA.

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

Carl Rosen, Florian Lauer, Louise America, Peter Bierman, and Gary Korbel[2]

ABSTRACT: This experiment was conducted at the Sand Plains Research Farm in Becker MN to determine the effects of boron and nitrogen on yield and quality of Russet Burbank and Reddale potatoes. A secondary objective was to follow the movement of soil nitrate-N when different rates of nitrogen fertilizer were applied. Boron applications (4 lb B/A) did not reduce the incidence of hollow heart or brown center. At the early harvest date (Aug. 2), boron applications increased yield of 7-14 oz potatoes. Nitrogen fertilizer significantly increased vine yields but had variable effects on tuber yields. At the early harvest date, tuber yield decreased as nitrogen increased from 70 to 140 lbs N/A. In Russet Burbank at the late harvest, tuber yield increased as nitrogen increased from 70 to 140 lbs. There was little response as nitrogen was increased from 140 to 280 lb N/A. 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 26), levels in the vine ranged from 41 - 116 lb N/A while at the late harvest (vines killed September 5) levels ranged from 9 - 49 lb N/A. Levels in the tubers at the early harvest ranged from 63 - 85 lb N/A while at the late harvest levels ranged from 92 - 149 lb N/A. Vines killed early may provide significant nitrogen to subsequent crops. Mineralized soil nitrogen provided 38 - 52 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 ($r^2 = 0.95$) with petiole nitrates determined by conventional laboratory procedures. Significant soil 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 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.

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

[2] Extension Soil Scientist, Soil Science Department, Professor, Horticulture Department, Junior Scientist, Graduate Assistant, and Research Technician, respectively.

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. Reported here is the second year of a three year study.

EXPERIMENTAL PROCEDURES

The experiment was conducted in Becker, MN at the Sand Plain Research Farm. The soil is a Hubbard loamy sand. The same site was used as in 1988. 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. Prior to planting, 300 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. Russet Burbank and Reddale "B" size potatoes were planted April 20, 1989 at a spacing of 36" between rows and 8" within the row for Reddale and 9" for Russet Burbank. 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 medium 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 - 1.2" rainfall, no irrigation; May 4.0" rainfall, no irrigation; June - 1.3" rainfall, 3.0" irrigation; July - 2.5" rainfall, 5.5" irrigation; August - 3.6" rainfall, 4.4" irrigation. Figure 1 shows the daily precipitation through the growing season.

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. All nitrate readings were converted to a nitrate-N basis.

Soil nitrates were determined in samples collected July 27 and September 7. Samples consisted of 3 cores from an individual plot taken to a depth of 3 ft. at 1 ft. increments. Two samples at each depth were collected from each plot: one from between rows and the other within rows. All 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 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 lb/A values should be considered approximate. To calculate lbs nitrate-N/A, it was assumed that 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 depths of 2.5 ft. and 4.5 ft. This differed from last year when there were suction tubes only at the 2.5 ft. depth. Vines were cut and removed at two harvest dates: July 26 and September 5. Potatoes were mechanically harvested August 2 and September 14. Subsamples of vines and tubers were collected to determine nutrient uptake and to evaluate tuber quality.

RESULTS AND DISCUSSION

Tuber and Vine Yields. Boron applications had no effect on total tuber yield at either harvest date, but significantly increased 7 -14 oz potatoes at the early harvest date (Table 1). Nitrogen rate had significant effects on tuber yield and size distribution at both harvest dates. At the early harvest (August 2), 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 14), Russet Burbank yields increased up to 140 lb N/A, but Reddale yields increased linearly with nitrogen rate up to 280 lb N/A. 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. Boron application 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 little effect on tuber quality in either cultivar or at either planting date. At the early harvest date there was actually an increase in brown center/hollow heart in Reddale when boron was applied. Under conditions of this experiment, boron does not appear to alleviate brown center or hollow heart disorders in potato. Nitrogen fertilizer did not affect incidence of hollow heart or brown center, within size categories, for either cultivar or either harvest date. However, since nitrogen increased the proportion of larger size tubers, there was actually a greater absolute number of tubers that exhibited the disorders as nitrogen rate increased.

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 July 3 averaged 30 ppm in the control and 78 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 July 3 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 up to this point.

Except for the increase in tissue boron, boron applications had no effect on concentrations of other elements in the leaf sampled July 3 (Table 6) or in the tubers sampled at the early and late harvest dates (Tables 7 and 8). Nitrogen fertilizer significantly increased leaf concentrations of iron, but decreased concentrations of boron. Tuber concentrations of calcium and zinc increased with nitrogen fertilizer at both harvests. Tuber potassium, manganese, and boron increased with increasing nitrogen at the early harvest date. Tuber magnesium, phosphorus, and potassium decreased with increasing nitrogen at the late harvest. Reddale leaves sampled July 3 had higher concentrations of nitrogen, phosphorus, iron, and zinc but lower concentrations of calcium, magnesium, and manganese. 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 application increased boron uptake by vines, but had little effect on uptake of other nutrients. At the early harvest, Reddale vines accumulated more phosphorus, calcium, iron, manganese, and boron, but less magnesium than Russet Burbank. At the later harvest, Reddale vines accumulated more phosphorus, iron, and manganese, but less potassium and magnesium than Russet Burbank. Due to the increase in vine growth with nitrogen fertilizer, uptake of nitrogen and most other nutrients increased with nitrogen application at both harvests.

Nutrient uptake by tubers is presented in Tables 9 and 10. Boron applications increased boron uptake at both the early and late harvest, but had no effect on uptake of other nutrients. At the early harvest, Reddale accumulated greater quantities of phosphorus, copper, and boron, but lower quantities of nitrogen, potassium, calcium, magnesium, and manganese compared to Russet Burbank. At the late harvest, Reddale accumulated more iron, but less nitrogen, potassium, magnesium, calcium, and manganese than Russet Burbank. At the early harvest, nitrogen uptake was slightly increased as nitrogen fertilizer applications increased. The effect of increased nitrogen on nutrient accumulation was not that great because of depressed yields at the high nitrogen rates. Phosphorus, potassium, magnesium, and boron uptake were actually lower at the high nitrogen rates compared to the lower rates. At the later harvest date, nitrogen, calcium, manganese, 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 26. The average uptake of nitrogen by Russet Burbank was less than 9 lb N/A during the month of August. For Reddale there was actually less nitrogen accounted for in September than in July. This apparent decrease in N was probably due to vines that had died and decomposed and could not be accounted for in the late harvest. 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 50 - 60 lb N/A over the growing season was mineralized. In contrast, at the highest nitrogen rate, 80 - 100 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 diagnostic 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 (in seconds) 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. There was a relatively good correlation ($r^2 = 0.95$) between the quick test and the conventional nitrate test. The equation relating the two tests is $y = 10.83x + 598.6$, where x is the concentration of nitrate-N in the petiole sap (ug/ml) from the quick test and y is the predicted concentration (ug/g or ppm) based on the water extract from dried tissue. 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 be taken in the morning if possible. Despite these cautions, with some practice a grower or consultant could monitor nitrate in the sap to determine qualitative nitrogen status of the plant. This may help make a further decision related to submitting a sample to the laboratory for more extensive tests. 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, there was an increase in residual nitrate in the field. Similar trends were also observed in the water samples collected at the 2.5 foot and 4.5 foot depths (Figures 2, 3 and 4). Nitrate-N levels at the 2.5 foot depth peaked at mid-season and then declined. Levels at the 4.5 foot depth were generally low for the 70 and 140 lb N/A rates, indicating that little movement beyond the root zone took place. In contrast, for the 280 lb N/A rate, nitrate-N levels were high at the 2.5 foot depth through most of the season and then decreased. Nitrate-N levels at the 4.5 foot level gradually increased through the season, indicating significant movement of N beyond the root zone at this nitrogen rate.

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

			Harvest Date									
			August 2					September 14				
Cultivar	B rate	N rate	Tuber Size				Total yield	Tuber Size				Total yield
	lb B/A	lb N/A	<4oz	4-7oz	7-14oz	>14oz	(Cwt/A)	<4oz	4-7oz	7-14oz	>14oz	(Cwt/A)
Russet B	0	70	65.3	252.6	99.1	0.0	417.0	77.8	368.3	144.8	25.6	616.5
	0	140	73.2	246.6	90.3	0.0	410.1	68.0	395.1	188.3	19.5	670.9
	0	280	83.0	220.5	81.4	0.0	384.9	84.1	361.0	214.8	31.0	690.9
	4	70	66.5	257.2	114.0	0.0	437.7	80.3	361.1	113.1	18.1	572.6
	4	140	76.9	223.4	106.9	0.0	407.2	67.4	377.6	196.5	19.7	661.2
	4	280	83.3	201.0	101.8	0.0	386.1	85.9	348.4	194.8	24.5	653.6
Reddale	0	70	11.2	190.0	169.3	3.4	373.8	15.4	136.0	329.9	57.5	538.7
	0	140	13.4	150.4	206.8	17.6	388.2	20.0	130.0	346.9	85.5	582.4
	0	280	14.4	138.6	170.6	18.6	337.7	27.7	147.5	308.1	179.4	662.6
	4	70	9.0	165.8	211.7	10.9	397.4	16.9	138.1	325.2	69.4	549.6
	4	140	13.7	142.2	210.8	16.3	383.1	23.7	144.1	340.6	106.6	615.0
	4	280	12.3	146.6	182.4	11.0	352.3	28.1	134.6	313.1	177.0	652.8
Analysis of Variance												
Cultivar (C)												
	Russet B		74.7	233.6	98.9	0.0	407.2	77.3	368.6	175.4	23.1	644.3
	Reddale		12.3	155.6	191.9	13.0	372.1	22.0	138.4	327.3	112.6	600.2
Signif.			**	**	**	**	**	**	**	**	**	**
B rate (B)												
	0		43.4	199.8	136.2	6.6	385.3	48.8	256.3	255.5	66.4	627.0
	4		43.6	189.4	154.6	6.4	394.0	50.4	250.6	247.2	69.2	617.5
Signif.			NS	NS	*	NS	NS	NS	NS	NS	NS	NS
N rate (N)												
	70		38.0	216.4	148.5	3.6	406.5	47.6	250.9	228.3	42.6	569.4
	140		44.3	190.7	153.7	8.5	397.1	44.8	261.7	268.1	57.8	632.4
	280		48.3	176.7	134.1	7.4	365.3	56.5	247.9	257.7	103.0	665.0
Signif.			NS	**	NS	NS	*	**	NS	NS	**	NS
Linear			*	**	NS	NS	**	**	NS	*	**	**
Quad.			NS	*	NS	NS	NS	NS	NS	**	NS	**
Interactions												
C X B			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 = 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 July 26).

			F.W.	Nutrient									
Cultivar	B rate	N rate	Yield	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb B/A	lb N/A	T/A	lb/A					oz/A				
Russet B	0	70	10.76	44.6	3.3	104.1	41.9	27.3	7.16	6.86	0.78	2.52	1.06
	0	140	13.44	66.0	4.1	118.6	43.8	35.2	9.00	5.97	0.77	2.77	1.14
	0	280	17.82	112.9	6.5	158.1	49.3	41.1	9.35	9.86	1.38	4.03	1.32
	4	70	12.12	50.7	3.6	113.5	43.8	29.6	8.32	6.86	0.93	2.91	2.08
	4	140	13.98	65.2	4.2	127.1	42.1	35.3	7.73	6.37	0.91	2.54	2.51
	4	280	15.78	97.9	5.2	141.8	47.3	38.6	8.90	9.46	1.12	4.47	2.43
Reddale	0	70	10.05	36.4	3.9	89.6	35.8	17.1	9.94	5.96	0.68	2.80	0.97
	0	140	15.26	65.6	5.7	136.6	49.0	26.7	9.25	7.28	0.91	3.15	1.35
	0	280	20.50	122.8	8.6	173.3	57.0	38.8	19.63	12.16	1.76	5.34	1.66
	4	70	12.25	46.4	4.8	113.2	41.4	20.7	9.62	7.87	1.06	3.91	2.17
	4	140	16.26	69.7	6.4	142.1	51.0	30.9	11.72	7.70	1.11	3.52	3.47
	4	280	18.95	110.5	7.6	160.4	54.2	36.9	14.93	10.91	1.30	4.15	2.81
Analysis of Variance													
Cultivar (C)													
Russet B			13.98	72.9	4.5	127.2	44.7	34.5	8.41	7.56	0.98	3.21	1.76
Reddale			15.55	75.2	6.2	135.9	48.1	28.5	12.51	8.65	1.14	3.81	2.07
Signif.			*	NS	**	NS	*	**	**	*	NS	*	**
B rate (B)													
	0		14.64	74.7	5.4	130.1	46.1	31.0	10.72	8.01	1.05	3.44	1.25
	4		14.89	73.4	5.3	133.0	46.6	32.0	10.20	8.19	1.07	3.59	2.58
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)													
		70	11.30	44.5	3.9	105.1	40.7	23.7	8.76	6.88	0.86	3.04	1.57
		140	14.73	66.6	5.1	131.1	46.5	32.0	9.43	6.83	0.93	3.00	2.12
		280	18.26	111.0	7.0	158.4	52.0	38.8	13.20	10.60	1.39	4.50	2.05
Signif.			**	**	**	**	**	**	**	*	**	NS	**
Linear			**	**	**	**	**	**	**	**	**	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	NS
C X N			NS	NS	NS	NS	**	NS	*	NS	NS	NS	NS
B X N			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 September 7).

			F.W.	Nutrient									
Cultivar	B rate	N rate	Yield	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb B/A	lb N/A	T/A	lb/A					oz/A				
Russet B	0	70	3.78	10.3	0.8	31.6	14.1	9.4	5.98	2.07	0.38	0.52	0.36
	0	140	7.20	19.7	1.4	46.7	24.4	19.3	7.99	3.24	0.52	1.33	0.64
	0	280	12.21	50.7	3.1	72.7	33.3	32.1	12.97	4.44	1.20	1.22	0.94
	4	70	2.80	8.6	0.7	26.6	9.3	6.7	4.56	1.22	0.26	0.25	0.29
	4	140	6.07	19.8	1.5	44.7	20.0	16.3	7.07	2.55	0.39	0.90	0.74
	4	280	11.16	47.6	2.8	69.9	29.4	28.8	12.56	3.94	0.84	0.94	1.13
Reddale	0	70	2.38	18.4	1.2	21.9	15.4	6.7	12.74	4.17	0.63	0.92	0.33
	0	140	3.24	16.8	1.6	28.2	18.4	9.4	15.52	4.31	0.41	1.23	0.38
	0	280	7.99	46.4	3.1	52.5	38.0	24.5	16.69	8.55	0.96	1.51	0.84
	4	70	2.27	12.0	1.4	21.7	16.2	7.0	15.13	4.69	0.68	1.17	0.49
	4	140	4.91	22.4	2.1	41.1	25.8	12.9	20.62	6.75	0.78	1.91	0.76
	4	280	7.24	38.0	2.6	47.5	27.0	20.4	18.91	6.37	0.59	0.95	0.90
Analysis of Variance													
Cultivar (C)													
Russet B			7.20	26.1	1.7	48.7	21.7	18.8	8.52	2.91	0.60	0.86	0.68
Reddale			4.67	25.7	2.0	35.5	23.4	13.5	16.60	5.81	0.68	1.28	0.61
Signif.			**	NS	*	**	NS	**	**	**	NS	**	NS
B rate (B)													
	0		6.13	27.0	1.9	42.3	23.9	16.9	11.98	4.46	0.68	1.12	0.57
	4		5.74	24.8	1.8	41.9	21.3	15.3	13.14	4.25	0.59	1.02	0.72
Signif.			NS	NS	NS	NS	*	NS	NS	NS	NS	NS	**
N rate (N)													
	70		2.81	12.3	1.0	25.4	13.7	7.4	9.60	3.04	0.49	0.72	0.37
	140		5.36	19.7	1.6	40.2	22.1	14.5	12.80	4.21	0.53	1.34	0.63
	280		9.65	45.7	2.9	60.7	31.9	26.5	15.28	5.82	0.90	1.16	0.94
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	*
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 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 2			September 14		
		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	1.0	6.3	8.3	3.0	13.4	58.2
0	140	0.0	12.1	20.2	2.9	19.0	54.0
0	280	0.0	3.0	65.0	6.0	11.2	45.5
4	70	3.0	11.0	29.2	0.0	20.0	61.4
4	140	2.0	15.1	57.7	5.0	11.2	52.4
4	280	1.0	11.0	31.3	3.0	9.3	46.1
B rate (B)							
	0	0.3	7.1	31.2	4.0	14.5	52.6
	4	2.0	12.4	39.4	2.7	13.5	53.3
Signif.		NS	*	NS	NS	NS	NS
N rate (N)							
	70	2.0	8.6	18.8	1.5	16.7	59.8
	140	1.0	13.6	38.9	4.0	15.1	53.2
	280	0.5	7.0	48.1	4.5	10.2	45.8
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

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 2			September 14		
		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	1.0	10.0	0.0	2.0	26.0	64.6
0	140	3.0	6.0	0.0	2.0	20.0	59.2
0	280	1.0	7.0	0.0	1.0	18.4	69.8
4	70	6.0	11.0	0.0	6.0	4.0	37.5
4	140	1.0	6.0	0.0	0.0	20.0	49.1
4	280	3.0	4.0	0.0	3.0	16.3	54.2
B rate (B)							
	0	1.7	7.7	0.0	1.7	21.5	64.5
	4	3.3	7.0	0.0	3.0	13.4	46.9
Signif.		NS	NS	--	NS	NS	NS
N rate (N)							
	70	3.5	10.5	0.0	4.0	15.0	51.0
	140	2.0	6.0	0.0	1.0	20.0	54.1
	280	2.0	5.5	0.0	2.0	17.3	62.0
Signif.		NS	NS	--	NS	NS	NS
Linear		NS	NS	--	NS	NS	NS
Quad.		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 July 3 (74 days after planting).

			Nutrient									
Cultivar	B rate	N rate	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb B/A	lb N/A	%					ppm				
Russet B	0	70	3.89	0.20	4.13	1.22	0.95	97	132	17	278	27
	0	140	4.63	0.21	4.11	1.30	1.11	95	122	16	219	24
	0	280	5.23	0.23	4.26	1.21	1.01	100	114	17	276	25
	4	70	4.13	0.23	4.40	1.21	0.99	97	151	21	297	89
	4	140	4.52	0.22	3.96	1.23	1.12	93	105	16	179	87
	4	280	5.09	0.22	4.18	1.27	1.05	93	123	16	205	61
Reddale	0	70	4.22	0.39	4.06	0.88	0.56	100	68	20	164	41
	0	140	4.57	0.36	3.64	0.94	0.64	106	59	21	184	31
	0	280	5.71	0.40	3.90	0.89	0.60	113	109	27	144	30
	4	70	4.44	0.39	3.94	0.87	0.59	104	71	23	209	91
	4	140	4.77	0.38	3.57	0.85	0.60	110	61	24	113	89
	4	280	5.71	0.39	4.04	0.88	0.63	114	91	24	154	53
Analysis of Variance												
Cultivar (C)												
	Russet B		4.58	0.22	4.17	1.24	1.04	96	124	17	242	52
	Reddale		4.87	0.39	3.86	0.89	0.60	108	76	23	161	56
Signif.			**	**	**	**	**	**	**	**	**	NS
B rate (B)												
	0		4.71	0.30	4.01	1.07	0.81	102	101	19	211	30
	4		4.74	0.30	4.02	1.05	0.83	102	100	20	193	78
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		4.17	0.30	4.13	1.04	0.77	99	105	20	237	62
	140		4.62	0.29	3.82	1.08	0.87	101	87	19	174	58
	280		5.42	0.31	4.09	1.06	0.82	105	109	21	195	43
Signif.			**	NS	NS	NS	NS	NS	*	NS	NS	**
Linear			**	NS	NS	NS	NS	*	NS	NS	NS	**
Quad.			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
B X N			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 7. Nutrient concentrations in tubers as affected by N rate and boron - early harvest (Aug. 2).

Cultivar	B rate	N rate	Nutrient									
			N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb B/A	lb N/A	-------- % -------			--------------------- ppm ---------------------						
Russet B	0	70	0.83	0.19	1.92	302	945	62	8.9	9.0	2.1	4.1
	0	140	0.97	0.19	2.08	334	972	125	9.6	11.4	2.3	4.9
	0	280	1.26	0.18	2.19	438	983	86	11.2	14.2	2.7	5.0
	4	70	0.94	0.19	2.01	318	978	99	10.1	10.8	2.6	5.8
	4	140	1.03	0.18	2.06	337	971	117	9.7	11.7	2.3	6.7
	4	280	1.29	0.18	2.22	437	1042	85	11.3	13.3	2.2	7.4
Reddale	0	70	1.07	0.28	2.22	213	1246	142	8.8	14.2	4.4	9.1
	0	140	1.34	0.27	2.21	240	1224	158	9.0	15.7	4.4	8.3
	0	280	1.55	0.27	2.35	336	1171	210	11.1	22.5	5.4	8.4
	4	70	1.05	0.27	2.21	215	1169	193	9.2	16.0	4.8	9.7
	4	140	1.29	0.28	2.26	266	1213	202	9.7	18.7	5.1	10.4
	4	280	1.49	0.27	2.31	318	1202	144	10.8	19.5	4.9	10.1
Analysis of Variance												
Cultivar (C)												
	Russet B		1.06	0.19	2.08	361	982	96	10.1	11.7	2.3	5.7
	Reddale		1.30	0.27	2.26	265	1204	175	9.8	17.8	4.8	9.3
Signif.			**	**	**	**	**	**	NS	**	**	**
B rate (B)												
	0		1.17	0.23	2.16	311	1090	131	9.7	14.5	3.5	6.6
	4		1.18	0.23	2.18	315	1096	140	10.1	15.0	3.6	8.4
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		0.98	0.23	2.09	262	1084	124	9.2	12.5	3.5	7.2
	140		1.16	0.23	2.15	294	1095	151	9.5	14.4	3.5	7.6
	280		1.40	0.23	2.27	382	1099	131	11.1	17.4	3.8	7.7
Signif.			**	NS	**	**	NS	NS	**	**	NS	*
Linear			**	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	**
B X N			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 14).

Cultivar	B rate	N rate	Nutrient									
			N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
lb B/A	lb N/A		------- % ------			---------------------- ppm ----------------------						
Russet B	0	70	0.93	0.24	2.05	299	1084	95	10.4	11.5	3.8	3.9
	0	140	1.04	0.22	2.01	300	1036	91	11.1	13.1	3.7	4.1
	0	280	1.21	0.20	1.96	366	1025	111	11.3	15.4	4.7	4.5
	4	70	1.02	0.26	2.18	319	1177	94	11.7	13.1	3.7	5.0
	4	140	0.99	0.20	1.91	286	1008	115	10.6	12.4	3.8	5.2
	4	280	1.08	0.20	1.89	341	964	125	10.8	16.0	4.9	5.7
Reddale	0	70	1.13	0.30	2.26	186	1191	235	9.0	18.4	5.9	7.8
	0	140	1.17	0.29	2.14	215	1182	181	9.2	18.3	5.6	6.9
	0	280	1.42	0.27	2.07	264	1089	207	10.2	21.6	6.4	6.8
	4	70	1.01	0.30	2.08	190	1114	234	9.1	17.3	6.2	7.8
	4	140	1.18	0.29	2.13	226	1122	262	9.3	19.6	6.2	8.1
	4	280	1.23	0.26	1.89	224	1009	265	9.3	18.7	5.8	7.6
Analysis of Variance												
Cultivar (C)												
	Russet B		1.04	0.22	2.00	318	1049	105	11.0	13.6	4.1	4.7
	Reddale		1.19	0.28	2.09	218	1118	231	9.3	19.0	6.0	7.5
Signif.			**	**	*	**	*	**	**	**	**	**
B rate (B)												
	0		1.15	0.25	2.08	272	1101	154	10.2	16.4	5.0	5.6
	4		1.08	0.25	2.01	264	1066	182	10.1	16.2	5.1	6.6
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		1.02	0.27	2.14	248	1142	165	10.1	15.1	4.9	6.1
	140		1.10	0.25	2.05	257	1087	162	10.0	15.9	4.8	6.0
	280		1.23	0.23	1.95	299	1022	177	10.4	17.9	5.5	6.1
Signif.			**	**	*	**	**	NS	NS	**	NS	NS
Linear			**	**	**	**	**	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	*
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 9. Nutrient uptake by tubers as affected by nitrogen and boron - early harvest (August 2).

Cultivar	B rate	N rate	Nutrient									
			N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb B/A	lb N/A	---------- lbs/A				------------	------------ oz/A				------------
Russet B	0	70	70.1	16.0	161.9	2.6	8.0	8.4	1.20	1.24	0.28	0.56
	0	140	72.5	14.0	155.0	2.5	7.3	15.0	1.16	1.36	0.24	0.60
	0	280	83.3	12.1	144.1	2.9	6.5	9.1	1.16	1.48	0.32	0.52
	4	70	78.5	15.9	167.6	2.6	8.1	13.2	1.36	1.44	0.36	0.76
	4	140	76.0	13.8	153.2	2.5	7.3	13.5	1.16	1.36	0.24	0.80
	4	280	87.0	12.4	149.0	2.9	7.0	9.1	1.24	1.44	0.28	0.80
Reddale	0	70	63.6	16.5	131.5	1.3	7.4	13.2	0.84	1.32	0.40	0.88
	0	140	79.1	15.8	129.8	1.4	7.2	14.1	0.80	1.44	0.44	0.76
	0	280	70.8	12.3	106.4	1.5	5.3	14.6	0.76	1.64	0.40	0.60
	4	70	63.1	16.4	132.1	1.3	7.0	18.6	0.92	1.56	0.44	0.96
	4	140	71.0	15.6	124.7	1.5	6.7	18.0	0.80	1.64	0.40	0.92
	4	280	71.8	13.4	113.6	1.6	5.9	11.8	0.84	1.56	0.40	0.80
Analysis of Variance												
Cultivar (C)												
	Russet B		77.9	14.0	155.1	2.7	7.4	11.4	1.21	1.39	0.29	0.67
	Reddale		69.9	15.0	123.0	1.4	6.6	15.1	0.83	1.53	0.41	0.82
Signif.			*	**	**	**	**	NS	**	NS	**	**
B rate (B)												
	0		73.2	14.4	138.1	2.0	6.9	12.4	0.99	1.41	0.35	0.65
	4		74.6	14.6	140.0	2.1	7.0	14.0	1.05	1.50	0.35	0.84
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		68.8	16.2	148.3	1.9	7.6	13.4	1.08	1.39	0.37	0.79
	140		74.6	14.8	140.6	2.0	7.1	15.2	0.98	1.45	0.33	0.77
	280		78.2	12.5	128.3	2.2	6.2	11.2	1.00	1.53	0.35	0.68
Signif.			NS	**	*	*	**	NS	NS	NS	NS	*
Linear			*	**	**	**	**	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	**
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 10. Nutrient uptake by tubers as affected by nitrogen and boron - late harvest (September 14).

Cultivar	B rate lb B/A	N rate lb N/A	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			Nutrient									
			lbs/A					oz/A				
Russet B	0	70	112.4	28.9	247.9	3.6	13.1	18.5	2.00	2.28	0.72	0.76
	0	140	141.2	29.4	271.8	4.0	14.0	19.6	2.40	2.84	0.84	0.92
	0	280	159.8	26.0	258.3	4.8	13.5	23.2	2.40	3.28	0.96	0.96
	4	70	112.9	28.2	240.3	3.5	13.0	16.4	2.04	2.32	0.64	0.92
	4	140	130.6	26.9	252.3	3.8	13.3	24.1	2.24	2.60	0.76	1.08
	4	280	138.1	25.8	241.0	4.4	12.3	25.6	2.20	3.28	1.00	1.16
Reddale	0	70	96.0	25.5	191.7	1.6	10.1	32.6	1.24	2.52	0.80	1.08
	0	140	108.6	26.7	198.3	2.0	11.0	26.2	1.40	2.68	0.84	1.00
	0	280	135.9	26.2	198.6	2.5	10.5	32.0	1.56	3.32	1.00	1.04
	4	70	89.4	26.0	182.8	1.6	9.8	31.0	1.28	2.44	0.88	1.12
	4	140	110.5	27.5	201.5	2.1	10.6	39.9	1.40	2.92	0.96	1.20
	4	280	120.4	25.2	185.1	2.2	9.9	42.0	1.44	2.96	0.92	1.16
Analysis of Variance												
Cultivar (C)												
	Russet B		132.5	27.5	251.9	4.0	13.2	21.2	2.21	2.77	0.82	0.97
	Reddale		110.1	26.2	193.0	2.0	10.3	34.0	1.39	2.81	0.90	1.10
Signif.			**	NS	**	**	**	**	**	NS	NS	**
B rate (B)												
	0		125.6	27.1	227.8	3.1	12.0	25.4	1.83	2.82	0.86	0.96
	4		117.0	26.6	217.1	2.9	11.5	29.8	1.77	2.75	0.86	1.11
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		102.7	27.2	215.7	2.6	11.5	24.6	1.64	2.39	0.76	0.97
	140		122.7	27.6	231.0	3.0	12.2	27.5	1.86	2.76	0.85	1.05
	280		138.5	25.8	220.7	3.5	11.6	30.7	1.90	3.21	0.97	1.08
Signif.			**	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	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 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			Late Harvest		
		Vines	Tubers	Total	Vines	Tubers	Total
		lb N/A					
Russet B	70	47.6	74.3	122.0	9.4	112.7	122.1
	140	65.6	74.2	139.8	19.8	135.9	155.7
	280	105.4	85.1	190.5	49.2	148.9	198.1
Reddale	70	41.4	63.4	104.7	15.2	92.7	107.9
	140	67.7	75.0	142.7	19.6	109.6	129.2
	280	116.6	71.3	187.9	42.2	128.1	170.4
Analysis of Variance							
Cultivar (C)							
	Russet B	72.9	77.9	150.8	26.1	132.5	158.6
	Reddale	75.2	69.9	145.1	25.7	110.1	135.8
Signif.		NS	*	NS	NS	**	**
N rate (N)							
	70	44.5	68.8	113.3	12.3	102.7	115.0
	140	66.6	74.6	141.2	19.7	122.7	142.4
	280	111.0	78.2	189.2	45.7	138.5	184.2
Signif.		**	NS	**	**	**	**
Linear		**	*	**	**	**	**
Quad.		NS	NS	NS	NS	NS	NS
Interaction							
C X N		NS	NS	NS	*	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 8 (56 DAP[1])					June 20 (74 DAP)					July 3 (84 DAP)				
Cultivar	N rate lb N/A	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
		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	5.62	3.63	5737	22057	1697	4.75	2.47	1886	9456	1079	4.01	1.77	609	3713	225
	140	5.81	3.64	5955	21726	1973	5.36	2.89	4621	18759	1714	4.57	2.58	4092	17147	1809
	280	5.77	3.73	6347	22844	2088	5.67	3.04	6965	21842	1816	5.16	2.95	7051	24539	2458
Reddale	70	5.90	3.94	7388	22386	1863	5.27	3.33	3683	15941	1235	4.33	2.09	1027	6400	641
	140	5.80	4.04	8255	22763	1978	6.01	3.73	5646	21016	1540	4.67	2.93	2513	15795	1293
	280	5.89	3.99	7659	25181	1951	6.32	3.90	6479	22877	1736	5.71	3.42	5197	24434	2014
Analysis of Variance																
Cultivar (C)																
Russet B		5.73	3.67	6013	22209	1919	4.26	2.80	4490	16685	1536	4.58	2.43	3917	15133	1497
Reddale		5.86	3.99	7767	22443	1931	5.85	3.65	5269	19945	1504	4.87	2.81	2912	15543	1316
Signif.		NS	**	**	NS	NS	**	**	**	**	NS	**	**	**	NS	NS
N rate (N)	70	5.76	3.79	6563	22221	1780	5.01	2.90	2784	12699	1157	4.17	1.93	818	5057	433
	140	5.80	3.84	7105	22244	1976	5.68	3.31	5133	19887	1627	4.62	2.76	3302	16471	1551
	280	5.83	3.86	7003	24013	2019	5.97	3.47	6722	22359	1776	5.42	3.18	6124	24486	2236
Signif.		NS	NS	NS	NS	**	**	**	**	**	**	**	**	**	**	**
Linear		NS	NS	NS	NS	*	**	**	**	**	**	**	**	**	**	**
Quad.		NS	NS	NS	NS	NS	**	**	**	**	*	NS	**	**	**	**
Interaction																
C X N		NS	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	**	**	**

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

[1] DAP = Days after planting

Table 12. Con't.

Cultivar	N rate	Sampling Date														
		July 17 (98 DAP)					July 31 (112 DAP)					August 14 (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
	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	3.33	1.14	61	384	39	2.99	1.18	66	181	3	2.86	1.23	62	57	1
	140	3.50	1.64	1166	5360	557	4.27	1.57	339	1391	50	3.65	1.44	113	419	24
	280	4.78	2.81	3809	16901	1932	4.92	2.56	2290	11557	1149	4.49	2.09	639	4445	170
Reddale	70	3.63	1.15	87	325	26	3.01	1.09	402	265	1	3.07	1.20	148	63	4
	140	3.76	1.47	454	2912	313	3.72	1.36	262	1320	28	3.30	1.25	182	994	36
	280	4.74	2.75	2634	14904	1835	4.78	2.33	2254	10363	998	4.31	1.97	1113	6632	299
Analysis of Variance																
Cultivar (C)																
Russet B		3.87	1.87	1679	7548	843	8.06	1.77	898	4376	401	3.67	1.59	271	1640	65
Reddale		4.01	1.79	1058	6047	7124	3.84	1.60	972	3983	342	3.56	1.47	481	2363	113
Signif.		NS	NS	**	NS	NS	NS	*	NS	NS	NS	NS	NS	*	**	NS
N rate (N)																
	70	3.48	1.15	74	355	32	3.00	1.14	234	223	2	2.97	1.22	105	60	3
	140	3.63	1.56	810	4136	435	3.99	1.47	300	1356	39	3.48	1.34	147	707	30
	280	4.76	2.78	3221	15902	1884	4.85	2.44	2272	10960	1074	4.40	2.03	876	5538	235
Signif.		**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Linear		**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Quad.		**	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

Table 13. Soil nitrate-N concentrations at the early (July 27) and late (Sept. 7) harvest.

N rate	Depth	Sampling Date			
		July 27		Sept. 7	
lb/A	Ft.	In Row	Betwn Row	In Row	Betwn Row
		lb NO_3-N/half acre[1]			
70	0-1	4.8 ± 1.8	3.6 ± 1.0	6.3 ± 1.9	5.3 ± 1.7
	1-2	1.6 ± 0.5	1.1 ± 0.6	2.3 ± 0.8	1.9 ± 0.7
	2-3	1.9 ± 1.4	1.4 ± 1.4	1.5 ± 0.5	1.1 ± 0.4
	Total	8.2 ± 2.1	6.0 ± 2.8	10.0 ± 3.0	8.3 ± 2.4
Total lbs NO_3-N/A in field[2]		14.1 ± 3.9		18.3 ± 5.1	
140	0-1	6.1 ± 1.6	4.5 ± 1.3	7.3 ± 2.5	5.7 ± 2.3
	1-2	5.0 ± 4.3	1.5 ± 0.7	2.5 ± 1.1	1.8 ± 0.8
	2-3	8.0 ± 5.7	1.9 ± 1.0	1.5 ± 0.7	0.9 ± 0.5
	Total	19.1 ± 8.6	7.8 ± 1.6	11.2 ± 3.9	8.5 ± 3.4
Total lbs NO_3-N/A in field		26.8 ± 8.9		19.7 ± 7.0	
280	0-1	19.6 ± 9.9	8.2 ± 3.0	9.4 ± 2.4	6.3 ± 1.8
	1-2	56.8 ± 42.6	6.7 ± 12.8	3.2 ± 1.8	1.7 ± 0.4
	2-3	23.0 ± 17.9	9.4 ± 24.2	2.1 ± 1.1	1.0 ± 0.3
	Total	99.4 ± 50.4	24.5 ± 40.2	14.8 ± 4.9	9.1 ± 2.1
Total lbs NO_3-N/A in field		123.8 ± 47.6		23.9 ± 5.4	

[1] Assumes half the field was row and the other half was between row.

[2] Total lbs NO_3-N/A in field = total in row plus total between row.

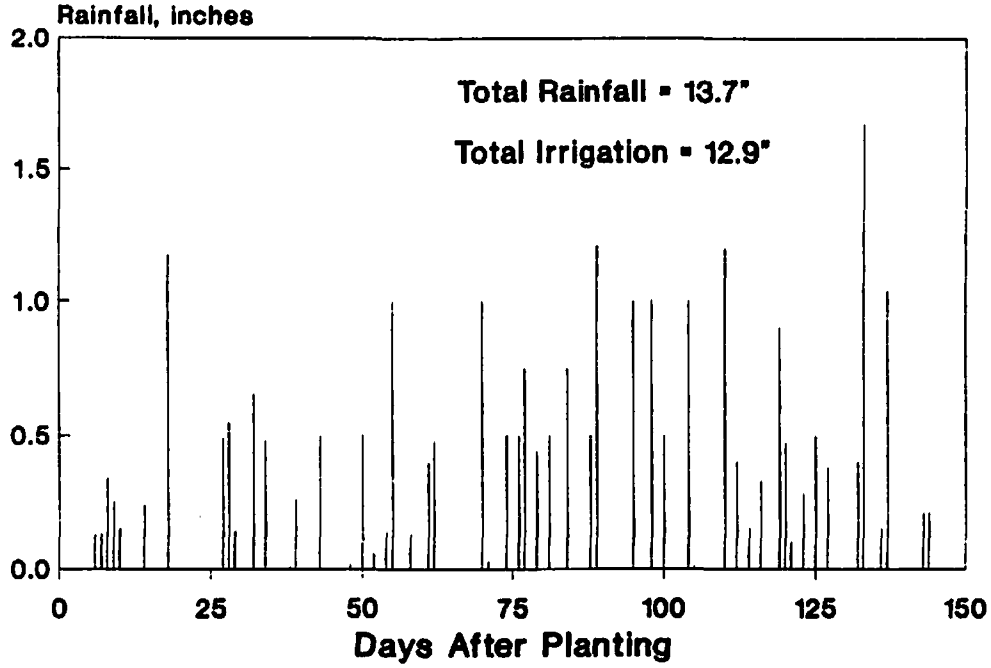

Figure 1. Rainfall and irrigation at Becker, MN during the 1989 growing season.

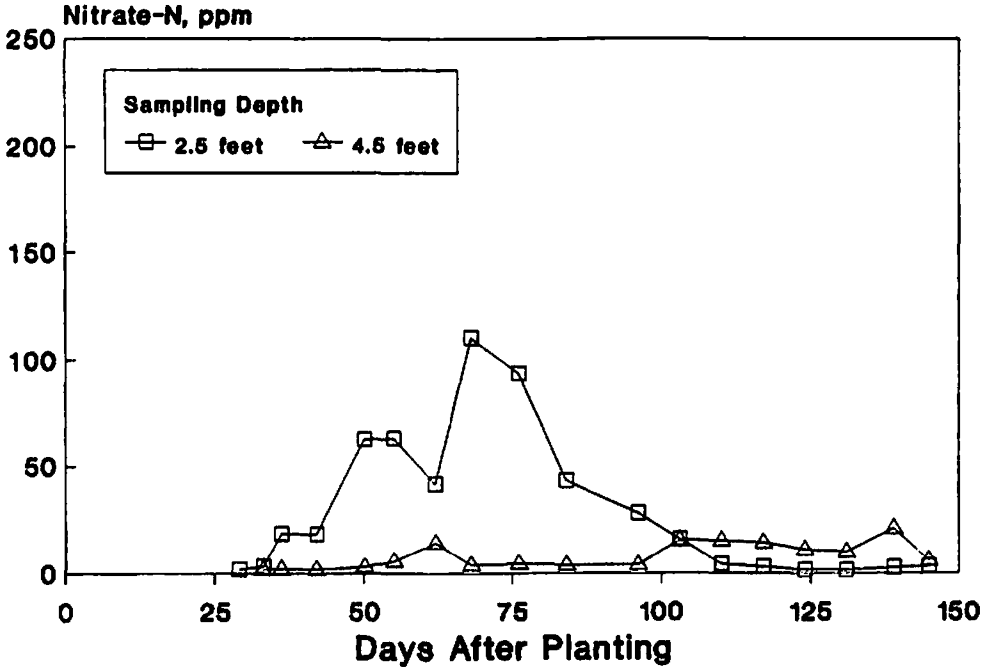

Figure 2. Nitrate-N concentrations in soil water at two depths during the 1989 growing season. Nitrogen application rate was 70 lb N/A.

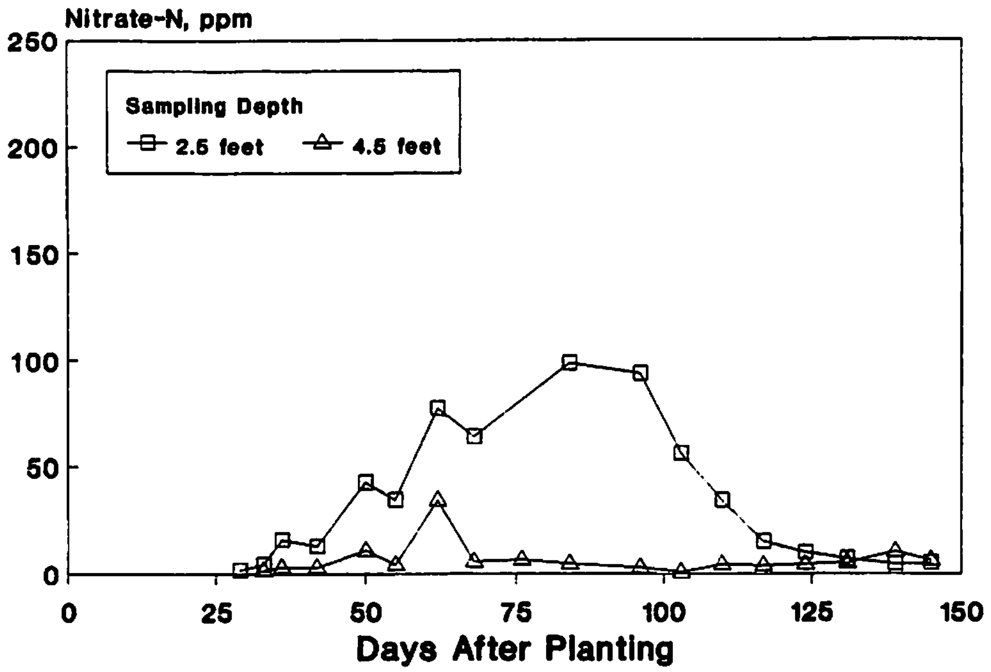

Figure 3. Nitrate-N concentrations in soil water at two depths during the 1989 growing season. Nitrogen application rate was 140 lb N/A.

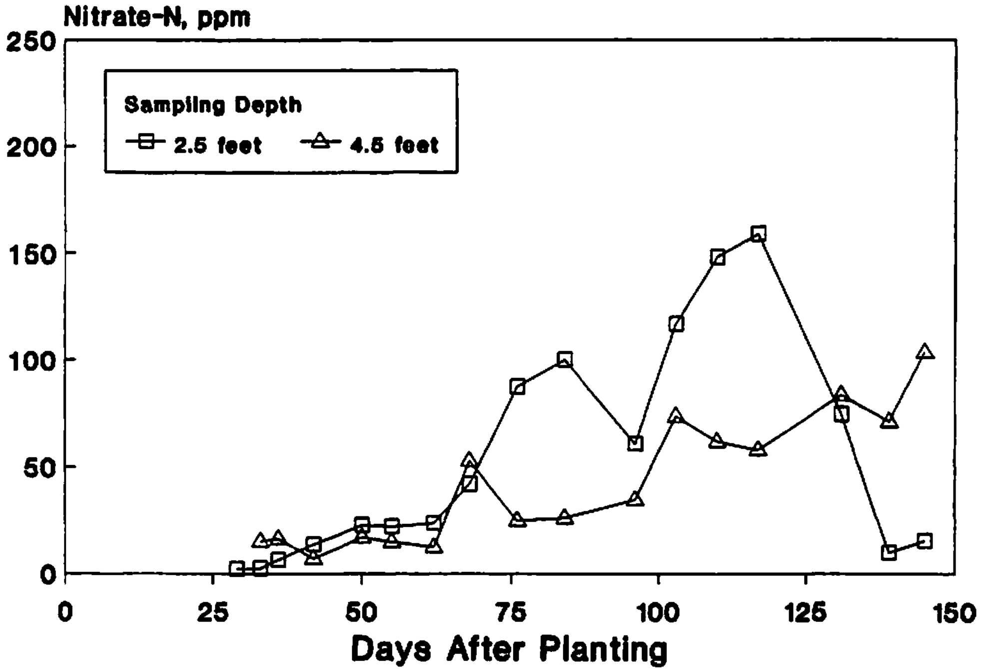

Figure 4. Nitrate-N concentrations in soil water at two depths during the 1989 growing season. Nitrogen application rate was 280 lb N/A.

1989 WEATHER DATA
NORTHWEST EXPERIMENT STATION, CROOKSTON, MN

T.E. Cymbaluk[1]

Nineteen eighty-nine was a drier year than the weather records show. The last 6 years, since 1984, the rainfall has been below normal with a total deficit of 14.47 inches. The drought of 1988 depleted the subsoil moisture, and 1989 was not a moisture-replenishing year. A precipitation a deficit of 2.48 inches occurred in 1989 with eight of the twelve months below normal. There were no precipitation events in 1989 that could be classified as a "soaker", precipitation in large enough quantity to thoroughly wet the soil profile and reach field capacity. During 1989, the precipitation usually came in a quarter-inch or less. The 1989 growing season had only 14 rains greater than a quarter of an inch of moisture.

Eight of the 12 months were below normal in regard to temperature. The average temperature in 1989 was 37.18° F. The highest temperature for 1989 occurred on August 3 at 100° F. The coldest day of the year occurred on January 10, a -36° F.

The ground frost reached a maximum depth of 41.5 inches by March 21. Surface thaw began on March 28 and by April 30, the ground frost was completely gone.

The last frost of the spring was on May 6, 1989 (28° F). The first hard killing frost occurred on September 22, 1989 (27° F). This made a 139-day frost-free period for 1989.

Table 1. Weather summary for 1989 with 90-year averages for precipitation and mean temperatures.

	Precipitation		Mean Temperatures	
Month	1989	1890-1979	1989	1890-1979
	------- inches -------		---------- °F ---------	
January	1.01	0.56	6.3	3.7
Febuary	0.13	0.59	-1.5	8.1
March	1.64	0.84	17.2	22.9
April	0.39	1.57	39.6	41.4
May	4.56	2.59	57.7	54.6
June	2.71	3.56	63.2	64.4
July	0.56	3.09	73.2	69.6
August	5.05	2.90	68.6	67.4
September	0.89	2.16	56.6	57.5
October	0.27	1.43	42.2	45.3
November	0.75	0.78	21.3	26.7
December	0.23	0.60	1.8	11.5
Total	18.19	20.67	Mean 37.2	39.4

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

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

Table 2. Records broken or matched at the Northwest Experiment Station, Crookston, MN in 1989.

Highest Maximum Temperature

Date	Old Record	New (1989)
	°F	
July 4	92 (1940)	94
August 1	98 (1930)	99
August 3	96 (1893)	100
September 30	86 (1976)	86
October 24	71 (1973)	78
October 25	72 (1901)	79

Lowest Maximum Temperature

Date	Old Record	New (1989)
	°F	
April 9	27 (1962)	26
April 8	25 (1950)	24
May 5	38 (1931)	37
June 13	54 (1917)	54
August 5	70 (1912)	66
August 20	65 (1902)	64
October 2	44 (1950)	39
November 16	14 (1903)	11
December 20	-18 (1916)	-19
December 21	-12 (1916)	-15

Highest Minimum Temperature

Date	Old Record	New (1989)
	°F	
August 1	73 (1936)	73
August 2	71 (1964)	74

Lowest Minimum Temperature

Date	Old Record	New (1989)
	°F	
January 9	-34 (1930)	-34
January 10	-32 (1979)	-36
August 5	45 (1957)	42
October 2	23 (1974)	13
October 3	22 (1965)	19
October 6	19 (1954)	15
October 8	17 (1986)	16
December 17	-25 (1901)	-25

ZINC APPLICATION ON SUGARBEET 1988-1989

John A. Lamb and Allan W. Cattanach[1]

OBJECTIVE:

Twenty years ago studies were conducted at the Northwest Experiment Station that suggested that sugarbeet may have responded to zinc. An update was needed to put the uncertainty to rest and to improve the soil test recommendations in Minnesota and North Dakota. With this in mind a study was conducted in 1988 and 1989 with the objective to determine if production practices developed in the last 20 years (varieties and quality payment system) influenced the response of sugarbeet to zinc fertilization.

MATERIALS AND METHODS:

Zinc fertilizer application studies were conducted at three locations in 1988 and four locations in 1989. Table 1 lists the locations and DTPA zinc soil test. Four zinc rates (0, 10, 20, and 40 lb zinc/A) in 1988 and five rates (0, 2.5, 5, 7.5, and 10 lb zinc/A) in 1989 were preplant broadcast applied and incorporated as zinc sulfate. At all locations variety KW 1745 was overplanted in 22-inch rows mid-April and thinned to 125 beets per 100 feet of row (29,700 plants/A). The plots were machine harvested late September and quality analyses were by the American Crystal Sugar Company Tare Lab, East Grand Forks, MN.

Table 1. The location and DTPA zinc soil test for zinc study 1988 and 1989.

Year	Location	Soil Test (ppm 0-6 inches)
1988	Crookston, MN (NWES)	0.3
1988	Perley, MN	0.3
1988	Maynard, MN	0.6
1989	Amenia, ND	0.3
1989	Felton, MN	0.5
1989	Crookston, MN (NWES)	0.3
1989	Sacred Heart, MN	0.6

RESULTS AND DISCUSSION:

Zinc applications on sugarbeet was researched in 1968 and 1969 by Dr. Soine, Soil Scientist, NWES. From these results it was concluded that there was a trend towards yield increase with the addition of zinc fertilizer (Table 2). The evidence was not conclusive enough to recommend use of this practice to growers. With production changes such payment system and varieties, new data was needed to determine if zinc fertilization is needed. The current soil test for zinc on other crops at the University of Minnesota uses a DTPA extractant and is quite reliable. A soil test of 0 to 0.5 ppm is classified as low, 0.5 to 1.0 ppm as marginal, and greater than 1.0 ppm as adequate.

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

[1] Soil Scientist, Northwest Experiment Station, University of Minnesota, Crookston, MN; and Extension Sugarbeet Specialist, North Dakota State University and University of Minnesota, Fargo, ND.

Table 2. The effect of zinc fertilization on sugarbeet in 1968 and 1969.

	1968			1969 - 4 locations		
Zinc Rate	Root Yield	Sugar	Impurity Index	Root Yield	Sugar	Impurity Index
lb Zn/A	T/A	%	---	T/A	%	---
0	16.4	12.9	904	18.5	15.7	763
10	18.0	13.3	824	19.0	15.7	761
40	18.6	13.4	824	18.5	15.7	729

The locations used in the study in 1988 and 1989 had soil tests in the low or marginal categories (Table 1). This was done to ensure the best probability of a yield response to zinc application. The results from seven locations in 1988 and 1989, Tables 3 and 4, indicate that the use of zinc fertilizer is still not nessessary. Root yield, sugar concentration, recoverable sugar, and impurity index were not affected by zinc fertilization at any of the seven locations. At this time zinc application for sugarbeet production is not recommended even with soil test values in the low category.

Table 3. The effect of zinc fertilization on sugarbeet root yield, sugar concentration, recoverable sugar, and impurity index in 1988.

Zinc Rate	Root Yield	Sugar	Recoverable Sugar		Impurity Index
lb $ZnSO_4$/A	T/A	%	lb/A	lb/T	---
0	11.8	17.3	3735	314	627
10	12.3	17.5	3935	317	626
20	12.4	17.4	3922	316	596
40	12.3	17.3	3889	314	623
Statistical Analyses					
Location	*	**	*	**	**
Zinc Rate	NS	NS	NS	NS	NS
Location * Rate	NS	NS	NS	NS	NS
C.V. %	12.5	3.2	13.6	4.0	12.2

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

Table 4. The effect of zinc fertilization on sugarbeet root yield, sugar concentration, recoverable sugar, and impurity index in 1989.

Zinc Rate	Root Yield	Sugar	Recoverable Sugar		Impurity Index
lb Zn/A	T/A	%	lb/A	lb/T	---
0	16.2	14.9	4271	263	797
2.5	15.8	15.0	4263	268	788
5.0	15.7	15.1	4245	267	783
7.5	15.9	15.1	4258	266	799
10.0	16.2	15.2	4266	263	812
Statistical Analyses					
Location	**	**	**	**	**
Zinc Rate	NS	NS	NS	NS	NS
Linear	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS
Location* Rate	NS	NS	NS	NS	NS
C.V. %	11.0	2.7	11.9	3.7	9.4

** is the 0.01 significance level, respectively.

PHOSPHORUS APPLICATION ON SUGARBEET 1987-1989

John A. Lamb[1]

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.

MATERIALS AND METHODS:

A phosphorus rate study was conducted over three years, 1987-1989, on a Wheatville loam at the Northwest Experiment Station. Five phosphate rates (0, 20, 40, 60, and 80 lb P_2O_5/A) as triple superphosphate (0-44-0) were applied spring 1987, fall 1987, and fall 1988. The fall soil tests each year were 9 lb/A in 1987, 9 lb/A in 1988, and 12 lb/A in 1989. Variety KW 3265 was overplanted in mid-April each year and thinned back to a population of 125 beets per 100 feet of row (29,700 plants/A). Each study was machine harvested mid-September and quality determined at the American Crystal Sugar Quality Lab, East Grand Forks, MN.

RESULTS AND DISCUSSION:

The growing conditions through the duration of this study were diverse. In 1987, sufficient rainfall occurred to produce an excellent sugarbeet crop. The fall of 1987 was the start of the current drought we are experiencing. In the 1988 cropping year the plants under went severe drought stress. The winter snows and early planting date in 1988-1989 were the reason the 1989 yield data was better than 1988. The early planting date allowed for quick plant establishment and excellent stands because of the better soil moisture conditions.

Tables 1 and 2 list the root yield, sugar concentration, recoverable sugar, and impurity index for 1987 and 1988, respectively. Even though the yield levels were considerably different in both years, the nonresponse to phosphorus was the same. As reported earlier the sodium bicarbonate phosphorus soil test in each year was 9 lb/A. This is in the low testing category where the probability of plant response to phosphorus fertilization is very good. This phenomenon has been observed in the past in field experiments on spring wheat and soybeans in northwest Minnesota. Evidently one of two possibilities exist to explain this: 1) sugarbeet is not a phosphorus responsive plant or, 2) the soil test used does not measure the capacity of the soil to provide phosphorus to the plant.

In 1989, a very large root yield and recoverable sugar per acre response occurred of 7.8 T/A and 1798 lb/A, respectively (Table 3). The sugar concentration was decreased approximately 0.5 %. Recoverable sugar per ton and impurity index were not effected by phosphorus fertilization in 1989. Phosphorus responses of these magnitudes are very unusual and were not expected particularly in view of the lack of response in 1987 and 1988. Why did the larger yield response occur? In 1989 the phosphorus plots were severely stunted by root maggot feeding. The sugarbeet plants that recieved phosphorus must have been growing faster and not stressed as much as the plant with no phosphorus. This allowed the plants to survive the stress from root maggot feeding better.

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

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

Table 1. The effect of phosphorus on sugarbeet root yield, sugar concentration, recoverable sugar, and impurity index in 1987 at NWES.

P Rate	Root Yield	Sugar	Recoverable Sugar		Impurity Index
lb P_2O_5/A	T/A	%	lb/A	lb/T	---
0	21.9	16.6	6561	300	623
20	22.7	16.7	6796	299	709
40	22.1	16.8	6750	305	593
60	23.3	16.0	6618	285	719
80	23.3	16.8	6996	300	699
Statistical Analyses					
Phosphorus	NS	NS	NS	NS	NS
Linear	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS
C.V. %	6.9	3.4	7.1	4.5	12.2

Table 2. The effect of phosphorus on sugarbeet root yield, sugar concentration, recoverable sugar, and impurity index in 1988 at NWES.

P Rate	Root Yield	Sugar	Recoverable Sugar		Impurity Index
lb P_2O_5/A	T/A	%	lb/A	lb/T	---
0	12.7	17.5	4088	322	535
20	13.4	17.5	4355	323	522
40	14.4	17.6	4673	324	541
60	14.0	17.7	4604	328	483
80	13.0	17.8	4273	330	472
Statistical Analyses					
Phosphorus	NS	NS	NS	NS	NS
Linear	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS
C.V. %	13.9	3.3	15.8	4.1	11.8

Table 3. The effect of phosphorus on sugarbeet root yield, sugar concentration, recoverable sugar, and impurity index in 1989 at NWES.

P Rate	Root Yield	Sugar	Recoverable Sugar		Impurity Index
lb P_2O_5/A	T/A	%	lb/A	lb/T	---
0	13.7	14.6	3502	256	847
20	19.0	14.4	4717	249	905
40	19.0	14.0	4534	239	962
60	21.5	14.3	5300	247	896
80	17.6	13.9	4202	239	918
Statistical Analyses					
Phosphorus	**	NS	*	NS	NS
Linear	*	++	++	NS	NS
Quadratic	**	NS	**	NS	NS
C.V. %	13.3	4.0	13.9	5.9	13.0

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

With the 1989 response and other references in the literature it can be concluded that sugarbeets need phosphorus to grow and if the phosphorus is not supplied to the plant from the soil phosphorus fertilization is needed. Work is needed to understand the phosphorus dynamics in Red River Valley soils to understand what governs the phosphorus availibility to plants. From this information a more accurate soil test method could then be developed.

COMPARISON OF SPRING-APPLIED DCD-UREA AND UREA OF HARD RED SPRING WHEAT IN NORTHWESTERN MINNESOTA

J.A. Lamb, T.E. Cymbaluk, and P. Nesse[1]

OBJECTIVE:

This study was conducted to compare the agronomic effects on spring wheat of DCD treated urea and urea.

MATERIALS AND METHODS:

A two-year study was conducted at the Northwest Experiment Station and in Mahnomen County in 1988 and 1989, respectively. Urea (46-0-0) and DCD-urea (47-0-0) was applied and incorporated in the spring at rates of 0, 40, 80, 120 and 160 lb N/A. The soil test NO_3^--N to 2-feet was 50 and 43 lbs N/A in 1988 and 1989, respectively. Marshall wheat was planted the last week of April with a press wheel double disk drill. In 1989 whole plant samples were taken at soft dough for N uptake. In both years, the plots were machine harvested with grain yields and protein determined and reported at 13.5% moisture. At the Mahnomen site, soil samples were taken after harvest to a depth of five feet and divided into one-foot increments.

RESULTS AND DISCUSSION:

The use of DCD-urea was intended to reduce N losses to leaching and denitrification. At the time of this study, northwest Minnesota was experiencing a drought, thus neither of the N loss conditions occurred. The Northwest Experiment Station experienced the fifth dryest growing season in 100 years in 1988. At the Mahnomen County location, the environmental conditions were much more favorable for wheat production in 1989 although the crop did suffer some drought stress during the growing season.

Grain Yield: In both years, grain yield responded to N fertilizer application (Table 1). At Crookston the response was quadratic with the maximum grain yield, 27.6 bu/A, a 3.9 bu/A increase, occurred with the addition of 40 lb N/A. In 1989 there was a source by N rate interaction ($P \leq 0.10$). The urea-fertilized wheat grain yield was maximized with 80 lb N/A applied and the DCD-urea treated wheat had a maximum grain yield at 120 lb N/A.

Grain Protein: Grain protein was increased both years of the study by N application (Table 1). Nitrogen source did not significantly affect this response. In 1988 the increase was linear and thus a maximum protein concentration was not reached. At Mahnomen County in 1989, the maximum grain protein occurred with the addition of 120 lb N/A. This data also indicates the inverse relationship between grain yield and grain protein. In situations with low yield (1988), the protein concentration is greater than when the grain yields are high (1989).

Forage Yield, N Concentration, N Uptake and Apparent Fertilizer N use Efficiency: Nitrogen source did not affect forage yield, N concentration or N uptake at soft dough in 1989 (Table 2). The application of N increased each parameter linearly so a maximum was not reached at even 160 lb N/A. The greatest N fertilizer use efficiency, 47%, occurred at 80 lb N/A which is the same as where maximum grain yield occurred with the urea source of N. This fertilizer use efficiency is similar to results from other N rate studies in northwestern Minnesota using 15N.

Residual Soil Nitrate-N: The application of N increased the residual nitrate-N content into a five-foot depth significantly (Fig. 1). At N rate of 80 lb/A or less, the residual nitrate-N was the same for both N sources. At N rates greater than 80 lb/A, the nitrate-N content was, on the average, greater in soil which had urea applied as N source.

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[1] Soil Scientist and Junior Scientist, Northwest Experiment Station, University of Minnestoa, Crookston, MN; and former Mahnomen County Agricultural Agent, Minnesota Extension Service, Mahnomen, MN.

Table 1. The effect of N source and rate on grain yield and protein in 1988 and 1989.

	1988				1989			
	Grain Yield		Grain Protein		Grain Yield		Grain Protein	
N Rate	Urea	DCD	Urea	DCD	Urea	DCD	Urea	DCD
lb N/A	-- bu/A --		--- % ---		-- bu/A --		--- % ---	
0	24.7	22.6	13.0	13.3	44.3	42.1	11.3	11.4
40	27.6	27.4	14.2	13.8	58.7	54.7	12.3	12.1
80	27.4	26.3	14.1	14.1	65.1	61.7	13.1	13.6
120	25.1	27.8	14.4	14.1	60.0	63.6	14.0	13.5
160	24.7	26.0	14.6	14.9	59.2	62.0	13.7	13.7
Statistical Analyses								
Source	NS		NS		NS		NS	
N Rate	NS		**		**		**	
Linear	NS		**		**		**	
Quadratic	*		NS		**		**	
Source x N Rate	NS		NS		++		NS	
C.V. %	12.3		2.9		6.7		3.9	

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

Table 2. The effect of N source and rate on forage yield, N concentration, N uptake, and fertilizer use efficiency at soft dough in 1989.

	Forage Yield		Forage N Concentration		Forage N Uptake		Apparent N Efficiency Ave. of Both Sources
N Rate	Urea	DCD	Urea	DCD	Urea	DCD	
lb N/A	-- lb/A --		--- % ---		-- lb/A --		% Applied
0	4326	4988	1.04	0.78	44.0	39.1	-
40	5358	6020	0.86	1.07	45.9	63.6	33
80	6663	7453	1.17	1.07	77.4	81.6	47
120	6899	5847	1.47	1.21	102.9	72.4	38
160	6345	7846	1.18	1.37	75.5	107.1	31
Statistical Analyses							
Source	NS		NS		NS		
N Rate	**		**		**		
Linear	**		**		**		
Quadratic	NS		NS		NS		
Source x N Rate	NS		NS		NS		
C.V. %	20.4		21.9		33.4		

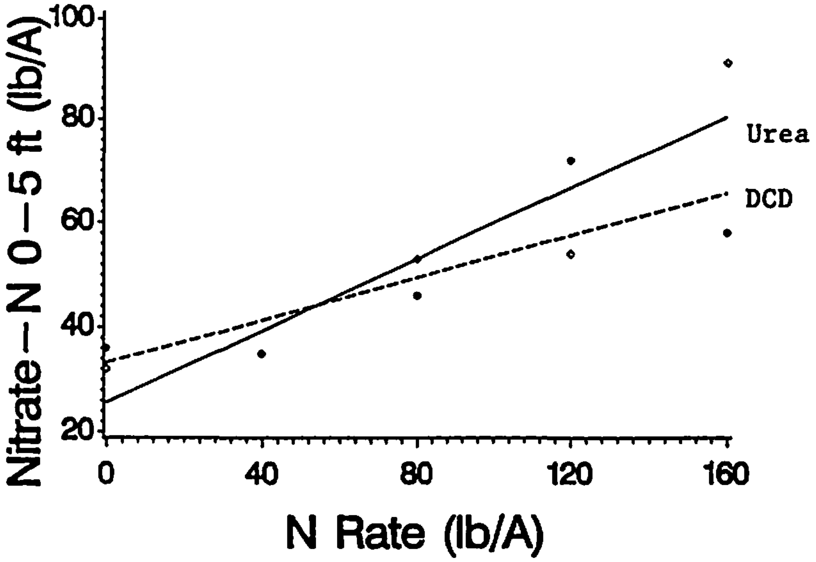

Figure 1. The effect of N source and rate on residual soil nitrate-N (0-5 ft) in 1989.

RESIDUAL NITROGEN STUDY AT LAMBERTON[1]

D.J. Fuchs 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. In all previous years, excluding 1988, N-rate response was noted for corn but not for soybeans. In 1989, for the first time since 1984, soybeans showed a significant positive N-rate response from increasing nitrogen rates applied on the previous corn crop. Corn yields demonstrated a non-linear response to increasing N-rates, characteristic of a diminishing return relationship.

(Annual report of this experiment has been included in past University of Minnesota, Soil Science Department's "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. 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 #/Ac applied side dress as urea during the corn year. Addition management data is given in Table 1.

Results: Yields are given in Table 2.

Regression analysis was used to determine if there was a significant effect of nitrogen rate on corn and soybean yields. There was a significant non-linear relationship between nitrogen rates and corn yields ($r^2 = 0.94$, see Table 2 and Figure 1). Corn yields increased with increasing nitrogen rates until the 200 lbs/ac rate, then the yields began to decline (see Table 2 and Figure 1). In the past, corn had a significant response to nitrogen each year. In 1989, there was also a significant non-linear relationship between the residual nitrogen rates applied to corn in 1988 ($r^2 = 0.95$, see Table 2 and Figure 2). Three possible reasons for this are 1) that some of the residual nitrogen may act like starter fertilizer for the under developed soybean plants, providing easy access to nutrients until the soybean plant is able to manufacture its own and/or; 2) the soybean nodules become inactive when seed fill takes place. If nitrogen is deep, it will not inhibit nodulation but be available below the area of nodules (mostly 9-12 inches) where water is available during seed fill and still a major portion of nitrogen is needed and/or; 3) The drought of 1988 may have negatively effected populations of symbiotic bacteria, increasing the soybean dependence on available nitrogen sources in the soil. Previously, soybeans did not have a response to residual nitrogen.

Table 1. Corn and Soybean Management Information.

Item		Corn	Soybean
1988 Fall Primary Tillage:		Soil Saver	Soil Saver
Secondary Tillage	Type:	Digger (Twice)	Disk (Twice)
	Date:	25 April	11 May
Seed	Hybrid/Variety:	P 3732	Hardin
	Rate:	26,000 ppa	150,000 seeds/ac
	Date:	2 May	11 May
Herbicide	Brand:	Eradicane-Bladex	Treflan-Amiben
	Rate:	2.5 & 1.5 #/ac	0.75 & 2.5 #/ac
	Date:	25 April	11 May

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[1] Funding provided by the Agricultural Experiment Station.

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

Table 2. Corn and Soybean Yields.

Nitrogen (lbs./ac.)	Corn (bu./ac.)	Soybeans (bu./ac.)
0	97.0	40.2
50	116.2	40.9
100	121.8	43.5
150	129.0	43.3
200	128.8	45.3
400	127.6	46.2

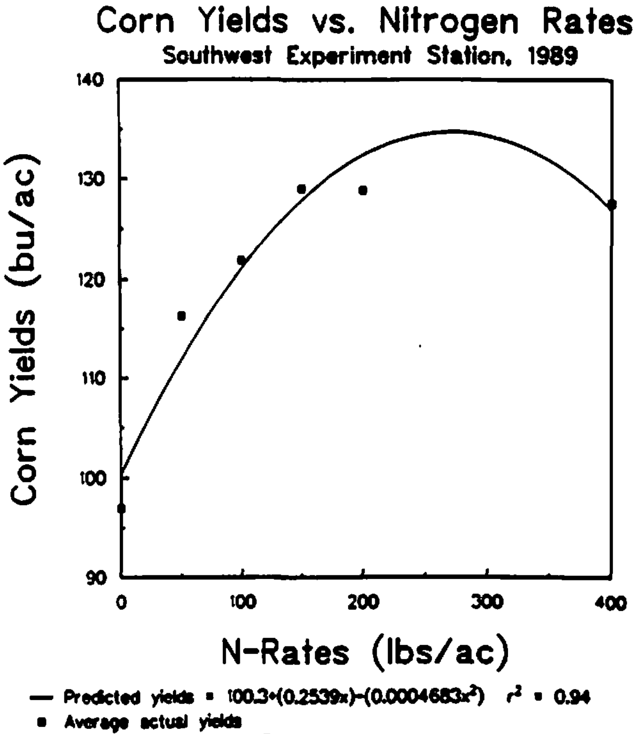

Figure 1.

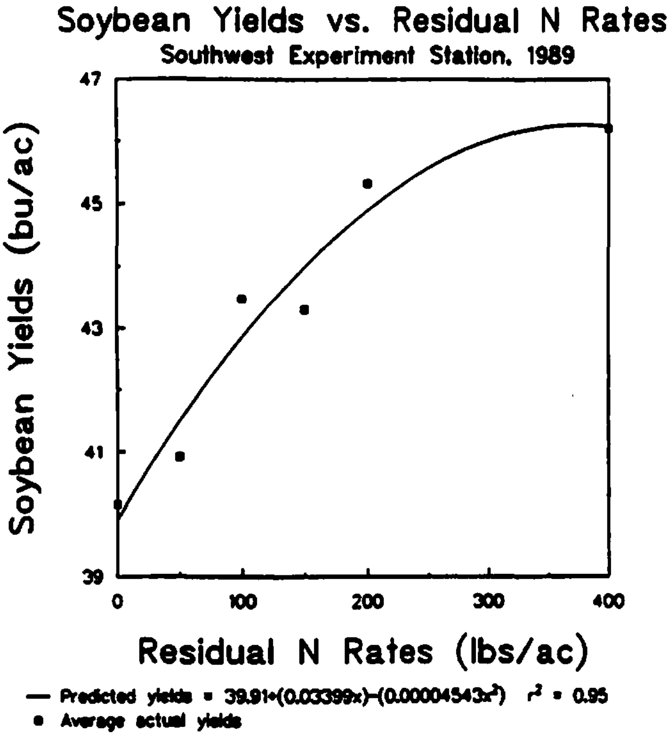

Figure 2.

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

D.J. Fuchs 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, spring or sidedressed) 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 1989, there was little difference between the 80 and 160 pounds N/Ac treatments, probably because of residual nitrogen from the drought of 1988. The 0 & 40 pounds N/Ac treatments had lower yields with the check having the lowest yields. The time of application and N forms affected yields as they have in the past 30 years. The 30 year average of the treatments indicate that 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 30 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.

1989 results: The 1989 yields from this experiment are given in Table 1. Also included are the 30-year averages (In 1976, no yields were obtained due to drought, thus only 29 years of data exist). The one-way analysis of variance (Table 2) indicates a significant treatment effect. The LSD for yield ($\alpha = 0.05$) is 16.8 bu/ac.

The results of 1989 did not completely follow the trend of the past where greatest yield response is to increasing N-rates. This may have been caused by residual nitrogen that was not used during the dry 1988 growing season and was available for use in 1989. The two highest yielding treatments were 80 pounds of N/Ac of urea spring applied and 80 pounds of N/Ac of ammonium nitrate sidedressed (see Table 1). However, there was no significant difference between those yields and the 160 pounds of N/Ac treatments (see Table 1). This year and in the past, there has been a moderate response to delayed application time, with the exception of the fall surface treatments. Urea nitrogen treatments had approximately a 2 bu/ac yield advantage over ammonium nitrate. This year, as in the past, 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 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 clay loam, Southwest Experiment Station, Lamberton, MN 1989.

Nitrogen Treatment			1989					29-year
Rate	Form	Time	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Avg.	Avg.
#N/Ac			Bu/Ac @ 15.5 % moisture					
--	Check	----	73.4	79.2	73.2	95.1	80.2	66.0
40	Ammonium Nitrate	Fall	102.5	101.9	110.4	107.8	105.7	84.0
40	Urea	Fall	79.0	103.2	108.0	122.2	103.1	87.0
40	Ammonium Nitrate	Fall Surface	87.3	99.3	97.3	105.1	97.3	82.0
40	Urea	Fall Surface	106.1	82.4	116.6	113.5	104.7	87.0
80	Ammonium Nitrate	Fall	119.5	117.7	98.2	136.2	117.9	104.0
80	Urea	Fall	105.5	121.9	111.7	146.8	121.5	103.0
160	Ammonium Nitrate	Fall	124.0	122.8	111.5	126.2	121.1	111.0
160	Urea	Fall	138.8	116.6	128.0	123.1	126.6	112.0
40	Ammonium Nitrate	Spring	83.5	92.9	115.8	95.2	96.9	95.0
40	Urea	Spring	81.8	103.2	90.7	114.0	97.4	93.0
80	Ammonium Nitrate	Spring	93.2	91.8	135.0	147.0	116.8	107.0
80	Urea	Spring	124.0	113.5	138.7	157.3	133.4	108.0
40	Ammonium Nitrate	Side Dress	108.4	106.7	123.3	124.2	115.7	97.0
40	Urea	Side Dress	105.9	97.9	122.3	123.9	112.5	97.0
80	Ammonium Nitrate	Side Dress	138.4	111.4	142.4	134.9	131.8	104.0
80	Urea	Side Dress	105.0	100.6	134.9	142.7	120.8	112.0
160	Ammonium Nitrate	Side Dress	119.7	139.6	126.3	127.8	128.4	116.0
	Average						111.5	98.1
	LSD (α=0.05)						16.8	

Table 2. One-way analysis of variance.

Source	DF	Sum of Squares	Mean Square	P value
Block	3	4708.0	1569.0	$7.37 * 10^{-6}$
Treatment	18	18360.0	1020.0	$5.26 * 10^{-9}$
Error	54	7501.0	138.9	

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

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 study 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 1989, tillage had no significant effect on yield. Erosion level had a significant effect on yield (alpha = 0.01) with the higher yields occurring on the less eroded treatments. Corn yields usually decrease with increasing erosion levels 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", and results from 1987 and 1988 were presented in the 1989 "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 in the past was applied based on the soil test of each erosion treatment. In 1989, 157-20-7 pounds of $N-P_2O_5-K_2O$ was broadcast over the entire study. Additional management information is given in Table 1.

Grain yields are given in Table 2. Analysis of variance, using a spilt plot design (tillage = whole plots, erosion class = split plots) is furnished in Table 3.

Summary of results: In 1989, there was no significant difference between moldboard plow and ridge tillage (see Table 6 and 7). The severe erosion class had significantly lower yields than the moderate and slight erosion class (see Table 2 & 3). Least significant differences (LSD's) are provided in the appropriate summary table if analysis of variance is significant.

The entire study was moldboard plowed in the fall of 1989 because of the visual and measured potassium deficiency symptoms that occurred in the ridge tillage treatment, and the study will be continued next year to further examine these nutrient deficiency problems (Table 4).

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

Table 1. Management Information.

Item	Type	Rate	Date
Secondary Tillage[1]	disk	twice	4/24/89
Insecticide	Counter	1.0 #/Ac	4/24/89
Seed	Pioneer 3732	26,000 p/Ac	" "
Herbicides	Lasso	3.0 #/Ac	4/24/89
	Bladex	2.0 #/Ac	" "

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

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

[2] 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 2. Mean yields (bu/ac) of tillage, erosion class and interactions.

Tillage	Erosion Class			Overall
	Slight	Moderate	Severe	Mean
Plow	128.8	128.1	116.3	124.4
Ridge	128.2	127.4	116.3	123.9
Overall Mean	128.5	127.7	116.3	124.2

$LSD_{0.05}$ = 7.6 for comparing erosion classes (averaged over both tillage treatments).

Table 3. Analysis of Variance.

Source	DF	SS	MS	P-value
Block	3	474.4	158.1	0.254
Tillage	1	1.354	1.354	0.897
Whole Plot Error	3	204.7	68.23	
Erosion	2	748.0	374.0	6.84×10^{-3} **
Interaction	2	0.63	0.315	0.994
Sub-Plot Error	12	577.6	48.13	

** significant at alpha = 0.01

Table 4. Earleaf samples at 50 % silking.

Erosion Class	Tillage	Average (%) K	P	N
Slight	Plow	1.67	0.29	3.1
	Ridge	1.33	0.31	3.4
Moderate	Plow	1.83	0.28	3.1
	Ridge	1.09	0.30	3.1
Severe	Plow	1.21	0.28	3.0
	Ridge	0.82	0.29	3.1

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

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%), three tillages (ridge tillage, moldboard plow, and chisel), and tillage/planting directions (up and down the slope, or contour to the slope) in a corn - soybean rotation. In 1989, tillage was the only significant treatment on soybean yields ($\alpha = 0.05$). In the past, slope position and/or planting direction also had significant effect on crop yields ($\alpha = 0.05$).

(The 1989 University of Minnesota "Blue Book" contains information for the years 1986, 1987 and 1988.)

Materials: This study began in the spring 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/planting directions (up and down the slope, or contour to the slope) in a corn and soybean rotation. The slope positions are not taken into account for the 4 and 1 percent slopes. Also the tillage/planting directions are not taken into account for the 1 percent slopes. Yields are measured every year. Soil movement is being monitored by grass catch strips and infrared transit survey.

Additional management information is provided in Table 1.

Results: Main effects are presented in tables followed by the interaction effects. Analysis of variance for each slope treatment is provided (Table 2-7). The 8 and 4% slope had a significant tillage effect with greatest yields occurring on moldboard plow treatments (see Table 2B & 3, and 4B & 5, respectively). Last year ridge tillage was the highest yielding tillage treatment for the first time in four years. All other treatments were not significantly different. Analysis of variance was not performed on the different slope percentages (8, 4 & 1%) however, the overall average yield decreased with increasing slope (see Table 2A, 4A & 6A).

Table 1. Management Information.

Item	Type	Rate	Date
Secondary Tillage[1]	Disk/Digger	1 pass each	4/20
Seed	Corsoy 79	150,000 seeds/ac	5/17
Herbicides	Lasso	3.0 lbs/ac	5/19
	Amiben	2.5 #/Ac	5/19

1/ No secondary tillage on ridge tillage plots.

Table 2 (A-H). Soybean Yields on the 8 Percent Slope.

2A. Overall Average.

	Avg	s[1]
Overall	38.7	3.5

n (sample no.) = 54

1/ s = sample standard deviation.

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

[2] 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.

2B. Tillage (Ranked by ascending averages).

Tillage	Avg	s
Ridge	36.1	3.8
Chisel	38.8	3.0
Moldboard	41.0	2.5

n = 27 LSD$_{0.05}$ = 4.2

2C. Row Direction.

Row Direction	Avg	s
Up & Down	38.6	3.5
Contour	38.7	3.9

n = 27

2D. Slope Position.

Slope Position	Avg	s
Top	38.9	4.2
Mid	38.6	3.7
Bottom	38.5	3.3

n = 18

2E. Tillage - Row Direction Interaction.

Tillage	Row Dir.	Avg	s
Chisel	Up & Down	38.8	2.6
Chisel	Contour	38.9	3.3
Moldboard	Up & Down	40.7	2.4
Moldboard	Contour	41.4	2.7
Ridge	Up & Down	36.4	4.0
Ridge	Contour	35.9	3.9

n = 9

2F. Tillage - Slope Position Interaction.

Tillage	Slope Pos.	Avg	s
Chisel	Top	38.9	3.7
Chisel	Mid	38.8	3.2
Chisel	Bottom	38.9	2.1
Moldboard	Top	41.9	2.8
Moldboard	Mid	41.2	2.6
Moldboard	Bottom	40.0	2.1
Ridge	Top	35.8	3.9
Ridge	Mid	35.9	3.6
Ridge	Bottom	36.7	4.5

n = 6

2G. Row Direction - Slope Position Interaction.

Row Dir.	Slope Pos.	Avg	s
Up & Down	Top	37.5	4.3
Up & Down	Mid	39.6	3.4
Up & Down	Bottom	38.8	2.4
Contour	Top	40.2	3.7
Contour	Mid	37.6	3.9
Contour	Bottom	38.2	4.1

n = 9

2H. Tillage - Row Direction - Slope Position Interaction.

Till[1]	Row Dir.	Slope Pos.	Avg	s
CH	Up & Down	Top	38.6	3.9
CH	Up & Down	Mid	38.8	2.6
CH	Up & Down	Bottom	39.0	2.3
CH	Contour	Top	39.1	4.3
CH	Contour	Mid	38.8	4.4
CH	Contour	Bottom	38.8	2.4
MP	Up & Down	Top	40.3	2.3
MP	Up & Down	Mid	42.3	2.6
MP	Up & Down	Bottom	39.5	2.1
MP	Contour	Top	43.6	2.5
MP	Contour	Mid	40.0	2.4
MP	Contour	Bottom	40.5	2.5
RT	Up & Down	Top	33.5	4.2
RT	Up & Down	Mid	37.7	4.0
RT	Up & Down	Bottom	37.9	3.3
RT	Contour	Top	38.0	2.3
RT	Contour	Mid	34.2	2.8
RT	Contour	Bottom	35.5	6.0

n = 3

1/ Tillage Codes: CH = Chisel Plow, MP = Moldboard Plow, RT = Ridge Tillage

Table 3. Analysis of Variance for the 8 Percent Slope.

Randomized block with split - split plot restriction

Number of: Cases = 54 Blocks = 3
Row Directions = 2 Tillage Levels = 3 Slope Positions = 3

Source	DF	SS	MS	P-value
Block	2	27.56	13.78	0.181
Row Dir.	1	0.0938	0.09375	0.877
Whole Plot Error	2	6.081	3.041	
Tillage	2	216.7	108.4	0.0162 *
Row*Tillage	2	2.929	1.464	0.908
Sub-Plot Error	8	120.3	15.04	
Position	2	1.176	0.5878	0.944
Row*Position	2	52.79	26.39	0.0959
Tillage*Position	4	13.79	3.447	0.849
Row*Till*Pos	4	27.77	6.942	0.612
Sub-Sub Plot Err	24	244.6	10.19	

* significant at alpha = 0.05

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

4A. Overall Average.

	Avg	s
Overall	43.9	2.7

n = 12

4B. Tillage. (ranked by ascending averages).

Tillage	Avg	s
Chisel	41.3	3.6
Ridge	43.9	2.8
Moldboard	46.3	1.8

n = 4 LSD$_{0.05}$ = 2.5

4C. Row Direction.

Row Dir.	Avg	s
Up & Down	41.9	3.4
Contour	45.9	1.9

n = 6

4D. Tillage - Row Direction Interaction.

Till	Row Dir.	Avg	s
CH	Up & Down	38.6	3.0
CH	Contour	44.1	0.7
MP	Up & Down	45.4	0.4
MP	Contour	47.5	2.2
RT	Up & Down	41.7	1.8
RT	Contour	46.1	1.0

n = 2

Table 5. Analysis of Variance for the 4 Percent Slope.

Randomized block with split plot restriction
Number of: Cases = 12 Blocks = 2
Tillage Levels = 3 Row Directions = 2

Source	DF	SS	MS	P-value
Block	1	5.4	5.4	0.440
Row Dir.	1	47.8	47.8	0.172
Whole Plot Error	1	3.685	3.685	
Tillage	2	51.77	25.88	0.0253 *
Row*Tillage	2	5.945	2.973	0.386
Sub-Plot Error	4	9.758	2.44	

* significant at alpha = 0.05

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

6A. Overall Average

	Avg	s
Overall	46.5	2.0

n = 6

6B. Tillage.

Tillage	Avg	s
Chisel	45.4	1.9
Moldboard	48.0	3.0
Ridge	45.8	1.9

n = 2

Table 7. Analysis of Variance for the 1 Percent Slope.

Randomized block

Number of: Cases = 6 Blocks = 2
Tillage Levels = 3

Source	DF	SS	MS	P-value
Block	1	0.2017	0.2017	0.890
Tillage	2	8.163	4.082	0.667
Whole Plot Error	2	16.33	8.167	

THE RETENTION OF NITROGEN FERTILIZER APPLIED DURING THE WINTER
SOUTHWEST EXPERIMENT STATION
LAMBERTON, MN[1]

D.J. Fuchs and W.W. Nelson[2]

Abstract: Fertilizer nitrogen loss occurs primarily by four methods: 1) leaching, 2) volatilization, 3) denitrification, 4) and runoff. This study was conducted to determine if winter application of nitrogen reduced corn yields in comparison to spring application. In this study, nitrogen (120 lbs./ac. as urea) was applied during mid-December, mid-February, and before planting in the spring. A check treatment of 0 lbs./ac. of nitrogen was also included. Three years of research indicate only a slight yield advantage to spring application in comparison to winter applications, but a significant difference between 0 and 120 lbs. nitrogen.

Environmental concerns about possible contamination of surface water and groundwater by nitrates and other agricultural chemicals has generated public interest. A study was needed to determine the possible reduction of corn yields from nitrogen fertilizer applied in the winter in comparison to spring application as the result of runoff and/or gaseous losses.

EXPERIMENTAL PROCEDURE:

This study was initiated in the winter of 1986/87 in a corn - soybean rotation, looking specifically at the corn portion of the rotation. Nitrogen (120 lbs./ac.) was applied as urea (46-0-0) mid-December, mid-February or in the spring before planting. A control treatment with no nitrogen was also included in the completely randomized block design.

Table 1. lists the management information and actual dates of nitrogen applications for 1989. Management did not vary much for the other years.

Corn grain samples from the plots were collected in the fall and yields were calculated.

RESULTS AND DISCUSSION:

The corn yields are summarized in Table 2. The yields from 1988 were drastically reduced from the drought in comparison to 1987 and 1989. The check exhibited the lowest 3-year average. The analysis of variance shows that there was a significant difference between nitrogen application dates. The major difference occurred between no nitrogen and nitrogen being applied (Table 3 and 2). There was a minor difference between the three application timings with the greatest yields occurring when nitrogen was applied in the spring (101.1 bu/ac) and reduced slightly when applied in mid-February and slightly more reduced when applied in mid-December (98.5 and 93.0, respectively, see Table 2). This seems to prove that there in some nitrogen being volatilized and/or being moved off the field plots by spring runoff. There was also a significant interaction between timing of nitrogen applied and year. This was probably caused by the drought of 1988 (Table 2 & 3).

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[1] Funding provided by Agricultural Experiment Station

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

Table 1. Corn Management Information.

Item		Info.
Soil Test:		P = 42, K = 277, ph = 5.6 (water) ----(lbs/ac)---
Mid-December N application:		13 December, 1988
Mid-February N application:		28 February, 1989
Spring N application:		25 April, 1989
1988 Fall Primary Tillage:		Soil Saver
Secondary Tillage	Type:	Disk/Digger
	Date:	25 April
Seed	Hybrid/Variety:	P 3732
	Rate:	26,000 ppa
	Date:	2 May
Herbicide	Brand:	Lasso-Bladex
	Rate:	3.0 & 2.0 #/ac
	Date:	4 May
Row Cultivation	Date 1:	23 May
	Date 2:	9 June

Table 2. Corn yields (bu/ac) for specific treatments, years and overall averages.

Year	Check	Mid-December	Mid-February	Spring	Average
1987	130.9	125.6	131.5	132.1	130.0
1988	29.7	42.6	48.6	46.8	41.9
1989	68.8	110.9	115.4	124.4	104.9
Average	76.5	93.0	98.5	101.1	92.3

Table 3. Analysis of Variance.

Variable	DF	SS	MS	p-value
Year	2	65920	32960.0	0
Yr * Replication	9	2028	225.4	0.195
Nitrogen Timing	3	4407	1469.0	0.00015
Yr * N Timing	6	3892	648.7	0.0034
Error	27	4032	149.3	---

SOIL SPECIFIC MANAGEMENT(1)

Pierre Robert, Scott Smith, Wayne Thompson,
Wally Nelson, Dennis Fuchs, and Dean Fairchild(2)

ABSTRACT: The study compared soil specific and conventional management in a 70 ac. field located about one mile west of the Southwest Experiment Station. Soils were grouped in 3 soil potential classes. The conventional treatment received a uniform amount of fertilizer and herbicide. The Soil Specific treatment had variable rates of fertilizer and herbicide as a function of soil classes. The conventional treatment had a yield of 133 bu/ac and the Soil Specific treatment had a yield of 145 bu/ac. The net return of the Soil Specific treatment was $20 higher than the net return of the conventional treatment. Continuous yield measurement was simulated with a plot combine. Results are showing the benefits of this practice. Correlation between soil potential classes and measured yields are shown. The experiment design to study the movement of pesticides on three different soils located on a toposequence under conventional and soil specific management did not yield significant results. Since rainfalls were below average and the soil moisture was extremely low, no water was collected in the samplers.

BACKGROUND AND JUSTIFICATION:

Soil spatial variability within fields has been identified by soil survey maps, soil testing, and yield differences throughout Minnesota. However, present day practices apply only one rate of fertilizer and herbicide to fields with varying soil conditions. This may increase field management costs and contribute to surface and groundwater pollution. The main objectives of the project are to study benefits of Farming by Soil practices on farm profitability and leaching and runoff of pesticides.

EXPERIMENTAL PROCEDURES:

The main study was conducted in a 70 ac. field located about 1 mile west of the Southwest Experiment Station, Lamberton. Soils were grouped in 3 soil potential conditions:

1) High: Glencoe, Canisteo, and Delft/Webster;
2) Medium: Normania, Ves (1 to 4% slopes), and Seaforth;
3) Low: Ves (3 to 6% slopes), Ves/Storden, and Ves/Esterville.

Soil samples were taken in the Fall of 1988 at depths of 0-6", 0-24", and 24-48". Samples were analyzed for N, P, K, and Zn. Samples were taken in the Spring of 1989 at a depth of 0-24" and analyzed for nitrate.

The field management procedures are described in Table 1.

Table 1. Field management information.

Series: HILDRETH 66. Acres

CROP	SECONDARY TILLAGE	PREPLANT INC. HERBICIDE
Type.........CORN	Type.......DIGGER	Name.....ERADICANE X
Exp. Name....Farm by Soil	Date.......05 11 1989	Rate.....4
Var/Hybrid...PIONEER 3732	Type2......DIGGER	Name2....5/11/89
DoP..........05 12 1989	Date2......05 11 1989	Rate2....
Population...26100	Type3......	
Seedbed......MOIST	Date3......	
Structure....GRANULAR	CultDate1..05 30 1989	
Crop Year....1989	CultDate2..	
	CultDate3..	
PRIMARY TILLAGE	**INSECTICIDE**	**FERTILIZER**
Type.........PLOW	Type.......COUNTER	Analysis...46-0-0
Residue......RETURNED	Rate.......1	Rate.......AS PLAN
		Date.......05 11 1989
		Analysis2..
		Rate2......
		Date2......

Notes: Stalks Chopped 10/26/89, Plowed 10/27/89, Harvested 10/6/89.

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(1) Funding provided by a USDA-CSRS grant.

(2) Assistant Professor, Junior Scientist, Student Junior Scientist, Dept. of Soil Science, Univ. of Minn; Superintendent, Junior Scientist, S.W. Exp. Sta., Univ. of Minn.; and agronomist, Soilteq, Inc., respectively.

Yield goals were adjusted for low soil moisture levels. Yield goals are given in Table 2.

Table 2. Yield goals (bu/A)

Soil condition	
High	150
Medium	135
Low	80
Conventional	130

Fertilizer rates were adjusted from soil test levels and yield potential on each soil condition. Phosphorus and potassium rates are based on soil samples taken in the Fall of 1988. Nitrogen rates were adjusted based on the nitrate levels from samples taken in the Spring of 1989. Eighty percent of the nitrate were used for the 0-24" depth. Levels in the 24-48" zone were generally below 30 lbs/A and not considered in determining nitrogen recommendations. Soil test results used for fertilizer recommendations are listed in Table 3. Fertilizers were broadcast on 5/11/89 using the Soilection equipment from the Co-op County Farmers Elevator in Renville, MN. The impregnation pump was calibrated with Eradicane Extra the day of application. Products used were Urea (46-0-0), Diammonium Phosphate (18-46-0), and Potash (0-0-60)(Table 4).

Table 3. Average soil test levels (lbs/A)

Soil condition	NO^3-N	P	K	Zn
High	67.2	27.5	285	>1.0 ppm
Medium	96	21.7	265	>1.0 ppm
Low	45	17.0	233	>1.0 ppm

Table 4. Fertilizer and herbicide application rates

Treatment	N	P_2O_5	K_2O	Eradicane Extra
1. Conventional	130	40	30	5.3
2. Control	0	0	0	5.3
3. High	140	40	30	5.3
Medium	75	55	30	5.3
Low	50	35	30	5.3
4. High	140	40	30	7.0
Medium	75	55	30	5.3
Low	50	35	30	4.0

Yields were taken using the plot combine late September on marked plots, 2 rows and 30 ft. long. Continuous yield measurements were taken for each treatment strip on rows 6 and 7 every 40 ft. Grain moisture was determined for every tenth harvest sample.

Table 5 gives the 1989 field treatments and Table 6 application costs. Each treatment strip was 60 ft. wide.

Table 5. Field treatment descriptions

Trt. 1.	Conventional broadcast fertilizer and herbicide applications. Uniform rates were applied over the entire treatment area.
Trt. 2.	Control. No fertilizer was applied to the treatment area. Herbicide was applied at a uniform rate over the entire treatment area.
Trt. 3.	Variable fertilizer rates were applied according to the varying soil conditions in the treatment area. Three levels were employed: High, Medium, and Low. A uniform application of herbicide was applied over the entire treatment area.
Trt. 4.	Variable fertilizer and herbicide rates were applied according to the varying soil conditions and pH in the treatment area. Three levels were applied: High, Medium and Low.

Table 6. Application costs

Treatment	N	P_2O_5	K_2O	Eradicane Extra	Input Total per Acre
1. Conventional	$27.30	$ 8.80	$3.60	$32.33	$63.03
2. Control	$ 0.00	$ 0.00	$0.00	$32.33	$32.33
3. High	$29.40	$ 8.80	$3.60	$32.33	$74.13
Medium	$15.75	$12.10	$3.60	$32.33	$63.78
Low	$10.50	$ 7.70	$3.60	$32.33	$21.80
4. High	$29.40	$ 8.80	$3.60	$42.70	$84.50
Medium	$15.75	$12.10	$3.60	$32.33	$63.78
Low	$10.50	$ 7.70	$3.60	$24.40	$46.20
Unit prices:	$.21/Lb.	$.22/Lb.	$.12/Lb.	$6.10/pt.	

RESULTS AND DISCUSSION:

Table 7. Grain yields and relative net return by treatment and soil condition.

Treatment	Level	Soil	Surface Available Water Capacity	Yield (bu/A)	Relative Net Return ($/Acre)
1	High	114	5.20	132±25	244±59
1	High	86	3.60	135±17	249±41
1	High	884	4.79	138±08	256±19
1	High	654	3.00	113±24	198±56
1	Medium	446	3.66	135±18	250±43
1	Medium	421B	2.10	143±16	268±38
1	Medium	423	3.15	147±05	278±11
1	Low	421B2	2.10	145±14	274±32
1	Low	954C2	1.85	97±25	159±60
1	Low	999B2	1.96	95±31	156±73
2	High	114	5.20	99±31	194±72
2	High	86	3.60	81±16	155±38
2	High	884	4.79	77±26	145±61
2	High	654	3.00	68±14	122±32
2	Medium	446	3.66	87±20	169±46
2	Medium	421B	2.10	75±23	138±54
2	Medium	423	3.15	82±04	158±09
2	Low	421B2	2.10	61±04	108±10
2	Low	954C2	1.85	42±25	63±50
2	Low	999B2	1.96	71±25	132±58
3	High	114	5.20	145±20	262±46
3	High	86	3.60	142±13	255±30
3	High	884	4.79	135±09	237±20
3	High	654	3.00	122±16	207±38
3	Medium	446	3.66	142±13	264±30
3	Medium	421B	2.10	132±20	241±47
3	Medium	423	3.15	146±10	273±23
3	Low	954C2	1.85	118±16	217±37
3	Low	999B2	1.96	124±24	231±56
4	High	114	5.20	147±17	256±39
4	High	86	3.60	149±15	259±35
4	High	884	4.79	131±23	217±53
4	High	654	3.00	145±04	251±10
4	Medium	446	3.66	147±17	276±41
4	Medium	421B	2.10	139±19	257±44
4	Medium	423	3.15	143±13	267±30
4	Low	421B2	2.10	152±08	306±19
4	Low	999B2	1.96	124±44	239±103

Table 8. Economic analysis results

Treatment	Gross Return[a]	Relative Net Return[b]	Expenses[c]
1	313±51	246±51	68±0
2	191±58	155±58	36±1
3	326±39	251±39	75±3
4	342±42	266±42	76±6

[a] dollar value @ 2.35 per bushel of corn.
[b] gross return minus expenses different between treatments.
[c] see Table 9 for breakdown.

Table 9. Dollar breakdown of production costs[a]

Treatment	Total Expenses[b]	Relative Input Costs[c]	Custom Service Charges[d]	Drying Costs[e]
1	68±0	63±0	4.50	0.01±0.15
2	37±1	32±0	3.50	0.52±0.82
3	75±3	69±3	5.50	0.00±0.00
4	76±6	70±7	5.50	0.08±0.27

[a] dollars per acre.

[b] sum of input costs, custom service charge and drying costs. Identical management costs are not included.

[c] based on pounds of nutrient and volume of herbicide applied: N @ $.21/lb., P2O5 @ $.22/lb., K2O @ $.12/lb., Eradicane Extra @ $6.10/pint. see Table 4 for rates applied per treatment. Weighted values were generated using ratios of linear plot measurements.

[d] application costs:
Trt 1 = Air-Flow with herbicide impregnation,
Trt 2 = Broadcast herbicide application,
Trt 3 & 4 = Soilection with herbicide impregnation.

[e] approximated using $.04/unit % over 15.5%/bushel.

Table 10. Treatment summary

	Treatments			
	1	2	3	4
Yield[a] (bu/A)	133±22	81±25	139±17	145±18
Input Cost[b] ($)	68±0	36±1	75±3	76±7
Relative Net Return[c] ($)	246±51	155±58	251±39[d]	266±42[d]

[a] based on 15.5% moisture content.
[b] include fertilizer and herbicide costs, custom application costs and estimated grain drying costs.
[c] corn value of $2.35/bu less input costs.
[d] weighted by soil condition acreage.

Grain yields and relative net returns are given in table 7 by treatments, soil conditions (high, medium, low) and soil types. They represent means of the three replications. Grain yields and relative net returns are summarized in Table 10.

The farming by soil treatments (treatment 4) shows a $20/acre benefit over the conventional treatment (treatment 1) (Table 10).

The large standard deviations are due to combinations of the following: 1) large range of response in soil complexes (421B2, 954C2, and 999B2); 2) high response to fertilizer applications on 421B2 soils; and 3) inherent variability of soil conditions within each soil type.

Table 11. Analysis of Covariance
Dependent variables: relative net return

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	23723.07	3942.85	36.25	0.0006
Error	5	545.32	109.06		
Corrected Total	11	24268.39			

R-Square	C.V.	Root MSE	Relative Net Return Mean
0.977530	4.56	10.44	229.10

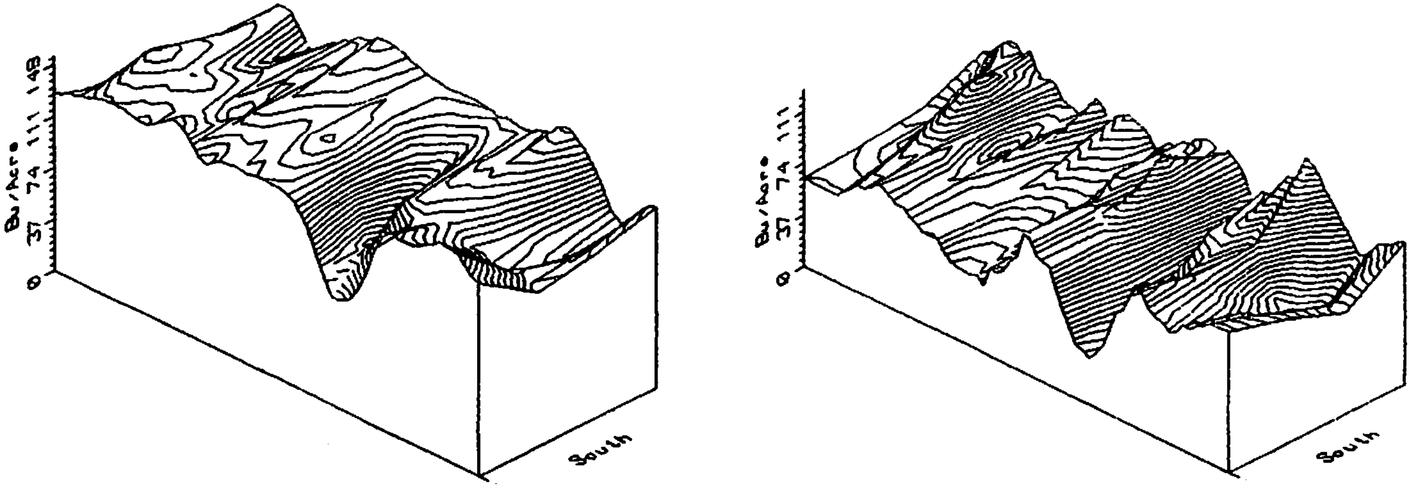
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Replication	2	966.24	483.12	4.43	0.0782
Treatment	3	22441.25	7480.42	68.59	0.0002
Expenses	1	315.58	315.58	2.89	0.1497

LSMeans

	1	2	3	4
1	.	0.01	0.15	0.05
2	0.01	.	0.02	0.02
3	0.15	0.02	.	0.09
4	0.05	0.02	0.09	.

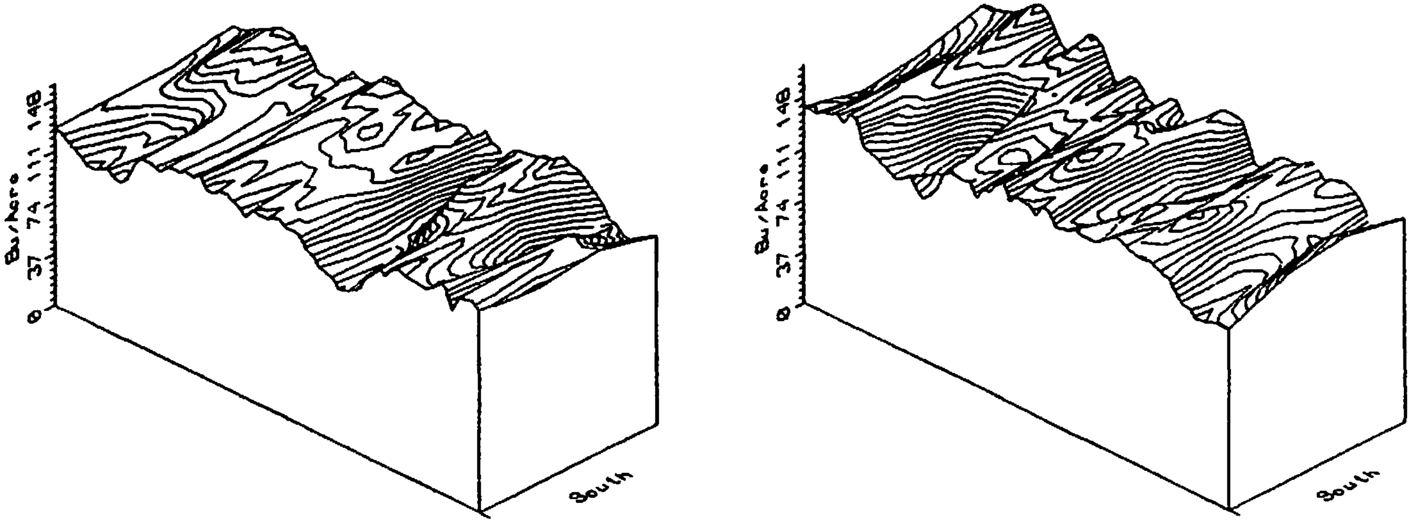
Covariate analysis of the strip means using expenses as covariate showed an 85% probability of receiving a greater net return using variable rate applications versus the conventional uniform rates. Error resulting from the soil variability between treatment strips was adjusted for by using expenses as a covariate, thus clarifying the differences between treatments (LSmeans) (Table 11).

The yield variability is represented by four 3D plots corresponding to each treatment (Figure 1). Each plot was generated using data from the three replications and represents the experimental field (2560 ft. x 1200 ft.). The greatest variability occurs with the check (no fertilizer and no herbicide) and the smallest with the farming by soil treatment.



Conventional (Trt 1)

Control (Trt 2)



Variable Fertilizer (Trt 3)

Variable Inputs (Trt 4)

Figure 1. Yield variability.

The effect of tillage and corn hybrid on available potassium, moisture stress, and yields at Lamberton, Minnesota, 1988 and 1989[1]

J.F. Moncrief, W.W. Nelson, D.J. Fuchs, A. Eynard, and J.B. Swan[2]

Tillage and corn hybrid both affected ear leaf concentrations of potassium on a calcareous clay loam soil in southwestern Minnesota in 1988 and 1989. In neither year however were ear leaf concentrations and grain yields correlated. Grain yields were better correlated with extracted soil water at the end of the season.

Tillage has often been observed by researchers to reduce potassium availability to corn on soils with indigenously low levels (eastern Minnesota, eastern Iowa, and Wisconsin) of potassium when full width deep primary tillage is eliminated (Swan, Moncrief, and Schreiber, 1983). Recently this reduction in availability has been observed on soils that have natively high levels of potassium in western Minnesota. Three years of data at the Southwest Experiment Station, Lamberton, Minnesota has shown about a 10 bushels per acre decline in corn yield when using a ridge till system compared to moldboard plowing (Swan, Lindstrom, and Nelson; 1988). This decline has been correlated to reduced levels of tissue potassium (ear leaf at 50% silk emergence) even though soil test levels have been 250 to 300 pounds per acre. Others have also observed that the reduced potassium availability has been associated with specific corn hybrids. In dry years the apparent tillage effect on potassium availability seems to be more severe.

In an effort to evaluate tillage and corn hybrid effects on potassium availability, tillage plots were monitored at the Southwest Experiment Station at Lamberton, Minnesota in 1988.

Methods and Materials

The tillage history at this site has been maintained for three years (first established in the fall of 1985). Corn was grown in rotation with soybeans. Tillage ranges from fall plowing with a moldboard, chisel, or paraplow or elimination of primary tillage (ridge till or no till systems). The paraplow is a unique type of subsoiler that leaves the surface relatively undisturbed but lifts the soil more than a conventional subsoiling operation. The tillage is reduced following soybeans in two treatments since less crop residue is being managed. The moldboard/chisel plow system is moldboard plowed following corn and chisel plowed following soybeans. The chisel/no till system is chisel plowed following corn and no tilled following soybeans. Only the ridge till plots were cultivated on July 7. Nitrogen was applied within two days after planting as anhydrous ammonia.

The soil at this site is a Ves clay loam (Udic Haplustoll) on replications 5, 6, and 7 and Normania clay loam (Aquic Haplustoll) on rep 8. Soil samples (5 cores per composite sample) were taken to a depth of 2 feet in 6 inch increments July 5 -11. Samples were taken on July 5, 6, 7, and 11 for replications 5, 6, 8, and 7 respectively. These samples were analyzed for ammonium acetate extractable potassium and gravimetric water was determined. Potassium has not been applied since 1982 when this field received an application of 100 lbs/acre of 0-0-60 broadcast. Ear leaf samples (20 per composite sample) were taken when the silk in a given treatment was at 50% emergence and analyzed for potassium.

Leaf water potential measurements were made on July 5 and 21 with a pressure chamber technique. Water loss by the leaves between the time of excision and reading was minimized by enclosing the sample in a cooled sheath and the time was kept below 3 minutes. Two leaves per plot were sampled near the daily maximum for evaporative demand under clear conditions.

Results and Discussion

Soil and Plant Tissue Potassium

The soil test potassium (K) is in the medium range (table 1). Although there was not a statistically significant tillage or depth effect on soil test K there was a interaction between the two variables. The trend is for the surface soil test to increase as the tillage is reduced. Fertilizer has not been applied to these plots. This has been shown at other locations in Minnesota. This is due to the phytocycling of K primarily by the corn.

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[1] This project is supported by the Minnesota Agricultural Experiment Station.

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Ear leaf concentrations of K at silk emergence are shown in tables 2-4. Chisel plowing (fall of 1987) alternated with moldboard plowing (fall of 1986) resulted in the highest concentration of K (Md/Ch treatment). The no till treatment in 1988 that was chisel plowed (ch/nt) in the fall of 1986 had similar concentrations of ear leaf K. Paraplowing, ridge till, and continuous no till treatments had similar concentrations which were lower than the chisel plowing treatment. The alternative tillage (chisel plowing after corn and no till after soybeans) is more like the continuous plowing treatment than the continuous no till treatment in the no till year. The established critical level for ear leaf potassium concentrations at 50% silk emergence is 1.80%. All but the continuous plowing and chisel/no till treatments are clearly below the critical level for K. The K level in the corn is linearly related to the amount of energy required for tillage (see figure 1). The paraplow system did not follow this relationship. It appears that energy expended below the plow layer is much less efficient at loosening the soil and increasing root proliferation.

There was also a large effect of corn hybrid on ear leaf concentrations of K (table 3). The Supercross 2410 and Pioneer 3732 were the highest and lowest with the other three falling in between. In this study, the Pioneer 3732 and the DeKalb 524 were clearly below the critical level for K. Grain yields were not closely correlated with ear leaf potassium trends due to tillage or hybrid. The ridge till grown corn had low concentrations of K but tended to have the highest yield. Similarly the Pioneer 3737 had intermediate levels of K but was clearly the highest yielding hybrid. Yields were also influenced by water stress.

Soil Water and Plant Water Stress

The plant water stress and soil water in the row to a depth of two feet in July are shown in table 5. Although tillage was not statistically significant the trend was for the no till treatment to result in higher levels of soil water. Since the samples were in the row the ridge till treatment would not be expected to be higher. The plant stress measurement is a better technique to assess tillage differences and does show less plant stress than the plowing treatments.

The first plant stress measurement was made before ridging (ridge till plots were ridged on July 7). Within six days of the first measurement and the three days following ridging .68 inches of rain fell. In the next eleven days (until the second plant stress measurement) .16 inches of rain fell. The plant water stress before cultivation is rather high (corn leaves roll at about -14 to -16 bars of leaf water potential energy). At the second reading levels were somewhat lower. Air temperatures were also lower (12°F).

The distribution of soil water levels with depth were affected by corn hybrid (table 7). The Pioneer 3737 had higher levels of soil water below 6 inches. There also was a significant effect of hybrid and a tillage by hybrid interaction for the plant stress variable Table 8. The Pioneer 3737 had less plant water stress with ridge tillage. The Pioneer 3732 showed the highest and lowest stress under the moldboard/chisel plowing and continuous no till conditions respectively. The DeKalb had the lowest plant stress and was lowest under continuous no till conditions. The Funks 4327 had the highest stress under moldboard/chisel plowing conditions.

In 1989 plots were split with 20 lbs. K_2O per acre applied with the planter. The paraplowing treatment became spring discing. Only four corn hybrids were evaluated.

Tillage and corn hybrid both influenced ear leaf concentrations of potassium and grain yields. Yield differences due to tillage or corn hybrid were not very well correlated with ear leaf potassium. There was a better correlation with extracted soil water (see figure 2). There was a small but significant response to row applied K (table 9, 4 bushels per acre).

Summary

Tillage and corn hybrid had a major influence on tissue levels of K in southwestern Minnesota in 1988 and 1989. As tillage was reduced soil test K increased in the surface 6 inches from phytocycling in 1988. Also as tillage was reduced tissue K levels also were reduced. There is a linear relationship with the energy associated with tillage and tissue K levels. Systems that eliminate primary tillage resulted in lower levels of plant water stress. Although the tillage effect on grain yields was not statistically significant, they appeared to be correlated with tillage effects on moisture stress more than potassium availability. Hybrid effects on potassium availability was not correlated with grain yields. Although both tillage and corn hybrid affected ear leaf concentrations of potassium, in neither year was ear leaf concentrations correlated with grain yield differences.

Table 1. The effect of tillage and depth on soil test potassium in July, 1988 at Lamberton, Minnesota.

Depth	Tillage(.226)				
	No til	Ridge	Md/Ch	Para	Average
(.174)	lbs/acre				
0-6"	222	218	191	203	208
6-12"	187	200	197	187	193
12-18"	201	214	203	203	205
16-24"	191	209	191	198	197
Average	200	210	195	198	201

1. The p value for the tillage by depth interaction is .022.

Table 2. The effect of tillage on corn ear leaf potassium concentration and yields at Lamberton, MN., 1988.

Tillage					
No til	Ridge	Md/Ch[1]	Para	Ch/NT[1]	
percent					Sign.
1.60b	1.65b	2.05a	1.57b	1.74ab	.033
bushels per acre					
69	79	72	64	67	.330

1. Tillage is alternated for corn and soybeans for these two treatments. The tillage treatment before the slash follows corn and after the slash soybeans. For the corn year tillage treatments were chisel plowing and no till for the Md/Ch and Ch/NT treatments respectively.

Table 3. The effect of corn hybrid on ear leaf potassium concentration and yields at Lamberton, MN., 1988.

Hybrid					
P3732	DK524	P3737	F4327	SC2410	
percent					Sign.
1.46c	1.65b	1.72b	1.78b	1.99a	<.000
bushels per acre					
70	70	82	62	67	<.000

Table 4. The effect of tillage and hybrid on the concentration of potassium in corn ear leaf at 50% silk emergence at Lamberton, MN., 1988.[1]

	Tillage				
	No til	Ridge	Md/Ch[2]	Para	Ch/NT[2]
Hybrid	percent				
P3732	1.12	1.50	1.48	1.72	1.48
DK524	1.66	1.66	1.97	1.20	1.76
3737	1.48	1.84	2.20	1.49	1.61
F4327	1.63	1.70	2.17	1.36	2.01
SC2410	2.10	1.54	2.45	2.07	1.81

1. The p value for the tillage by hybrid interaction is .024
2. Tillage is alternated for corn and soybeans for these two treatments. The tillage treatment before the slash follows corn and after the slash soybeans. For the corn year, tillage treatments were chisel plowing and no till for the Md/Ch and Ch/NT treatments respectively.

Table 5. The effect of tillage on plant moisture stress, soil water, and yield in July, 1988 at Lamberton, MN.

	Hybrid(<.000)				
	Tillage(.020)				
	No til	Ridge	Md/Ch[1]	Para	Average
Date(.066)[2]	(-bars)				
7/5/88	14.0	14.5	14.9	14.9	14.6
7/21/88	13.4	13.2	14.4	13.5	13.6
Average	13.7	13.9	14.7	14.2	14.1
Soil Water[3]	%w/w				
(.163)	10.5	9.6	9.7	9.9	
	Bushels/acre				
Yield(.330)	69	79	72	64	

1. Tillage is alternated for corn and soybeans for this treatment. The tillage treatment before the slash follows corn and after the slash soybeans. For the corn year the tillage treatment was chisel plowing.
2. The tillage by date interaction has a p value of .329, n=32. Ridge till plots were cultivated to form ridges on July 7.
3. Average soil water in a two foot sample taken in the row between July 5 to 11, 1988.

Table 6. The effect of corn hybrid and depth on soil water taken between July 5 and 11, Lamberton, Minnesota.

Depth	Hybrid(.357)				
	P3737	P3732	DK524	F4327	Average
(.052)	%w/w				
0-6"	9.2	9.2	9.7	8.9	9.3
6-12"	11.6	10.8	11.2	10.6	11.0
12-18"	9.7	9.0	9.2	9.2	9.3
18-24"	10.6	9.9	9.6	9.7	9.9
Average	10.3	9.7	10.0	9.6	

1. The numbers in parenthesis are p values. The p value for the hybrid by depth interaction is .049, n=16.

Table 7. The effect of corn hybrid on plant moisture stress in July, 1988 at Lamberton, MN.[1]

	Hybrid(<.000)				
	P3737	P3732	DK524	F4327	Average
Date(.066)	(-bars)				
7/5/88	15.0	15.1	13.4	14.8	14.6
7/21/88	14.0	13.2	13.3	13.9	13.6
Average	14.5	14.2	13.4	14.4	14.1
Yield(<.000)	82	70	70	62	

1. The hybrid by date interaction has a p value of .001, n=32.

Table 8. The effect of tillage and depth on soil test potassium in July, 1989 at Lamberton, Minnesota.

	Tillage					
Depth	Ntl	Rdge	Md/ch	Ch/Nt	Dsc	Average
(<.001)	lbs/acre					
0-1'	274	263	304	202	260	275a
1-2'	267	246	282	273	239	258b
2-3'	238	219	251	259	232	233c
3-4'	167	176	185	194	178	180d
4-5'	186	190	202	190	193	192d
Avg.	226a	219a	244a	228a	220a	

Table 9. The effect of corn hybrid on ear leaf potassium concentration and yields at Lamberton, MN., 1989.

Hybrid				Row K with Planter (lbs K_2O/acre)	
P3732	DK524	P3737	SC2410	0	20
percent					
1.14a	1.17b	1.56a	1.46a	1.29a	1.37a
bushels per acre					
127c	139a	135ab	129bc	131a	135b

Table 10. The effect of tillage on corn ear leaf potassium concentration and yields at Lamberton, MN., 1988.

Tillage				
No tl	Ridge	Md/Ch[1]	Ch/NT[1]	Disc
percent				
1.23b	1.12b	1.70a	1.27b	1.34b
bushels per acre				
124b	135ab	141a	130ab	134ab

1. Tillage is alternated for corn and soybeans for these two treatments. The tillage treatment before the slash follows corn and after the slash soybeans. For the corn year tillage treatments were chisel plowing and no till for the Md/Ch and Ch/NT treatments respectively.

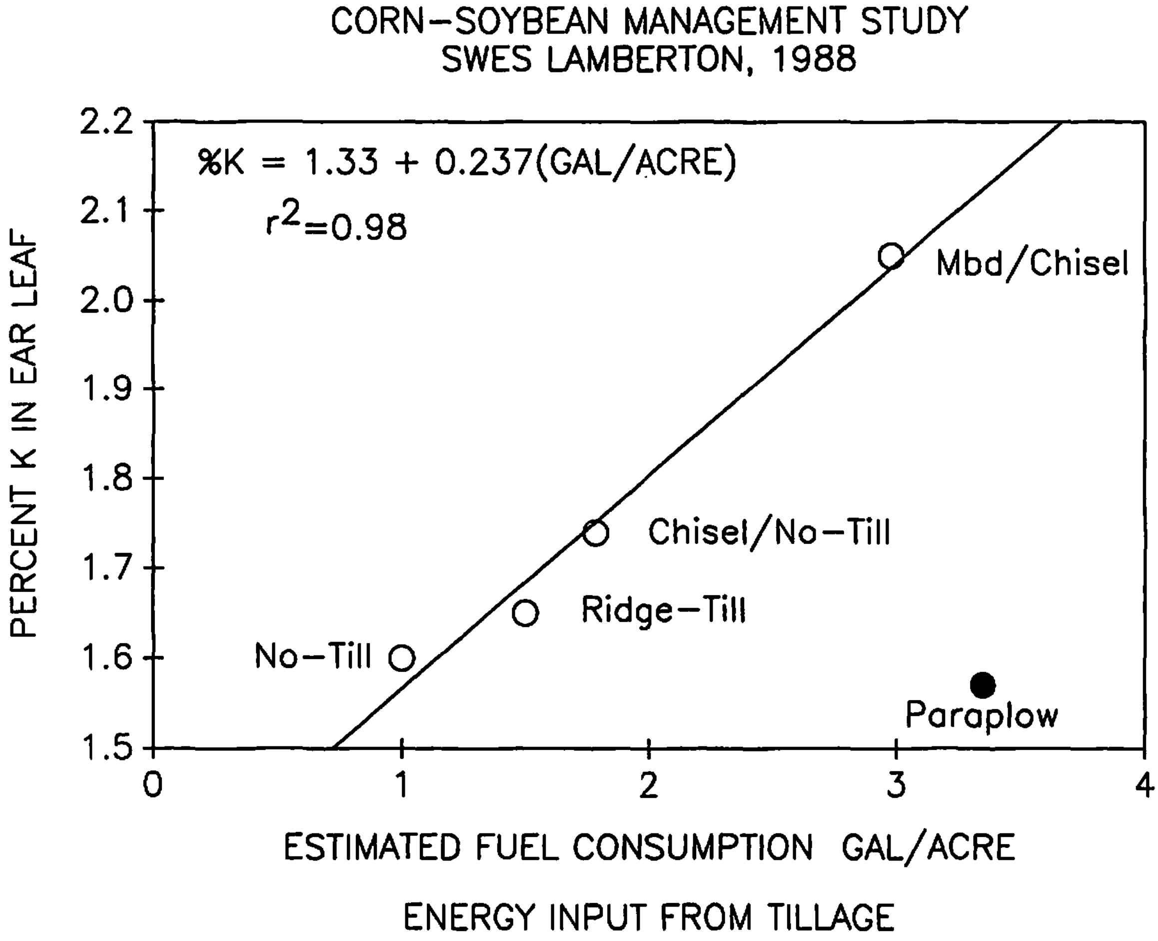

Figure 1. The relationship between energy associated with tillage and ear leaf potassium concentration.

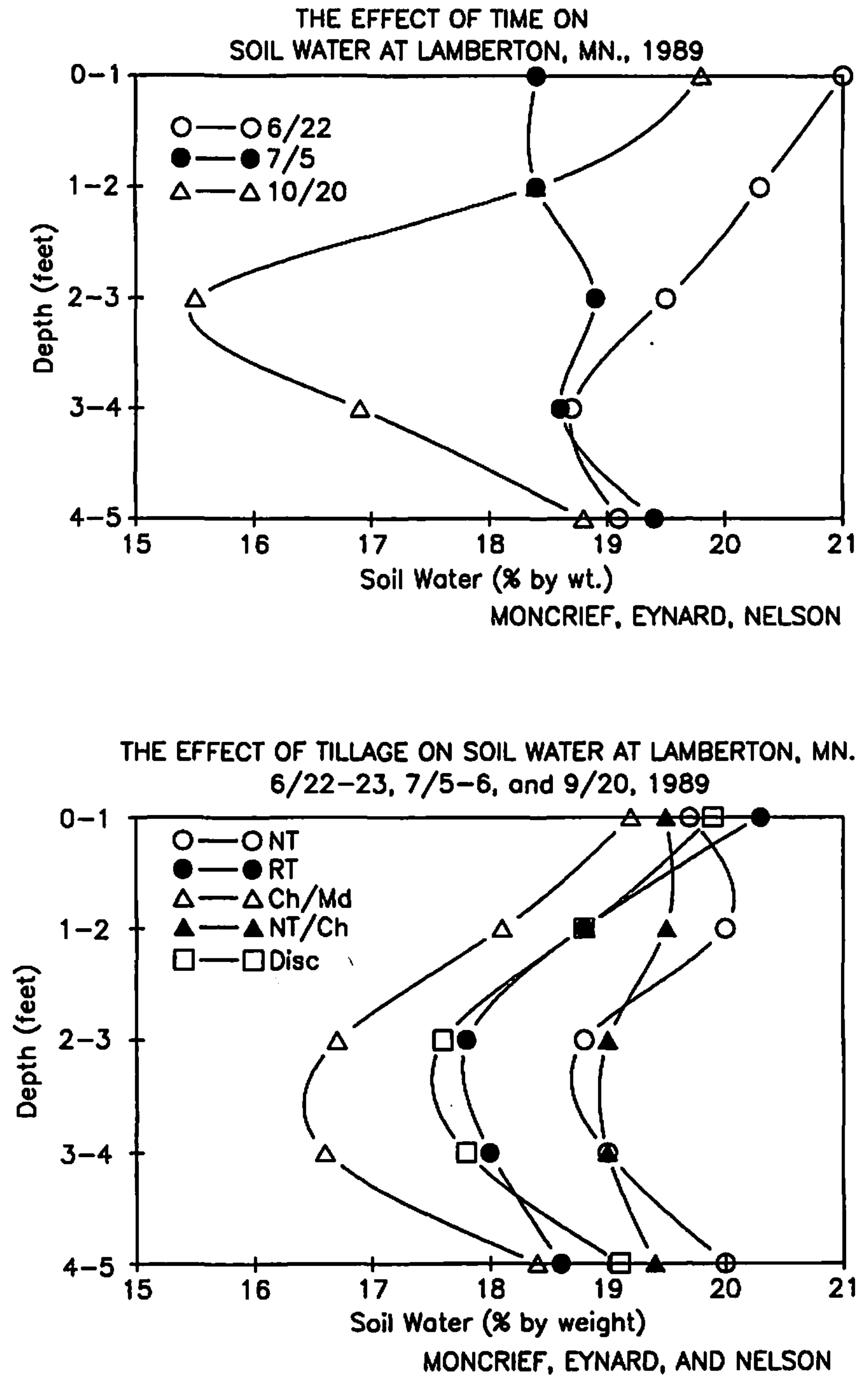

Figure 2. The effect of tillage and time on soil water during the growing season, 1989.

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1989

		Precipitation			Temperature			Soil Temperature	
			100-yr.	Dev.		100-yr.	Dev.	(10 cm depth)	
Month	Period	1989	av.	from av.	1989	av.	from av.	1989	10 yr. av.
January	1-31	0.59	0.68	-0.09	15.7	8.0	+ 7.7	24.6	20.7
February	1-28	0.58	0.67	-0.09	2.8	12.8	-10.0	14.7	23.9
March	1-31	1.37	1.13	+0.24	21.5	26.7	- 5.2	28.9	29.2
April	1-10	0.70	0.57	+0.13	33.7	38.0	- 4.3	36.1	
	11-20	0.14	0.64	-0.50	40.4	44.4	- 4.0	40.7	
	21-30	1.56	1.05	+0.51	52.7	48.3	+ 4.4	51.6	
Total or av.		2.40	2.26	+0.14	42.1	43.6	- 1.5	42.8	41.4
May	1-10	0.78	0.77	+0.01	45.1	52.0	- 6.9	48.1	
	11-20	0.40	0.95	-0.55	63.7	55.8	+ 7.9	64.9	
	21-31	0.75	1.25	-0.50	61.1	60.0	+ 1.1	63.0	
Total or av.		1.93	2.97	-1.04	56.6	56.1	+ 0.5	58.8	57.1
June	1-10	0.03	1.29	-1.26	59.5	63.0	- 3.5	66.6	
	11-20	2.30	1.30	+1.00	64.0	66.3	- 2.3	67.5	
	21-30	2.26	1.37	+0.89	70.3	68.1	+ 2.2	74.9	
Total or av.		4.59	3.96	+0.63	64.5	65.8	- 1.3	69.6	69.3
July	1-10	2.34	1.44	+0.90	75.8	70.1	+ 5.7	83.2	
	11-20	1.64	1.06	+0.58	69.6	71.4	- 1.8	79.8	
	21-31	0.33	1.01	-0.68	73.4	71.4	+ 2.0	81.5	
Total or av.		4.31	3.51	+0.80	73.0	70.9	+ 2.1	81.5	76.7
August	1-10	0.02	1.04	-1.02	70.5	70.4	+ 0.1	80.1	
	11-20	1.88	0.93	+0.95	70.1	69.0	+ 1.1	75.8	
	21-31	1.13	1.04	+0.09	66.7	66.9	- 0.2	71.8	
Total or av.		3.03	3.01	+0.02	69.0	68.7	- 0.3	75.7	73.9
September	1-30	3.75	2.20	+1.50	58.2	59.0	- 0.8	62.1	61.5
October	1-31	1.00	1.74	-0.74	47.0	47.2	- 0.2	50.5	47.8
November	1-30	0.50	0.97	-0.47	25.9	29.7	- 3.8	33.0	33.6
December	1-31	0.39	0.68	-0.29	7.4	15.2	- 7.8	16.7	23.4
April-Aug. Growing Season		16.26	15.71	+0.55	61.1	61.0	+ 0.1	65.8	63.8
January-December Annual		24.44	23.78	+0.66	40.5	42.0	- 1.5	46.8	46.7

FOLIAR UAN CONCENTRATIONS ON HARD RED SPRING WHEAT[1]
MORRIS, 1989

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, when applied at the flag leaf stage of wheat. Results of this study indicate that increasing amounts of leaf burn occured with increasing concentrations of 28% UAN. Yield was not affected by leaf burn at the flag leaf stage of application. This same study conducted in 1988 with application of UAN at the tillering stage of growth resulted in similar results.

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 evaluate the effects of leaf burn, as related to N concentration in the spray, and if/or how much leaf burn is permissible before yield decreases occur.

Experimental Procedure: The experiment was established on a Hamerly clay loam soil (Aeric Calciaquoll). A radomized complete block design with four replications was used. Soil samples collected in the fall of 1988 showed NO_3-N levels of 78 lbs./acre in the 0-24 inch zone and 44 lbs./acre in the 24-48 inch zone. The entire plot received an additional 70 lbs. N/acre as urea on April 24. 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 at 30 psi pressure at the flag leaf stage of wheat to provide 40 lbs. N/acre for treatments 1, 2, 3, and 4, respectively. Marshall wheat was seeded at 100 lbs./acre on April 24. Bronate (.25 lbs./acre a.i.) and Hoelon (.25 lbs./acre a.i.) were broadcast for weed control on May 18 and 24 respectively. A second application of Bronate, at the same rate, was broadcast on May 30. The foliar UAN was applied on the fully emerged flag leaf on June 19 and leaf damage ratings were recorded on June 22. Sevin was applied for grasshopper control on June 28. Plant heights were recorded on July 31 and plots were harvested with a plot combine on August 1. Samples of grain were taken for grain yield, test weight, and moisture.

Results and Discussion: Leaf damage on the 100% UAN treatment was significantly greater than the 50% and 33% UAN treatments, which in turn had greater leaf damage than the 25% UAN treatment. Grain yield, test weight, grain moisture, and plant height were not affected by UAN concentration. These are the same results as achieved in 1988 when the UAN was applied at the 4-5 leaf stage of growth.

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[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, when applied at 40 lbs/N acre, on spring wheat applied at tillering (1988) and flag leaf (1989) stage of growth.

Trt. No.	Spray Concentration	Leaf[1] Damage		Plant Height		Grain Moisture at harvest		Test weight		Grain yield at 13% moisture	
		1988	1989	1988	1989	1988	1989	1988	1989	1988	1989
				- inches -		- - % - -		- lbs./bu.		bu./acre	
1	100% UAN	3.75	4.75	16.8	24.8	15.4	14.2	53.7	61.0	17.0	54.7
2	50% UAN 50% H_2O	3.50	3.75	16.3	24.3	15.6	13.9	55.8	60.8	17.8	54.5
3	33% UAN 67% H_2O	2.50	3.25	16.0	25.3	15.6	14.2	55.3	60.9	16.7	55.9
4	25% UAN	2.00	2.00	16.0	25.3	15.4	14.3	56.1	60.8	16.8	55.4
Signif. level (%)		<99	>99	31	91	59	34	90	11	43	81
BLSD (.05)		0.8	0.7	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)		16.3	13.9	6.2	2.2	1.1	3.0	2.3	0.6	7.6	1.7

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

CHLORIDE FERTILIZER ON SPRING WHEAT[1]
Morris, 1987-89

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

ABSTRACT: A three year study to determine the need for chloride fertilizer for spring wheat production in west central Minnesota was completed in 1989. The experiment was established on a Hamerly clay loam (Aeric Calciaquoll) soil with soil tests that indicated possible chloride response. Two rates of chloride fertilizer were band applied at seeding in 1988 and 1989 on Marshall and Guard. In 1987 the study included only Marshall at two chloride rates. No agronomic responses from chloride fertilization occurred in any of the three years. In 1988 and 1989 there were significant differences between varieties, but no interaction between variety and chloride.

There has been interest in increasing yields of hard red spring wheat through chloride fertilization. This study was set up to evaluate the yield response to 2 rates of chloride fertilizer. Studies in South Dakota have indicated that Marshall responds to chloride fertilization and Guard does not.

Experimental Procedure: In 1989 the experiment was established on a Hamerly clay loam soil. Plot size was 8 ft. X 45 ft. and a randomized complete block design with 4 replications was used. Soil samples collected in the fall of 1988 showed NO_3-N levels of 78 lbs./acre in the 0-24 inch zone and 44 lbs./acre in the 24-48 inch zone. The entire plot received an additional 70 lbs. N/acre as urea on April 24. Treatments 1, 2, and 3, were 0, 15, and 30 lbs. chloride/acre, respectively. The experiment was seeded to Marshall and Guard wheat varieties at 100 lbs./acre on April 24. Chloride fertilizer (using KCl, 0-0-60, as the chloride source) was applied through the drill in a band next to the seed at seeding. Bronate (.25 lbs./acre a.i.) was broadcast for weed control on May 18 and a second application at the same rate was made on May 30. Hoelon (.25 lbs./acre a.i.) was broadcast for grass control on May 24. Emergence was uniform on all plots with wheat fully emerged on May 9. Heading dates and plant heights were recorded at maturity. On June 28 the plots were sprayed with Sevin for grasshopper control. Plots were harvested with a plot combine on July 31 and the total grain sample was weighed for grain yield. A grain sample was saved for bushel weight and grain moisture.

Results and Discussion, 1989: There were no significant effects of chloride on plant height, heading date, grain moisture, bushel weight, or grain yield (Table 1) yielded significantly more than Guard, but there was no interaction of variety and chloride on yield. Yields averaged 50 bu./acre with good growing conditions.

Results and Discussion, 1987 - 1989: In 1987, 1988, and 1989 there were no significant effects of chloride fertilization on plant height, grain moisture, heading date, or grain yield (Table 2). In 1987 bushel weight was significantly affected by chloride, but the bushel weight data was quite variable. There were no significant effects on bushel weight in 1988 and 1989. In both 1988 and 1989 there was a significant effect of variety on yield, but no interaction between variety and chloride (Table 3). With soil tests for chloride in the top 2 feet testing at 23 lbs./acre in 1987, 28 lbs./acre in 1988, and 16 lbs./acre in 1989, the possibility of a response to chloride fertilizer was expected. Rates of chloride applied in 1987, 1988, and 1989 are given in table 4. Even with low chloride soil tests and high chloride application rates, there were no effects on yield. This non-response to chloride over the last 3 years indicates the possibility (1) that chloride requirements for wheat are much less than we expected, (2) that chloride fertilization has not been fine tuned enough to be a profitable practice at this time, or (3) that the wheat was able to obtain sufficient chloride from depths below 24 inches.

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[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. Effect of chloride treatment on date of heading, plant height, grain moisture, bushel weight, and grain yeild on wheat, 1989.

Treatment No.	Chloride	Date of Heading	Plant Height	Grain Moisture	Test Weight	Yield
	lbs/acre		inches	%	lbs./bu.	bu./acre
1	0	6/22	24.4	13.1	60.7	51.1
2	15	6/22	23.8	12.8	60.6	49.1
3	30	6/22	24.3	13.0	60.7	51.2
Signif. level(%)		0	62	56	45	48
LSD (.05)		NS	NS	NS	NS	NS
CV (%)		NS	2.1	3.2	0.3	7.4

Table 2. Statistical analysis of wheat chloride study for 1987, 1988, and 1989

Year	Plant Height	Grain Moisture	Test Weight	Date of Heading	Grain Yield
1987					
Signif. level (%)	76	43	>99	---	83
LSD (.05)	NS	NS	3.3	---	NS
CV (%)	3.5	13.3	3.6	---	6.0
1988					
Signif. level(%)	78	26	12	0	31
LSD (.05)	NS	NS	NS	NS	NS
CV (%)	5.9	5.2	1.6	NS	8.2
1989					
Signif. level(%)	62	56	45	0	48
LSD (.05)	NS	NS	NS	NS	NS
CV (%)	2.1	3.2	0.3	NS	7.4

Table 3. Effect of variety and chloride on grain yield, 1988 and 1989.

Variety		1988 Grain Yield bu./acre	Variety		1989 Grain Yield bu./acre
Marshall		16.5	Marshall		53.8
Guard		14.2	Guard		47.2
Chloride -lbs./acre -			Chloride -lbs./acre -		
0		15.7	0		51.1
17		15.0	15		49.1
35		15.4	30		51.2
Variety	Chloride lbs./acre		Variety	Chloride lbs./acre	
Guard +	0	15.0	Guard +	0	49.2
Marshall +	0	16.5	Marshall +	0	52.9
Guard +	17	13.6	Guard +	15	46.3
Marshall +	17	16.3	Marshall +	15	52.0
Guard +	33	14.0	Guard +	30	46.0
Marshall +	33	16.8	Marshall +	30	56.4
Signif. level (%)			Signif. level (%)		
Chloride		31	Chloride		48
Variety		>99	Variety		>99
Interaction		40	Interaction		76

Table 4. Summary of plant measurements for 1987, 1988, and 1989.

Year	Chloride Treatment	Plant Height	Grain Moisture	Test Weight	Date of Heading	Grain Yield
- - - -	lbs./acre - -	inches - - -	% - - - -	lbs./bu. - - - - - -		bu./acre
1987	0	21.3	16.5	55.8	---	32.9
	20	20.8	18.3	48.8	---	30.0
	40	21.8	17.9	52.2	---	32.3
1988	0	14.9	15.4	57.0	6/13	15.7
	17	15.6	15.4	57.0	6/13	15.0
	35	14.6	15.6	56.9	6/13	15.4
1989	0	24.4	13.1	60.7	6/22	51.1
	15	23.8	12.8	60.6	6/22	49.1
	30	24.3	13.0	60.7	6/22	51.2

WINTER UREA APPLICATION ON HIGH PH SOILS[1]
MORRIS, 1989

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

ABSTRACT: This study was designed to record the effects of winter application of urea nitrogen on high pH soils for corn production. Applying nitrogen during the winter months may help reduce fall and spring workloads allowing for timely spring planting, but losses may occur due to application of the nitrogen on frozen soil and/or snow. Results in 1989 showed no differences between winter application and traditional spring application of nitrogen.

Objective: The nitrogen retention study was designed to record the effects of winter application of nitrogen on high pH soils for corn production. Applying nitrogen fertilizer during non-cropping times may allow for more timely spring planting operations. The retention study had four treatments: 1) a check with no nitrogen application, 2) nitrogen applied on frozen soil, 3) nitrogen applied in mid-winter with at least a 3-inch snow cover, and 4) nitrogen applied in the spring prior to corn planting. This study will determine if nitrogen loss primarily from volatilization is a problem with late fall and mid-winter applications of urea on high pH soils.

Experimental Procedure: The experimental site was established on a McIntosh silt loam (Aeric Calciaquoll) in 1988 and was cropped to wheat. Soil tests in the fall of 1988 were as follows: pH=7.9, $NaHCO_3$ P=27 lbs./acre, K=357 lbs./acre, NO_3-N (0-24 inches) = 113 lbs./acre, and NO_3-N (24-48 inches) = 84 lbs./acre. The area was moldboard plowed October 28, 1988 and the plots were flagged out October 31. The frozen soil treatment (Trt. 2) was applied on November 17, 1988 on frozen soil with cover depth of 4 to 6 inches. The spring treatment (Trt. 4) was applied April 25, 1989. Urea (46-0-0) was applied to provide 100 lbs. N/acre. The experimental area was field cultivated first on April 25 (immediately after Trt. 4 was applied) and again on May 3. The plot area was seeded to Pioneer 3906 corn at 30,000 seeds/acre on May 3. Lasso @ 3.0 lbs./acre a.i. + Bladex @ 2.2 lbs./acre a.i. were broadcast preemergence after corn planting on May 3. The experiment was sprayed postemergence on June 6 and again on June 15 with Atrazine (0.75 lbs./acre a.i.) and 1 qt./acre of crop oil concentrate. The experiment was cultivated on June 16, stand count taken on June 23, and tasseling and silking notes taken in July. The plots were harvested on October 3 with a plot combine and grain yield, moisture, and test weight were recorded. The harvest area was four 65-foot rows.

Results and Discussion: Plant measurements are given in Table 1. No differences were found between treatments for tassel date, silk date, grain yield, grain moisture, or grain test weight. This was probably due to the high residual soil NO_3-N levels indicated by the lack of nitrogen response when the check treatment is compared to the other treatments. The experiment will be conducted again in 1990.

Table 1. Winter Urea Application Study, Morris 1989 - Plant Measurements

Trt. No.	Treatment Description	Tassel Date from 7/1	Silk Date from 7/1	6/23 Plant Popn.	Grain Yield	Grain Moisture	Grain Test Weight
				1000's/A	bu./A	%	lbs./bu.
1	Check	22.3	24.5	28.6	158.5	22.2	54.0
2	Frozen Ground	22.0	24.3	29.0	157.3	22.2	55.1
3	Snow Cover	22.3	24.8	29.5	155.8	22.3	55.1
4	Spring	22.8	24.8	29.9	154.4	22.5	54.3
Signif. Levels:							
	Treatment (%)	43	14	24	10	9	69
BLSD	(.05)	NS	NS	NS	NS	NS	NS
CV	(%)	3.4	3.9	6.0	5.3	3.0	1.8

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

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

CONTINUOUS CORN SILAGE[1]
MORRIS, 1989

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 24 years show no yield differences due to the removal of silage versus grain. A significant difference in yield exists between the long-term high and low fertilizer rates.

Objective: This is the 24th year of a continuing study initiated in 1965 on a McIntosh silt loam soil. The study was initiated to determine the effects of removal of continuous corn silage and fertilizer rate on soil properties and yield. Half the plots receive a fertilizer rate of 74+48+48 ($N+P_2O_5+K_2O$) lbs/acre and the other half a rate of 148+96+96.

Experimental Procedure: The experiment is set up as a latin square with 4 treatments: (1) silage, low fertility (2) silage, high fertility (3) grain, low fertility (4) grain, high fertility. The fertilizer was applied Oct. 18, 1988. The experimental area was moldboard plowed on Oct. 20, 1988 and field cultivated on April 25 and again on May 3, 1989. Dekalb 461 was planted at 30,000 seeds/acre on May 3. Counter 15G was applied in the row at seeding at 10 lbs/acre (1.5 lbs./acre a.i.). Lasso @ 3 lbs./acre a.i. + Bladex @ 2.2 lbs./acre a.i. were applied preemergence broadcast om May 3. Silage yields were taken from 3 10-foot rows on September 20 and grain yields were taken from 2 45-foot rows on October 3. 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 2 measured areas.

Results and Discussion: Silage yields are given in Table 1. There were no significant differences in silage yields in 1989. The 24-year average shows no effect of silage versus grain but does show significant differences between high and low fertility treatments. Grain yields and an average of the two unfertilized checks adjacent to the experimental area are given in Table 2. The 24-year average and 1989 yields show no significant differences in grain yield between the high and low fertility treatments.

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[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 continuous silage or grain on silage yields.

Treatment	1989 Yield	1966-89 Yield
	- - - - - dry matter,	tons/acre - - - - -
Silage, low fertility	7.26	5.51
Silage, high fertility	7.89	6.02
Grain, low fertility	8.02	5.57
Grain, high fertility	7.56	5.87
Signif. levels (%)		
Treatment	91	>99
Year	--	>99
Treatment x year	--	99
LSD, treatment (.05)	NS	0.22

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

Treatment	1988 Yield	1966-89 Yield
	- - - - - bu./acre @ 15.5% M.	- - - - - -
Grain, low fertility	131.0	86.5
Grain, high fertility	120.9	91.1
Signif. levels (%)		
Treatment	93	>99
Year	--	>99
Treatment x year	--	>99
LSD, treatment (.05)	NS	5.9
	- - - - - bu./acre @ 15.5% M.	- - - - - -
Grain, check	48.2	46.8
	- - - - - dry matter,	tons/acre - - - - -
Silage, check	4.54	3.56

EFFECT OF TILLAGE AND SUBSOILING ON SOIL WATER RECHARGE AND CORN YIELDS[1]
Morris, 1989

S.D. Evans, M.J. Lindstrom, J.F. Moncrief, W.B. Voorhees, and G. A. Nelson[2]

Abstract: Many producers are using subsoilers to alleviate expected compaction due to traffic from tillage, planting, and harvesting equipment. In the fall of 1989 a study was initiated at the West Central Experiment to study the effects of a one-time subsoiling and its interaction with various primary tillage systems on subsequent soil water recharge and corn growth and yield. In the spring of 1989 it was found that the subsoiled areas had a lower bulk density and a lower volumetric moisture content that non-subsoiled areas. By the fall of 1989 the moisture differences disappeared, but the bulk density differences remained. Traffic from planting, cultivating, and harvesting equipment repacked the soil to its original density. There were no effects of tillage or subsoiling on corn grain yields.

Objectives: A 3 year study was initiated at the West Central Experiment Station in the fall of 1988 to study the effects of a one-time subsoiling on subsequent soil bulk density, soil moisture, corn growth, and corn yield in 4 primary tillage systems: fall moldboard plow, fall chisel plow, spring disk, and no-till. The experiment was established on a Hamerly clay loam (Aeric Calciaquoll) and Aastad clay loam (Pachic Udic Haploboroll) complex and will be cropped to continuous corn.

Tillage, Planting, and Harvest Procedures: The experimental plot area was established the fall of 1988. The entire plot area was fertilized with 150 lbs. P_2O_5/acre + 10 lbs. Zn/acre on October 13,1988. Four main plot treatments were then established in the experimental plot area with each treatment split into subsoiled and non-subsoiled subtreatments. A split plot design with 4 replications was used with plots 30 feet wide by 100 feet long. The 1988 crop was corn harvested as silage. The plot areas will be seeded with a 6-row planter to continuous corn for the 3 year duration of the study. The treatments are moldboard, subsoiled (MSS); moldboard, no subsoiling (MNS); chisel, subsoiled (CSS); chisel, no subsoiling (CNS); no-till, subsoiled (NSS); no-till, no subsoiling (NNS); spring disk, subsoiled (DSS); and spring disk, no subsoiling (DNS). One-half of each main plot was subsoiled on October 14, 1988. A 5-tooth subsoiler with a 30-inch tooth spacing operating approximately 16 inches deep was used on the MSS, CSS, and NSS treatments. A paraplow operating approximately 13 inches deep was used on the DSS treatment. The MSS, CSS, NSS, and DSS plots were not tilled with any other implement in the fall of 1988. The non-subsoiled treatments were treated as follows: (1) The MNS treatment was plowed using an onland hitch with 6 18-inch bottoms and CNS treatment was chiseled with a mounted 10-foot chisel plow, (2) The MSS and CSS treatments were not moldboard plowed or chisel plowed before or after the subsoiling operation in the fall of 1988, and (3) The DNS and NNS treatments were not tilled in the fall of 1988.

Crop residue measurements were taken on April 19, 1989. On May 11 the MSS, MNS, CSS, CNS, DSS, and DNS plots were all disked for seedbed preparation. All wheel traffic from tractors during the tillage operations were confined to the position to be used by the tractor pulling the corn planter. The NSS and NNS treatments were not tilled. The plots were seeded to corn, Pioneer 3772 @ 30,000 seeds/acre, on May 12 with a 6-row planter. Counter 15G @ 10 lbs./acre (1.5 lbs./acre a.i.) was applied at seeding. No starter fertilizer was used. Lasso + Bladex (3 + 2.2 lbs./acre a.i. respectively) was broadcast preemergence on May 15. Crop residue measurements after planting were taken on May 17. Anhydrous ammonia was applied at 120 lbs. N/acre on May 22 with a 6-row mounted applicator. Two 10-foot rows in each plot were staked out on May 22 and heights of corn plants were measured on June 15, June 28, July 10, and July 27 to record any plant growth differences. Plots were cultivated on June 16 and sprayed with Atrazine @ 2 lbs./acre a.i. + Tandem @ .75 lbs./acre a.i. for control of escaped weeds on July 7. Tasseling and silking notes were recorded between July 21 and 27. A final stand count was taken in the harvest areas on August 25. Each plot had 2 2-row harvest areas at least 60 feet in length. Plots were harvested for grain with a JD 3300 combine on October 3-4, 1989, again restricting traffic to areas

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[1] Funds provided by West Cent. Expt. Sta., Univ. of Minnesota. Measurements taken by USDA-ARS, Morris, MN, and Soils Dept. Univ. of Minnesota.

[2] S.D. Evans and G.A. Nelson are Professor and Junior Scientist respectively with the West Cent. Expt. Sta., Univ. of Minnesota. M.J. Lindstrom and W.B. Voorhees are Soil Scientists with the Agricultural Research Service, USDA, Morris, MN, and J.F. Moncrief is Associate Professor, Soil Science Dept., Univ. of Minnesota.

previously tracked either by tractor or planter wheels. A grain sample was retained for further analysis. Corn stalks were chopped on MSS, MNS, CSS, and CNS treatments. The MSS and MNS treatments were plowed using an onland hitch with 6 18-inch bottoms and CSS and CNS treatments were chiseled with a 15-foot pull type chisel plow on October 23, 1989. Post-tillage crop residue measurements were taken on November 1.

Soil Sampling Procedures: Three cores were taken from each plot in the fall of 1988, prior to any subsoiling or other tillage, for bulk density and soil moisture determination. Two cores were taken to a depth of 60 inches in increments of 0-6, 6-12, 12-18, 18-24, 24-30, 30-36, 36-48, and 48-60 inches on October 11 and 12, 1988. One additional core was taken in the same manner only to a depth of 24 inches. The soil samples were weighed, dried at 105°C, and weighed back for bulk density and soil moisture determination. Penetrometer readings were taken on October 12.

On May 15, 1989, after spring tillage and corn planting, two 2-foot soil cores were taken in tractor wheel traffic areas and two 2-foot soil cores were taken in non-wheel tracked areas of each plot. No attempt was made to keep track of the subsoiler slots, so some sampling may have coincided with the slots and some sampling would have occurred in areas between subsoiler slots. Spring soil moisture and bulk density were then determined from these samples. Penetrometer readings were also taken on May 15. After grain harvest in the fall of 1989, but before any fall tillage, two 5-foot soil cores (0-6, 6-12, 12-18, 18-24, 24-36, 36-48, 48-60 inch increments) were again taken in tractor wheel tracked and non-wheel tracked areas of each plot. Bulk density was determined on the 0 to 24-inch samples and soil moisture was determined on the 0 to 60-inch samples. Sampling took place on October 10 and 11 and penetrometer readings were taken on October 11.

Measurements and Discussion: Growing conditions were very good in 1989 with very timely rainfall. As a result of this, corn growth was excellent and grain yields were very high. Summaries of residue and plant measurements are given in Table 1. Fall subsoiling significantly reduced residue cover both before spring tillage and after planting and there were significant differences in residue measurements between tillage systems, but there was no tillage by subsoiling interaction in the post-plant measurements. There was a significant tillage by subsoiling interaction on the residue measurements made prior to spring tillage (Tables 1 and 2). This was due to a decrease in residue cover from subsoiling on all tillage treatments except moldboard. With moldboard plow the MSS treatment received only a subsoiling and was not moldboard plowed in the fall of 1988. The MNS treatment was moldboard plowed and this left a residue cover of only 9.5%. Harvest population was significantly influenced by tillage. The no-till treatments averaged more plants/acre than the moldboard and chisel plots, but yielded the same. Therefore, no-till had fewer ears or smaller ears. Grain yield, % moisture, and bushel weight, were not influenced by tillage, subsoiling, or their interaction. The height of corn plants measured at 2 week intervals (data not shown) beginning 33 days after planting was not influenced by any of the tillage and subsoiling treatments.

There was a significant wheeltrack by subsoiling interaction on bulk density both in the spring and fall of 1989 (Table 3). Bulk density was decreased by subsoiling , but tractor traffic increased the bulk density to the point that there were no differences between subsoiled and non-subsoiled areas (Table 4). The subsoiling by depth interaction was significant in the fall of 1989 (Table 6). Subsoiling decreased bulk densities in the top 12 inches of soil while below that depth bulk density differences were not observed. There was a significant wheeltrack by soil depth interaction on bulk density in both the spring and fall of 1989. Below the 12-inch depth the presence of wheel tracks did not affect bulk density while above the 12-inch depth bulk density was significantly increased by wheel traffic (Tables 5 and 7). The tillage by wheel traffic interaction in the fall of 1989 (Table 8) shows that the moldboard and chisel treatments had lower bulk densities than the spring disk and no-till treatments in the absence of wheel traffic. Once the treatments were subjected to wheel traffic the differences were not apparent.

Statistical analysis (Table 9) shows that three of the 2-way interactions significantly affected volumetric moisture content in the spring of 1989. The wheel traffic by depth interaction (Table 10) shows that moisture content was greater in the wheel track than in non-wheel track zones at the 0-12 inch depth, while at the 12-24 inch depth there was little difference in moisture content. The subsoiling by depth interaction (Table 11) shows a similar pattern with differences above the 12-inch depth and no differences below the 12-inch depth. The wheel traffic by subsoiler interaction (Table 12) shows a greater difference between NWT and WT where the soil was subsoiled than there it was not subsoiled. In the wheel track areas subsoiled and non-subsoiled areas were nearly equal in moisture content.

In the fall of 1989 the main effect of subsoiling (Table 13) shows slightly greater volumetric moisture in the non-subsoiled areas. The wheel traffic by depth interaction (Table 14) shows equal or greater moisture content under wheel traffic as compared to non-wheel traffic areas, but the greatest differences occur at the 0-6 and 6-12 inch depths. The tillage by wheel traffic interaction in the fall of 1989

(Table 15) shows a lower water content on the moldboard, non-wheel tracked treatment as compared to the chisel, spring disk, and not-till treatments in the non-wheel track areas. Once the treatments were tracked the differences were not apparent.

In conclusion, results from the first year of a three year study, show subsoiling had no effect on grain yield and most other agronomic characteristics in 4 different primary tillage systems. Bulk density was significantly affected by subsoiling, but wheel traffic from tillage and planting tractors repacked to essentially the initial bulk density. Volumetric soil moisture content was significantly affected by subsoiling, wheel traffic, and interactions of these with each other with soil depth. In general, moisture was greater in the wheel tracked and non-subsoiled areas in the top 12 inches of the soil. Below 12 inches there was very little difference in volumetric moisture content. The moisture content was lower in the non-wheel tracked, moldboard treatments than in all other treatments in the fall of 1989.

Growing season precipitation was very timely in this plot site in 1989 and thus differences in soil water and soil physical properties did not translate into yield differences. Under wetter or drier soil conditions, different results may be expected.

Table 1. Summary of plant measurements due to tillage and subsoiling, 1989.

Treatment	4/19	5/17	Tassel Date from 7/1	Silk Date from 7/1	Harvest Plant Popl'n. x 10^{-3}	Grain Hvst. Mst.	Grain Yield 15.5%M.	Grain Test Wt.
	- % cover -				pl/ac	%	bu/ac	lbs/bu
Moldboard	19.0	7.5	22.6	23.6	26.2	20.9	160.2	56.5
Chisel	31.2	11.5	22.9	24.1	26.8	20.9	158.8	56.6
Spr. Disk	49.5	17.0	23.0	24.1	27.0	21.0	157.0	56.3
No-Till	35.8	21.8	23.3	24.8	28.5	21.1	153.7	56.3
Main plots:								
Signif.								
Level (%)	>99	>99	21	71	96	34	54	23
LSD(.05)	5.6	7.0	NS	NS	1.7	NS	NS	NS
C.V.(%)	21.8	34.4	2.1	2.4	4.1	1.5	4.0	1.0
Subsoiled	29.1	11.8	23.1	24.3	26.7	21.0	157.5	56.3
Not Subsl.	38.6	17.1	22.8	24.1	27.5	21.0	157.3	56.5
Sub-plots:								
Signif.								
Level (%)	>99	>99	83	62	93	13	6	56
Interaction:								
Signif.								
Level (%)	>99	87	89	60	48	49	54	39

Table 2. Effect of tillage treatments on residue cover in 1989.

Trt.	4/19/89	5/17/89
	- - - - % cover - - - -	
MNS	9.5	7.5
MSS	28.5	7.5
CNS	38.5	14.5
CSS	24.0	8.5
DNS	57.5	18.5
DSS	41.5	15.5
NNS	49.0	28.0
NSS	22.5	15.5

Table 3. Statistical analysis of bulk densities in subsoiler study.

Variable	10/11-12/88	5/15/89	10/10-11/89
		Pr>F	
Tillage (T)	.1217	.1157	.1025
Using Rep * T as an error term			
Subsoiling (SS)	.4717	.0079	.0051
T * SS	.5412	.7136	.2761
Using Rep * T * SS as an error term			
Wheel Traffic (WT)	- -	.0001	.0001
T * WT	- -	.1013	.0397
SS * WT	- -	.0014	.0005
T * SS * WT	- -	.9367	.1258
Using Rep * T * SS * WT as an error term			
Depth (D)	.0001	.0001	.0001
T * D	.0001	.5022	.5668
SS * D	.8673	.1135	.0001
WT * D	- -	.0449	.0001
T * SS * D	.1962	.5574	.8035
T * WT * D	- -	.9569	.1687
SS * WT * D	- -	.6424	.0001
T * SS * WT * D	- -	.6933	.2765
C.V. (%)	4.0	10.2	5.5

Table 4. Effect of subsoiling and wheel traffic on bulk density, 1989.

	4/19/89			5/17/89		
Trt.	NSS	SS	Mean	NSS	SS	Mean
	- - g/cm³ - -			- - g/cm³ - -		
NWT	1.30	1.18	1.24	1.26	1.17	1.28
WT	1.39	1.38	1.39	1.38	1.38	1.38
Mean	1.35	1.28		1.32	1.28	

Table 5. Effect of wheel traffic and depth on bulk density, 5/17/89.

	Depth (inches)		
Trt.	0-12	12-24	Mean
	- - g/cm³ - -		
NWT	1.10	1.38	1.24
WT	1.30	1.47	1.39
Mean	1.20	1.43	

Table 6. Effect of subsoiling and depth on bulk density, 10/10-11/89.

Trt.	Depth (inches) 0-6	6-12	12-18	18-24	Mean
	g/cm^3				
SS	.91	1.30	1.40	1.50	1.28
NSS	.98	1.40	1.44	1.47	1.32
Mean	.95	1.35	1.42	1.48	

Table 7. Effect of traffic and depth on bulk density, 10/10-11/89.

Trt.	Depth (inches) 0-6	6-12	12-18	18-24	Mean
	g/cm^3				
NWT	.72	1.28	1.40	1.47	1.21
WT	1.19	1.42	1.44	1.50	1.38
Mean	.95	1.35	1.42	1.48	

Table 8. Effect of tillage and wheel traffic on bulk density, 10/10-11/89.

Trt.	Moldboard	Chisel	Spring Disk	No-Till	Mean
	g/cm^3				
NWT	1.18	1.18	1.26	1.23	1.21
WT	1.40	1.36	1.41	1.37	1.38
Mean	1.29	1.27	1.33	1.30	

Table 9. Statistical analysis of volumetric moisture content in subsoiler study.

Variable	10/11-12/88	5/15/89	10/10-11/89
		Pr>F	
Tillage (T)	.7556	.1497	.8443
Using Rep * T as an error term			
Subsoiling (SS)	.2330	.0132	.0122
T * SS	.1557	.9983	.5366
Using Rep * T * SS as an error term			
Wheel Traffic (WT)	- -	.0001	.0001
T * WT	- -	.0169	.1335
SS * WT	- -	.0008	.3603
T * SS * WT	- -	.7793	.2570
Using Rep * T * SS * WT as an error term			
Depth (D)	.0001	.2640	.0001
T * D	.8254	.7138	.5195
SS * D	.7566	.0443	.3798
WT * D	- -	.0008	.0001
T * SS * D	.8376	.4612	.9405
T * WT * D	- -	.9720	.9992
SS * WT * D	- -	.1965	.3359
T * SS * WT * D	- -	.3684	.9999
C.V.(%)	9.1	8.6	15.5

Table 10. Effect of wheel traffic and depth on volumetric water content, 5/15/89.

	Depth (inches)		
Trt.	0-12	12-24	Mean
		%	
NWT	30.8	32.0	31.4
WT	35.8	33.4	33.4
Mean	33.3	32.7	

Table 11. Effect of subsoiling and depth on volumetric water content, 5/15/89.

	Depth (inches)		
Trt.	0-12	12-24	Mean
		%	
SS	31.7	32.2	31.9
NSS	34.9	33.3	34.1
Mean	33.3	32.7	

Table 12. Effect of subsoiling and wheel traffic on volumetric water content, 5/15/89.

Trt.	NSS	SS	Mean
	%		
NWT	33.0	29.8	31.4
WT	35.1	34.1	34.6
Mean	34.1	31.9	

Table 13. Effect of subsoiling on volumetric water content, 10/10-11/89.

Trt.	Water Content
	%
SS	33.5
NSS	35.4

Table 14. Effect of wheel traffic and depth on volumetric water content, 10/10-11/89.

	Wheel Traffic		
Depth	No	Yes	Mean
inches		%	
0-6	18.6	30.6	24.7
6-12	35.2	39.1	37.1
12-18	33.4	33.4	33.4
18-24	31.2	32.5	31.9
24-36	34.8	36.4	35.6
36-48	37.6	39.2	38.4
48-60	39.3	40.9	40.2
Mean	32.9	36.0	

Table 15. Effect of tillage and wheel traffic on volumetric water content, 10/10-11/89.

Trt.	Moldboard	Chisel	Spring Disk	No-Till	Mean
			%		
NWT	29.0	31.2	32.5	32.9	31.4
WT	33.7	34.9	35.0	34.8	34.6
Mean	31.3	33.1	33.8	33.9	

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

Morris, 1989

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

ABSTRACT: This study completed its 19th year in 1989 and will continue. Nitrate movement and yield responses from two initial annual applications of manure have been measured. Results over 19 years show 1986 as the first year the fertilized check yielded significantly more than the manure treatments and this occurred again in 1989. In 1987 the fertilized check yielded more than the manure treatments, but yields were not significantly greater. In 1988 all yields were low due to the drouth and averaged 50 bu./acre. Soil samples taken to a depth of 4 feet in the fall of 1989 showed that the fertilized treatment had more NO_3-N in the root zone than any of the manure treatments. Mineralization of organic N from the manure treatments has evidently slowed to a point were less N is being mineralized from the manure treatments than is being supplied by the mineralization and annual fertilizer applications on the fertilized treatment.

This is the 19th 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-136,000 gal/acre, and Liquid Hog Manure-136,000 gal/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).

Experimental Procedure: The fertilized plots received 120+50+50 ($N+P_2O_5+K_2O$) lbs./acre on October 18,1988 and the entire was moldboard plowed the same day. The study was planted to Pioneer 3906 corn at 30,000 seeds/acre on May 3. Counter 15G was applied at 10 lbs./acre (1.5 lbs./acre a.i.) in the row at seeding. Lasso and Bladex (3.0 lbs./acre a.i. + 2.2 lbs./acre a.i. respectively) tank mix were applied broadcast preemergence on May 3. Plots were sprayed with Basagran (0.75 lbs./acre a.i.) on June 15. Plots were cultivated twice, June 16 and June 21. Corn heights and plant samples were taken on June 21. Tasseling and silking dates were recorded and ear leaf samples were also taken at the mid-silk date. Two 10-foot rows were harvested for silage yields on September 20. Grain yields were calculated from two 110-foot rows harvested with a plot combine on October 3. Three soil cores were taken from each plot in the fall of 1989 to a depth of 4 feet in 1-foot increments. These cores were combined, subsampled, and submitted for nitrogen analysis.

Results and Discussion: Early plant height, early plant dry weight, grain yields, and silage yields are given in table 1. Early plant height was significantly higher for the solid and liquid beef manure treatments over the fertilizer treatment and grain yield and ear weight (as a % of silage) were significantly higher for the fertilized treatment over all other treatments. The fertilized treatment has now outyielded the manure treatments the last 4 years (significantly in 1986 and 1989) with 1986 being the first year since the study was initiated for this to happen. In 1986 and 1989 the effect of the 1970-71 manure applications on yield has decreased to the extent that the fertilized treatment is yielding significantly better than the manure treatments. However, the liquid and solid beef manure treatments are still yielding more than the check treatment. The results of the nitrate and ammonium analyses are given in table 2. There were no significant differences between the manure and fertilized treatments. Nitrate-N levels generally increased with depth while ammonium-N levels decreased with depth.

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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.

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Table 1. Summary of plant measurements - 1989.

			Grain		Silage		
Treatment	Early plant height	Early plant (10) dry weight	Moisture at harvest	Yield at 15.5% moisture	Dry matter at harvest	Silage yield (D.M.)	Ear wt. as a% of Silage
	inches	grams	- -% - -	bu/acre	- - % -	lb./acre	--%--
Check	18.7	31.7	22.5	76.0	44.5	8971	50.2
Fertilized	23.7	66.0	21.4	164.1	41.1	15973	63.9
Solid Beef Manure	26.1	80.3	21.0	118.9	46.4	13031	50.2
Liquid Beef Manure	27.2	83.3	20.8	120.0	49.2	13869	45.5
Liquid Hog Manure	24.0	58.0	20.9	95.9	49.6	12783	47.6
Signif. level (%)	>99	>99	86	>99	86	82	99
LSD (.05)	2.1	17.6	NS	21.1	NS	NS	9.2
CV (%)	4.8	15.0	3.7	10.2	8.6	23.7	9.2

Table 2. Nitrate and ammonium nitrogen levels of a Tara Soil 19 years (Fall 1989) after application of high rates of manure.

	Treatment						Treatment					
Depth Incr.	CK	Fert.	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean	CK	Fert.	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean
ft.	ppm NO_3-N							ppm NH_4-N				
0-1	2.3	8.1	4.3	4.5	2.9	4.4	4.4	5.8	1.8	4.9	5.3	4.4
1-2	0.4	16.8	1.0	1.0	0.5	3.9	3.0	3.5	1.9	4.1	2.9	3.1
2-3	1.5	26.6	0.9	7.9	0.4	7.5	2.6	2.1	1.8	2.6	2.1	2.2
3-4	5.5	12.9	6.3	11.0	6.0	8.3	3.1	2.2	2.5	2.5	2.3	2.5
Mean	2.4	16.1	3.1	6.1	2.5		3.3	3.4	2.0	3.5	3.2	

Signif. Level (%):

Replication	- 43	Replication	- 55
Treatment	- 87	Treatment	- 69
Depth	- 88	Depth	- >99 BLSD (.05) 0.5
Trt. x Depth	- 87	Trt x Depth	- >99

The effect of tillage and corn hybrid on nitrogen response by continuous corn: a six year summary[1]

J.F. Moncrief, S.D. Evans, A.E. Olness, and G. Nelson[2]

This is a six year summary of a study to evaluate tillage, nitrogen, and corn hybrid effects on grain response in a continuous corn sequence. The soil is silt loam in texture and has poor internal drainage. Tillage effects were variable from year to year but over the study period the moldboard, chisel, and ridge till systems resulted in similar yields. Yields were reduced under no till conditions. Nitrogen response was quite variable from year to year. Tillage and corn hybrid also affected nitrogen response. A Pioneer 3906 hybrid consistantly resulted in a higher yield than a DeKalb XL8 although differences were affected by year. The DeKalb XL8 hybrid was affected by tillage more than the Pioneer 3906.

There has been data in the upper midwest that show tillage and corn hybrid affecting the nitrogen response by corn when grown following corn. In an effort to evaluate this, plots were established at Morris, MN. on a Pachic Udic Haploboroll (Tara silt loam). This soil has poor internal drainage and developed in glacial till. This study was conducted from 1984 to 1989.

Methods and Materials

Tillage treatments include: fall moldboard and chisel plowing followed by one field cultivation in the spring, ridge till (two cultivations), and no till systems. Treatments were established in the fall of 1983. Plots were planted with a Hiniker Series One Econo Till planter. In ridge till plots the row area was cleared with planter mounted discs. This was followed with a 2" fluted coulter. Clearing discs were raised for the other tillage systems.

Anhydrous ammonia was applied in the fall before tillage between corn rows from 0 to 160 pounds per acre in 40 pound per acre increments. The only exception to tillage and nitrogen application was in 1985. The fall of 1984 was too wet to accomplish tillage or anhydrous application therefore these operations were done in the spring.

Two single cross corn hybrids were evaluated (Pioneer 3906 and DeKalb XL8, 95 and 85 day relative maturity). Hybrid plots were alternated each year so each hybrid always followed the other. The experimental design is a split-split plot with tillage main plots, nitrogen subplots, and hybrid sub subplots. Sub subplots were four rows wide (30" rows) and 40 feet long. There are four replications.

Weed control was accomplished with a preemergence application of Lasso and Bladex.

Residue measurement were made with a line transect method. Measurements were made within a week following planting. Soil cover was characterized in and between the row (four inches centered over the row and the remainder respectively). Two adjacent rows were measured in each sub subplot. The line traversed the area to be measured diagonally.

Results and discussion

Analysis of Variance

There were significant year, tillage, nitrogen, and hybrid main effects on soil cover by corn residue. In addition there were significant year by tillage and year by nitrogen interactions.

The results of analysis of variance for grain yield is shown in table 1. There were also significant main effects of year, tillage, hybrid, and nitrogen. In addition first order interactions were all significant except the hybrid by nitrogen interaction. The only second order interactions that were statistically significant were the year by tillage by nitrogen and year by hybrid by nitrogen interactions. The third order interaction was not significant.

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[1] This research was supported by the Minnesota Agricultural Experiment Station, and the Agricultural Research Service.

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Table 1. Analysis of variance for grain yields 1984-1989 Morris, MN.

Source of Variance	P>F
Rep	.4171
tillage	.0610
rep x year Error 1	
nitrogen	.0001
tillage x nitrogen	.0515
rep x nitrogen (tillage) Error2	
hybrid	.0001
hybrid x tillage	.0100
hybrid x nitrogen	.7724
hybrid x tillage x nitrogen	.4362
rep x hybrid(tillage x nitrogen) Error 3	
year	.0001
year x tillage	.0020
year x nitrogen	.0001
year x tillage x nitrogen	.0075
hybrid x year	.0001
hybrid x tillage x year	.2558
hybrid x nitrogen x year	.0686
hybrid x tillage x nitrogen x year	.9445
rep x hybrid x (tillage x nitrogen) Error 4	

Soil Cover by Corn Residue

Soil cover by crop residue is shown in figures 1a-c and 2a-d. Soil cover ranged from about 10% with moldboard plowing to about 80% with the no till system (figure 1a). All conservation tillage options resulted in adequate cover by crop residue for erosion control. The fluted coulter reduced the soil cover in the row by about 20% with no other tillage (fig 1a-no till). Soil cover in the row was reduced about 10% and 2% cover with the chisel and moldboard plowing systems respectively. The clearing discs reduced cover 40% with the ridge till system. Soil cover between the row is about 20% lower than the no till system due to the cultivation operation which eliminates residue from two years before and soil covering during the planting operation.

Soil cover did not vary much from year to year (figure 1b). In 1985 clearing discs were not raised for the no till system resulting in lower average values. Soil cover was higher in 1988 due to high yields the previous year. The Pioneer 3906 hybrid resulted in slightly higher soil cover value also most likely due to higher yields (figure 1c).

Tillage effects for individual years are shown in figure 2a-d. The cover reduction in the row was greatest for all systems in 1985.

Table 2. The effect of tillage on soil cover by corn residue.

	Position Relative to Corn Row	
	In row	Between
Tillage	----percent----	
Chisel	32.1	40.9
Moldboard	7.6	9.7
No Till	60.1	77.3
Ridge Till	22.0	60.6

1. In and between the row are defined as four inches centered over the row and the remainder respectively.

Grain Yields

Tillage

Tillage effects on grain yields are shown in figure 3a-c. Tillage effects were quite variable from year to year. In 1985 there was an early frost and the no till system resulted in a decrease in yield. In 1984 the fall was wet and didn't allow plowing. In 1985 spring moldboard plowing, ridge tillage, and no till systems resulted in the lower grain yields than spring chisel plowing. The following year moldboard plowing was again a lower yielding system. In 1987 this system was clearly superior. In the drought year of 1988 moldboard plowing and no tillage had highest yields. In 1989 moldboard plowing and ridge till systems had yields higher than those of the chisel and no till systems. Average yields over the six years of the study resulted in similar yields for the moldboard and chisel plowing and ridge tillage systems. Yields were lower when corn was grown with a no till system due to increased nitrogen requirement, stand loss, delayed phenology, and the alleopathy associated with in seed furrow corn residue.

Hybrid

Interactions of corn hybrid and tillage or year are shown in figure 3b-c. In all years the Pioneer 3906 resulted in higher yields than the DeKalb XL8. Year effects on hybrid differences appeared to be related to yield level. Differences were greater as the yield level increases (see 1985 and 1988 vs 1987 and 1989).

Tillage effects on hybrid performance were variable. Hybrid differences were the smallest under moldboard plowing (number in parentheses are yield differences). Chisel and no till systems were intermediate. Greatest differences between hybrid was found with the ridge till system. This may have been due to greater sensitivity to root pruning by this hybrid.

Nitrogen Response

Nitrogen responses are shown in figure 4a and 4b. Corn responses to levels of applied nitrogen ranged from none in 1988 to the entire range in 1984 and 1986. Nitrogen response does not appear to be related to yield level. The two highest yielding years (1987 and 1989) required less than 80 pounds per acre for optimum yields. The two years in which corn required in excess of twice this level of applied nitrogen were intermediate in yield level (1984 and 1986). The corn grown in 1989 did not require more than 80 pounds per acre of applied nitrogen due to high residual soil levels from the drought year of 1988 (data not shown). This was not the case for the 1986 year.

Tillage had an effect on nitrogen response. The chisel and moldboard plowing systems resulted in congruent nitrogen response curves. Tillage systems that eliminate full width deep tillage (ridge till and no till systems) require higher levels of applied nitrogen. This appears to be about 20 and 40 pounds per acre additional nitrogen for the ridge till and no till systems. Other Minnesota data has shown that the nitrogen response by corn following soybeans is not affected by tillage.

Tillage affects on nitrogen response was also different in different years (figures 5a-f). Nitrogen responses were similar in 1985. No till and ridge till grown corn required more applied nitrogen in 1987, 1988, and 1989.

Hybrid effects on nitrogen response also interacted with year (figures 6a-f). In 1986 and 1989 hybrid differences in the response to applied nitrogen are greater at the higher levels of applied nitrogen. The DeKalb XL8 appears to be limited by some other factor in these two years. In 1984 the DeKalb XL8 appeared to approach the yield of the Pioneer 3906 at the higher nitrogen rates. Although hybrid effects on nitrogen response varied from year to year there was no hybrid effect on nitrogen response when averaged over years.

Summary

1. Although tillage effects were variable from year to year, yields were similar between the chisel, moldboard, and ridge till systems.

2. The effect of corn hybrid on grain yield was also affected by year. Differences were greater at higher yield levels.

3. Hybrid yield differences were lowest with the moldboard system and greatest with the ridge till system.

4. Nitrogen response was quite variable from year to year and did not correlate well with yield level.

5. No till and ridge till corn appeared to require higher levels of applied nitrogen. Tillage effects on nitrogen response was similar in three years of the six year study different in others.

6. Hybrid effected the nitrogen response from year to year but when hybrid were averaged over all years they did not show different nitrogen responses.

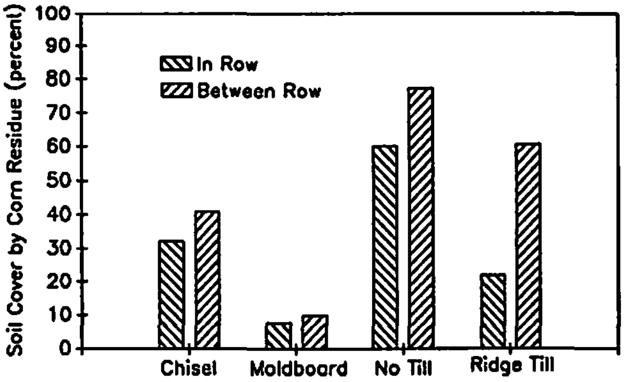

FIGURE 1a. THE EFFECT OF TILLAGE ON SOIL COVER BY CORN RESIDUE, MORRIS, MN. 1985–1989

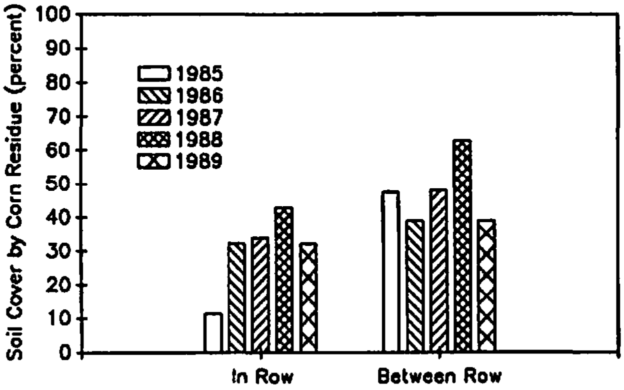

FIGURE 1b. THE EFFECT OF YEAR ON SOIL COVER BY CORN RESIDUE, MORRIS, MN.

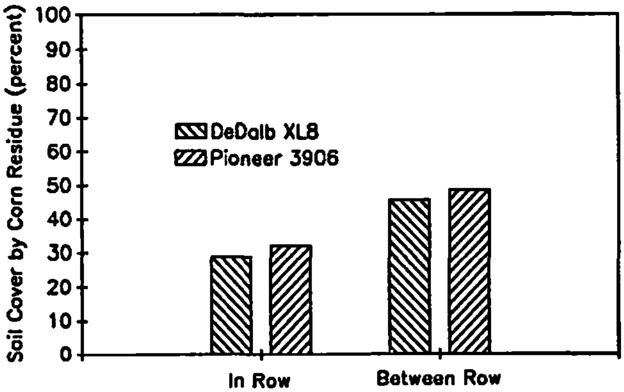

FIGURE 1c. THE EFFECT OF HYBRID ON SOIL COVER BY CORN RESIDUE, MORRIS, MN. 1985–1989

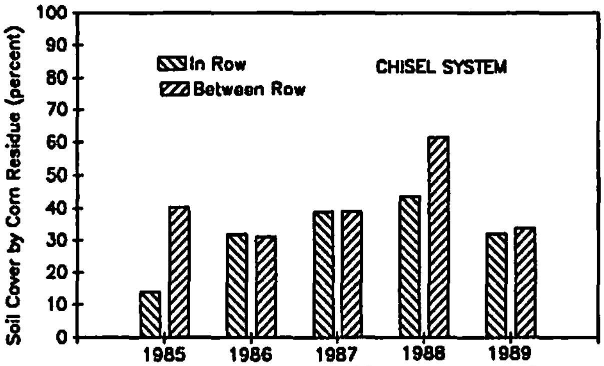

FIGURE 2a. YEAR EFFECT ON SOIL COVER WITH THE CHISEL PLOWING SYSTEM.

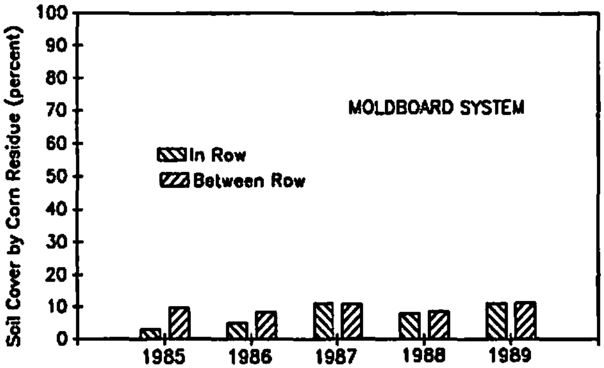

FIGURE 2b. THE EFFECT OF YEAR ON SOIL COVER WITH THE MOLDBOARD PLOWING SYSTEM

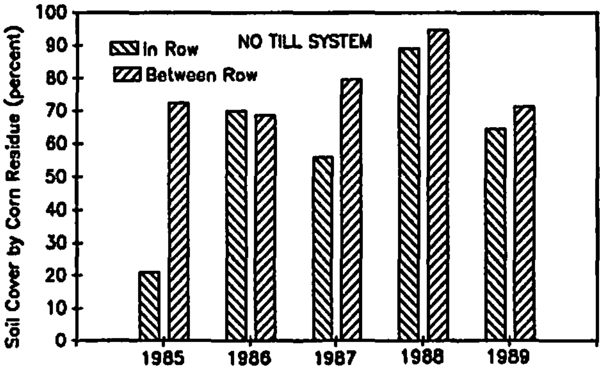

FIGURE 2c. THE EFFECT OF YEAR ON SOIL COVER WITH THE NO TILL SYSTEM

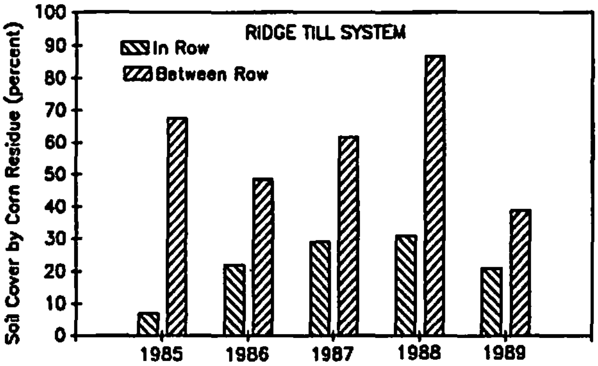

FIGURE 2d. THE EFFECT OF YEAR ON SOIL COVER WITH THE RIDGE TILL SYSTEM

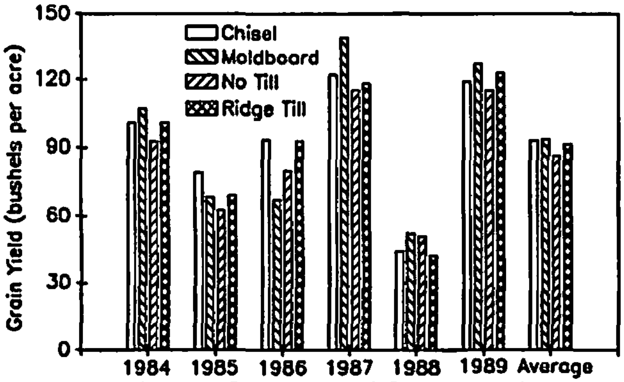

FIGURE 3a. THE EFFECT OF YEAR AND TILLAGE ON GRAIN YIELDS, MORRIS, MN., 1984–1989

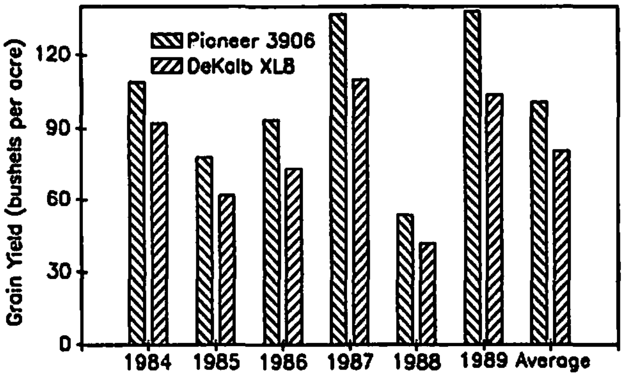

FIGURE 3b. THE EFFECT OF YEAR AND CORN HYBRID ON GRAIN YIELDS, MORRIS, MN., 1984–1989

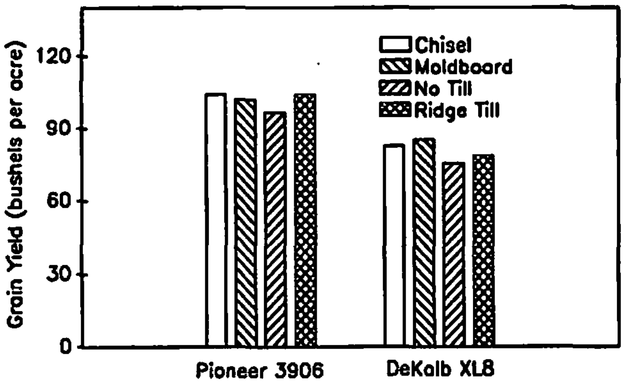

FIGURE 3c. THE EFFECT OF TILLAGE AND CORN HYBRID ON GRAIN YIELDS, MORRIS, MN., 1984–1989

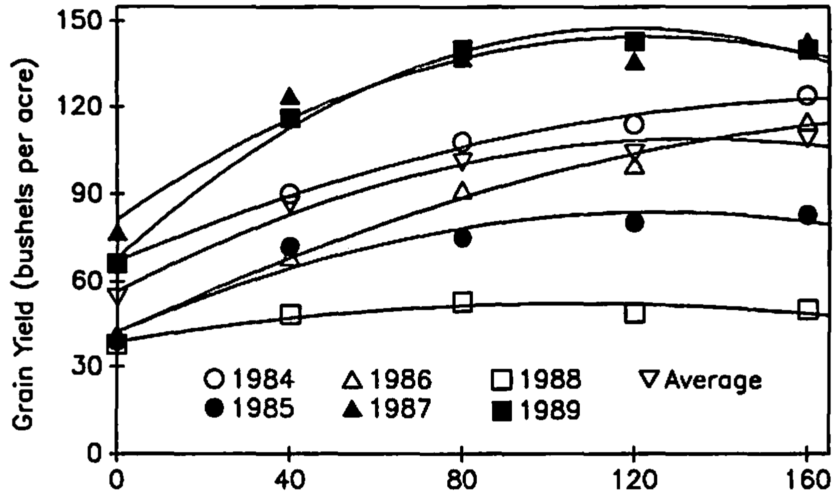

FIGURE 4a. THE EFFECT OF YEAR ON NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1984-1989

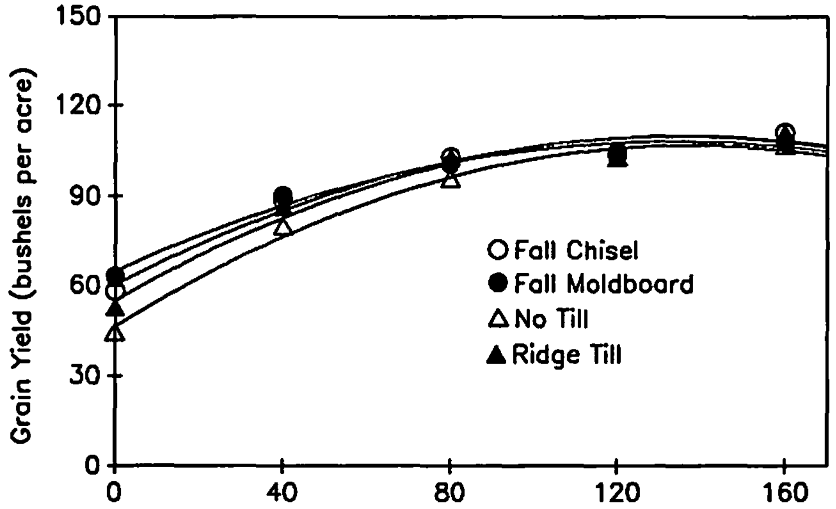

FIGURE 4b. THE EFFECT OF TILLAGE ON NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1984-1989

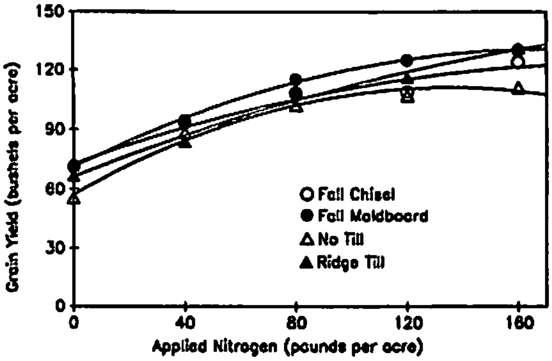

FIGURE 5a. THE EFFECT OF TILLAGE ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1984

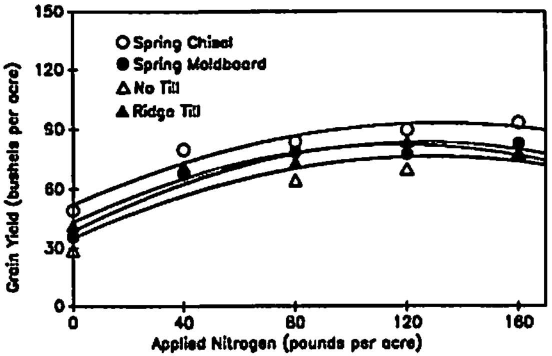

FIGURE 5b. THE EFFECT OF TILLAGE ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1985

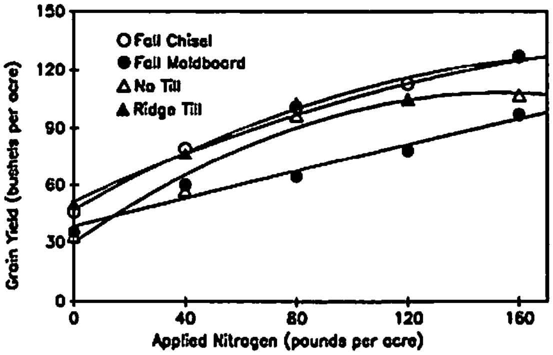

FIGURE 5c. THE EFFECT OF TILLAGE ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1986

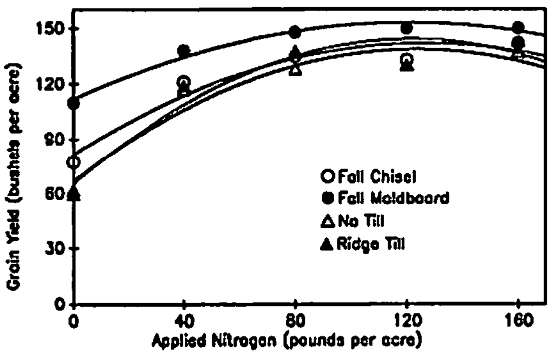

FIGURE 5d. THE EFFECT OF TILLAGE ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1987

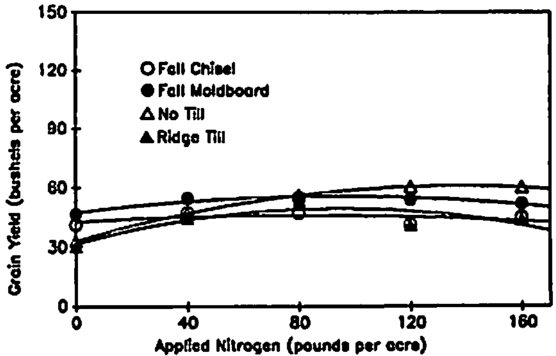

FIGURE 5e. THE EFFECT OF TILLAGE ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1988

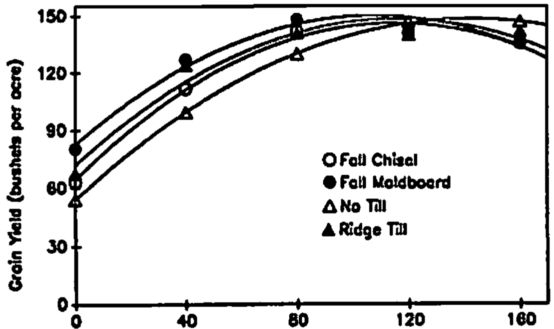

FIGURE 5f. THE EFFECT OF TILLAGE ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1989

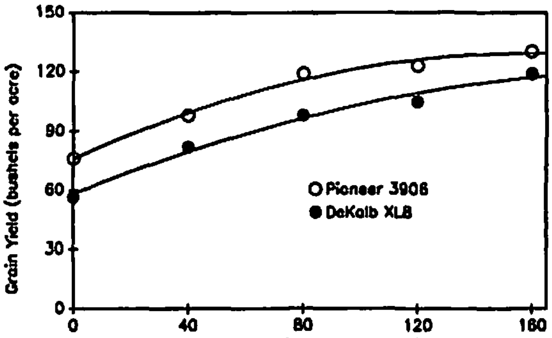

FIGURE 6a. THE EFFECT OF HYBRID ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1984

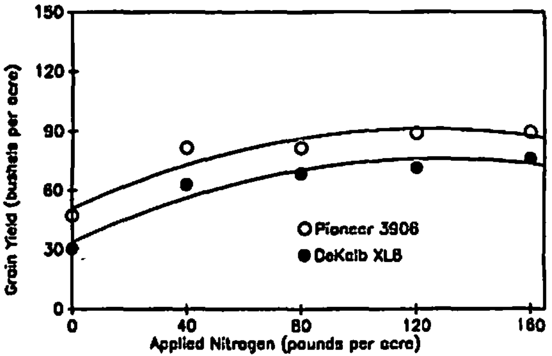

FIGURE 6b. THE EFFECT OF HYBRID ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1985

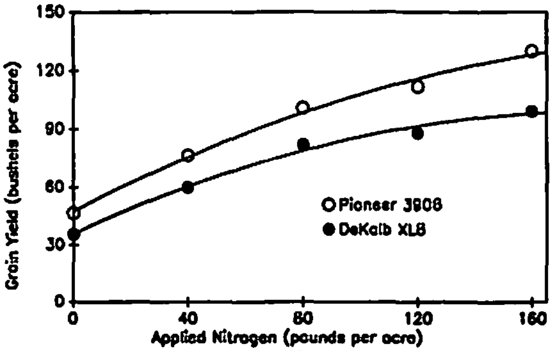

FIGURE 6c. THE EFFECT OF HYBRID ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1986

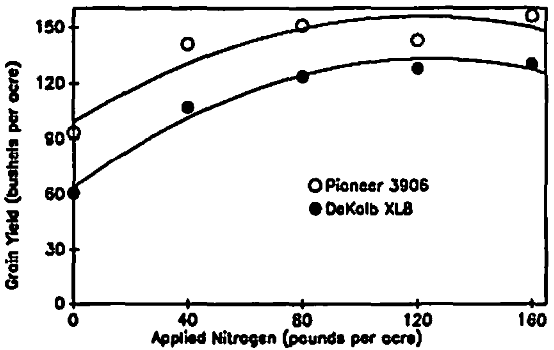

FIGURE 6d. THE EFFECT OF HYBRID ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1987

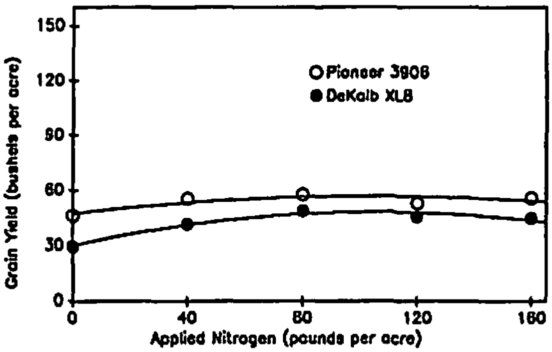

FIGURE 6e. THE EFFECT OF HYBRID ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1988

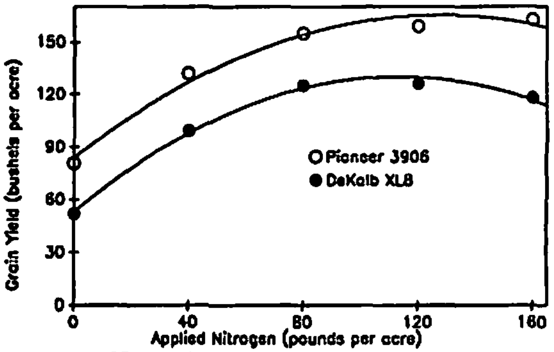

FIGURE 6f. THE EFFECT OF HYBRID ON THE NITROGEN RESPONSE BY CONTINUOUS CORN, MORRIS, MN., 1989

NITROGEN MANAGEMENT FOR CORN PRODUCTION ON IRRIGATED SANDY SOILS

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

ABSTRACT: Detailed research projects conducted for the past 15-20 years have identified and refined the nitrogen management practices needed for irrigated corn production on sandy soils. This research/demonstration project was designed to demonstrate that these practices could be used to grow high-yielding corn. Applied N was used very efficiently. Split applications and the use of a nitrification inhibitor had no positive effect on yield. There were no leaching rains and this would be expected. The amount of NO_3-N measured to a depth of 3 feet was small and not affected by treatment use.

Introduction:

Research studies, which have focused on nitrogen (N) management for corn production on irrigated sandy soils, have shown that split applications of fertilizer N are important. Nitrification inhibitors have proven to be beneficial for this soil if they were added to fertilizer N sources that were applied either before planting or as an early sidedress treatment. There is also some indication that split applications may allow for the use of reduced rates of fertilizer N.

Objective:

This research/demonstration project was conducted to measure the effect of N rate, method of application, and nitrification inhibitor usage on corn yield, and the amount of No_3-N remaining in the root zone at the end of the growing season.

Experimental Procedure:

This study was conducted at the Irrigation Center at Staples. The soil is classified as a Sverdrup sandy loam. Treatments were designed to provide for 2 levels of each of 3 variables and were arranged in a randomized complete block design with 4 replications. The N rates were 160 and 200 lb. per acre. The 2 methods of application consisted of a single application at early sidedress and a split application with equal amounts of fertilizer N applied as both an early and a late sidedress treatment. The fertilizer N was applied either with or without a nitrification inhibitor.

Corn (Pioneer 3790) was planted on May 10. All treatments received a starter fertilizer (20-7-20-7) in a band to the side of and below the seed. Bladex (3 pint/acre) and Dual (2 pint/acre) were applied preemergence for weed control. The early sidedress treatment was made at the 4 - 6 leaf stage. The second application of N for the split treatments was made at the 8 - 10 leaf stage of development. The "checkbook" method was used for irrigation scheduling and a total of 10.35 inches of irrigation water was applied.

Grain yields were measured in mid-October. Soil samples were also taken from depths of 0-12, 12-24, and 24-36 inches at this time. These samples were dried and analyzed for NO_3-N.

Results and Discussion:

In 1989, grain yield was not significantly affected by the N rate, method of application, or the use of the nitrification inhibitor (Table 1). The high yields measured indicated a very efficient use of the fertilizer N that was applied. There were no excessive rains in 1989. Therefore, a response to the use of split applications of N and a nitrification inhibitor would not be expected.

The effect of treatment on the amount of NO_3-N measured to a depth of 3 feet at the end of the growing season is provided in Table 2. As was the case with yield, the N rate, method of application, and nitrification inhibitor use had no significant effect on the amount of NO_3-N in the soil. This was true for all depths sampled.

The amount of NO_3-N found varied from 35 to 52 lb./acre. These are relatively low values for NO_3-N and confirm the use of good management practices for corn production. The results of this study show that high yields of irrigated corn can be achieved on sandy soil if good N management practices are combined with good management of irrigation water. If fertilizer N is used efficiently, only small amounts of NO_3-N will remain in the root zone at the end of the growing season.

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[1] County Extension Agents, Wadena and East Ottertail Counties, and Extension Soil Scientist, respectively.

Table 1. The effect of N management on the yield of corn.

Treatment*	Inhibitor Used	Yield
		bu./acre
200 lb. N/acre early post-emergence	No	191 a*
200 lb. N/acre early post-emergence	Yes	188 a
160 lb. N/acre early post-emergence	No	189 a
160 lb. N/acre early post-emergence	Yes	192 a
200 lb. N/acre post emergence split application	No	186 a
200 lb. N/acre post emergence split application	Yes	194 a
160 lb. N/acre post-emergence split application	No	188 a
160 lb. N/acre post-emergence split application	Yes	193 a

* Treatment averages followed by the same letter are not significantly different from each other at the .05 confidence level.

Table 2. The effect of N management on the NO_3-N in the root zone at the end of the growing season.

Treatment	Inhibitor Use	Depth (in.) 0-12	12-24	24-36	Total
200 lb. N/acre early post-emergence	No	21 a*	9 a	5 a	35 a
200 lb. N/acre early post-emergence	Yes	26 a	13 a	5 a	44 a
160 lb. N/acre early post-emergence	No	29 a	12 a	4 a	45 a
160 lb. N/acre early post-emergence	Yes	23 a	11 a	4 a	38 a
200 lb. N/acre post-emergence split application	No	29 a	12 a	7 a	48 a
200 lb. N/acre post-emergence split application	Yes	29 a	10 a	5 a	44 a
160 lb. N/acre post-emergence split application	No	28 a	16 a	8 a	52 a
160 lb. N/acre post-emergence split application	Yes	26 a	12 a	4 a	42 a

* Treatment averages in each column followed by the same letter are not significantly different at the .05 confidence level.

LUPIN BEAN FERTILITY STUDY

H. Meredith, Mel Weins, Greg Cremers, and Andy Scobbie[5]

ABSTRACT: A fertility study initiated in 1984 to determine the nutrient requirements of lupin beans (Lupinis albus) was continued in 1989. Population density and weed control were excellent in 1989. Insects as grasshoppers, blister beetles, and dung beetles feeding on flowers were noted. The first observed incidence of stem and seed pod disease likely inflicted significant damage to the lupin crop. Pleiochaeta and Ascochyta were two organisms identified. Ascochyta organisms were responsible for the observed stem cankers and pod spots and the resultant loss in seed quality.

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

		Yield, bu/A									
No.	Treatment	1984	1985	1986		1987		1988		1989	
1	Check	39.1[1]	71.4[2]	40.6[3]	32.0[4]	57.2[3]	61.8[4]	47.6[3]	61.9[4]	37.3[3]	31.9[4]
2	Sulfur (S)	43.2	71.2	44.0	31.7	54.2	62.8	58.7	67.2	40.1	33.0
3	S + K	40.5	63.8	40.6	43.3	49.9	61.9	50.9	61.1	31.9	27.3
4	S + K + P	39.4	68.8	39.2	40.2	56.6	61.8	42.3	57.2	40.6	33.9
5	S + K + P + Zn	39.4	64.1	41.8	37.4	47.2	56.3	42.8	58.0	35.6	27.7
6	S + K + P + Zn + B	41.5	64.9	33.8	32.8	54.8	60.8	52.0	52.3	35.9	29.5

[1] 30-inch rows
[2] 6-inch drill rows
[3] Old fertility site
[4] New fertility site
[5] Regional Director, Tennessee Valley Authority, Research Plot Supervisor, Staples Irrigation Center, Assistant Scientist, Jr. Scientist, University of Minnesota, respectively.

Percent Nitrogen in Lupin Beans, Staples Station

Treatment	1985	1986		1987		1988		1989	
	[1]	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]
1	5.4	5.6	5.4	5.5	5.0	6.2	5.6	5.6	6.2
2	5.4	5.5	5.5	5.5	5.1	6.4	5.6	5.7	6.2
3	5.6	5.6	5.3	5.3	5.0	6.3	5.4	5.8	6.2
4	5.6	5.5	5.1	5.6	4.8	6.0	5.5	5.8	6.0
5	5.7	5.6	5.4	5.6	4.8	6.1	5.5	5.7	6.1
6	5.6	5.6	5.4	5.5	4.8	6.0	5.4	5.7	6.0

[1] Old fertility site
[2] New fertility site

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 Irrigation Center, 1989.

Well ID	N	S	Mn	Zn	Na	Ca	Mg
	pounds/A inch water						
Well A	5.4	1.55	.283	T	1.67	48.5	13.8
Well B	1.4	.46	.302	.213	1.90	49.9	14.1
Well C	2.4	1.18	.250	.051	1.41	54.0	16.1
Well D	3.2	1.07	.16	.015	1.00	36.4	9.7
Barry Torps	10.6	5.25	T	.034	2.06	51.7	22.7
Two Towers	3.1	8.25	.19	T	2.25	61.0	23.1

All other nutrients tested were below detection levels.

It is of value to convert PPM to pounds per acre inch to get a feel for the magnitude of nutrients in irrigation water. It is obvious that the nutrients of greatest value from these wells are the liming nutrients calcium and magnesioum. An acre inch of water is equal to 0.226 million

Table 2. Nutrients in irrigation water expressed in pounds per acre inch of water applied.

Well ID	N	S	Mn	Zn	Na	Ca	Mg	Calcium Carbonate Equivalent (lime)
	pounds/A inch water							
Well A	1.22	.35	.064	T	.38	11.0	3.1	40.4
Well B	.32	.10	.068	.048	.43	11.3	3.2	41.5
Well C	.54	.27	.056	.012	.32	12.2	3.6	45.5
Well D	.72	.24	.036	.003	.23	8.2	2.2	29.7
Barry Torps	2.40	1.19	T	.008	.46	11.7	5.1	50.5
Two Towers	.70	1.86	.043	T	.51	13.8	5.2	56.2

If 10 acre inches of water are applied for several years, irrigation water influences the soil pH. In the above case, if 50 pounds of lime is added per acre inch, this amounts to 500 pounds of lime per year if 10 inches of irrigation water are applied each year. Over a 10-year period, 5000 pounds of 2.5 tons of a high quality fine lime is added to the soil.

If 10 PPM N is detected in the irrigation water, application of 10 acre inches would add 22.6 pounds of N per year or 226 pounds of N over a 10-year period. Typically, irrigation water contains considerably less than 10 PPM N. Measurement of nitrogen in precipitation indicates that 10-15 pounds or more N per acre is deposited in areas of moderate to high total precipitation.

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

SOUTHERN EXPERIMENT STATION
WASECA, MINNESOTA

WEATHER DATA - 1989

Month	Period	Precipitation 1989	Precipitation Normal[1]	Avg. Air Temp. 1989	Avg. Air Temp. Normal[1]	Growing Degree Days 1989	Growing Degree Days Normal[1]
		---- inches ----		------ °F -----			
January	1-31	0.55	0.84	21.1	10.0		
February	1-28	0.80	0.99	9.1	16.4		
March	1-31	2.70	1.99	25.9	27.6		
April	1-30	3.21	2.64	44.7	44.7		
May	1-10	0.70		45.4		34.5	
	11-20	0.46		64.4		153.0	
	21-31	0.40		61.8		147.5	
	Total	1.56	3.76	57.4	57.7	335.0	334
June	1-10	0.10		62.4		136.0	
	11-20	0.33		64.3		151.0	
	20-30	1.78		72.8		219.0	
	Total	2.21	4.48	66.5	67.1	506.0	518
July	1-10	0.56		78.8		262.5	
	11-20	2.73		71.1		207.0	
	21-31	0.65		73.9		261.0	
	Total	3.94	4.02	74.6	71.2	730.5	641
August	1-10	0.05		70.8		205.0	
	11-20	0.46		69.4		193.0	
	21-31	1.92		71.2		230.5	
	Total	2.43	3.99	70.5	68.8	628.5	579
September	1-30	2.35	3.36	59.7	59.8	312.5	311
October	1-31	0.20	2.08	50.1	48.9		38
November	1-30	1.64	1.43	26.8	32.5		
December	1-31	0.35	1.02	8.8	18.0		
Year	Jan-Dec	21.94	30.60	43.0	43.6	2512.5[2]	2421
Growing Season	May-Sep	12.49	19.61	65.8	64.9	2512.5	2383

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

Notes:
1) Highest temperature on July 10 and August 5 -- 97°.
2) Highest 24-hour precipitation on August 28 -- 1.26".
3) Highest 2-day precipitation on June 25 & 26 -- 1.73".
4) Last spring frost -- May 7.
5) First fall frost -- September 23.
6) Driest year since 1976 and 6th driest year in 75 years of records.

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

Waseca, 1989

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 1989 was 8.7" below normal and tile flow was limited. Although NO_3 concentrations were similar for the two tillage systems, higher discharge volume with NT (1.64 vs 0.92 acre-inches) resulted in slightly higher NO_3-N losses to the drainage water with the NT system. Corn yields, N uptake, and N removal in the grain were all significantly higher for MP compared to NT. 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 1988. The stalks were chopped in October, 1988 and moldboard plots plowed.

On May 11, 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 12 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. Furadan was applied at 1 lb (ai)/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3½ lb/A) and Bladex (3 lb/A) applied May 18. Weed and insect control were excellent. Percent surface residue was measured on April 11 and averaged 8 and 94% 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 24 and NT = July 31) 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 intermittently from April 28 to June 3. 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 31, 1989.

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[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

Yields, N uptake by the whole plant (silage), and N removal in the grain were all significantly higher for the moldboard plow (MP) system compared to no tillage (NT) (Table 1). This was the fourth year of eight where MP yields were significantly higher. Neither leaf N nor grain N concentration was affected by tillage, however.

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1989.

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	26.2	3.06	7.39	151.8	153.2	1.39	100.8
No Tillage	28.9	2.94	6.33	137.0	128.0	1.41	85.3
Signif. Level (%):[1]	99	76	99	95	99	42	99
CV (%) :	2.6	4.0	3.0	4.7	2.6	2.9	4.0

[1] Probability level of significance.

Precipitation during the growing season was 8.7" below normal. Thus, tile flow was confined from late-April into early June. Although tile flow for 1989 was very low, discharge in the NT system was 78% higher than for MP (Table 2). Nitrate-N concentrations were not different between the two tillage systems. Consequently, NO_3-N losses to the drainage water were slightly higher for NT. These losses were very small, however, and represent only a small portion of the fertilizer N added to these plots.

Table 2. Influence of tillage system on tile flow, NO_3-N concentration and NO_3-N loss in 1989.

Tillage system	Tile flow	Nitrate-N Concentration[1]	Nitrate-N Loss
	acre inches	mg/L	lb N/A
Moldboard Plow	.92	13.6	2.71
No Tillage	1.64	12.8	4.75

[1] Flow-weighted

Residual NO_3-N in the soil profile at the end of the 1989 growing season showed about 102 lb/A more N remaining with the MP system (Table 3). The largest differences between the two tillage systems occurred in the top 1' where substantially more NO_3 accumulated with MP. These results are similar to 1987 and 1988.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in Oct., 1989.

Profile depth	Tillage System Mb. Plow	Tillage System No Tillage
feet	NO_3-N (lb/A)	
0-1	93.7	29.6
1-2	30.5	19.8
2-3	41.5	25.3
3-4	21.1	13.3
4-5	16.3	11.8
5-6	12.0	13.6
6-7	11.8	11.6
7-8	12.6	12.2
Total (lb NO_3-N/A 0-8')	239.5	137.2

EIGHT-YEAR SUMMARY

The cumulative totals for the 8-year period (1982-1989) are shown in Table 4. Corn yields over this period have averaged 11 bu/A better with moldboard plow tillage. Approximately 12% 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 (50% vs 45% for MP vs NT, respectively). Even though total water flow and NO_3-N lost through the tile lines was about 9% higher with no tillage, this small difference is considered to be insignificant when considering tile flow variability among the eight plots over this 8-year period.

Table 4. Cumulative effects of the two tillage systems over the 8-year period.

Parameter	Tillage System	
	Mb. plow	No tillage
Fert. N applied (lb/A)	1440	1440
Corn grain removed (bu/A)	1085	997
N removed in grain (lb/A)	724	644
N removed in grain as a percent of applied N (%)	50	45
Tile flow (acre inches)	61.3	66.8
Nitrate-N lost in tile (lb/A)	149.1	162.6
N lost via tile lines as a percent of applied N (%)	10	11

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

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

Experiments were conducted at two locations in 1989 to determine the influence of tillage, N rate and corn hybrid on residual NO_3 for second year corn following alfalfa. Spring residual NO_3 levels were very high in Waseca Co. due to the drought in 1988 and in the moldboard plowed plots that received fertilizer N in Winona Co. On average residual NO_3 increased by 8% and decreased by 26% from October 1988 to April 1989 in Waseca and Winona Counties, respectively. Samples taken from the top foot indicate a slight increase in NO_3-N concentration between preplant sampling and the V2 and V6 stages. Highest levels of residual soil NO_3 occurred at both sites where N had been applied to the MP plots. Residual N was lowest with no tillage in Winona Co. Significantly less residual NO_3 remained with DK547 compared to P3732. These data indicate that soil NO_3-N levels are greatly affected by tillage, N rate, and hybrid even for second year corn following alfalfa. Management systems can be employed that reduce carryover of NO_3 and thus minimize the potential for NO_3 leaching.

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 residual NO_3-N remaining in the spring after 1st year corn following alfalfa, (2) the effect of tillage on soil NO_3-N at the preplant, V2 and V6 growth stages, and (3) the effect of tillage, corn hybrid, and fertilizer N rate on residual NO_3-N following second year corn after alfalfa.

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.

Following harvest and soil sampling in October, 1988, all moldboard plots were plowed at the Waseca and Winona Co. sites. Soil samples were taken in 1-foot increments to a depth of 5' from the 0 and 100-lb plots (1989 N rate) of the P3732 hybrid on both tillage systems in late-April, 1989 prior to planting. Additional samples were taken from the 0-lb N rate plots of this hybrid at the V2 stage (Winona Co.) and V6 stage at both sites. After harvest, soil samples were again taken from both tillage systems in 1-foot increments to a depth of 5' from the P3732 and DK547 plots receiving the 0 and 100-lb N rates. All soil samples were forced-air, oven-dried at 120°F, crushed to pass a 2 mm sieve, and analyzed for NO_3-N.

The corn hybrids planted in 1988 were repeated again on the same plots in 1989. The N rate was raised from 60 lb/A in 1988 to 100 lb/A in 1989 on those plots receiving N.

RESULTS AND DISCUSSION

Spring sampling

Samples taken prior to planting and N fertilization indicate substantial carryover of residual NO_3-N at both locations (Table 1). Residual NO_3 levels were very high for all previous N rate/tillage systems in Waseca Co. because of the extremely low corn yields in 1988 due to drought. In Winona Co., residual NO_3 was highest for the MP system especially those plots that received 60 lb N/A in 1988. Residual NO_3 in the top 5' increased by 8% between October 1988 and April 1989 in Waseca Co. probably due to additional nitrification and very dry conditions that minimized any NO_3 losses. In Winona Co. where significant fall rain occurred after sampling, residual NO_3 decreased by 26% during this 6-month period.

[1/] Funding provided by the Minnesota Agric. Exp. Stn. and the So. Exp. Stn. at Waseca.

[2/] Professor and Assistant Scientist, So. Exp. Stn., Waseca.

Table 3. Residual soil nitrate-N after harvest in October, 1989 at Waseca as influenced by tillage, hybrid, and N rate.

Profile		Moldboard				No-tillage			
		P3732		DK547		P3732		DK547	
depth	lb N/A:	0	100	0	100	0	100	0	100
feet		lb NO_3-N/A							
0 - 1		19.6	101.5	16.4	56.3	22.9	53.9	17.5	50.1
1 - 2		8.4	41.6	6.3	28.3	6.9	27.4	6.2	38.3
2 - 3		13.4	29.5	5.3	23.2	11.7	31.3	8.5	28.0
3 - 4		10.4	16.1	6.6	13.4	13.9	16.3	10.3	13.2
4 - 5		6.3	8.5	6.6	9.0	9.5	8.3	8.2	6.9
Total in 0-5' profile		58	197	41	130	65	137	51	136

Table 4. Residual soil nitrate-N after harvest in October, 1989 in Winona Co. as influenced by tillage, hybrid, and N rate.

Profile		Moldboard				No-tillage			
		P3732		DK547		P3732		DK547	
depth	lb N/A:	0	100	0	100	0	100	0	100
feet		lb NO_3-N/A							
0 - 1		33.0	142.5	17.0	89.1	19.3	59.9	18.8	17.9
1 - 2		17.5	86.5	3.3	34.7	3.4	23.7	4.0	5.7
2 - 3		11.9	34.1	3.3	17.1	5.2	13.0	2.6	6.7
3 - 4		10.5	12.4	7.8	7.7	7.3	8.9	4.5	5.6
4 - 5		5.2	7.2	4.7	7.5	6.7	6.5	4.9	5.6
Total in 0-5' profile		78	283	36	156	42	112	35	42

Fall sampling

Samples were taken from the 0-1' and 1-2' depths at the preplant, V2 and V6 growth stages to determine if the NO_3 concentrations would change greatly during this period due to nitrification or loss of N. Information of this type may be helpful as agronomists evaluate the pre-sidedress soil nitrate test. Results shown in Table 2 show a slight increase in NO_3-N concentration in the top foot for both tillage systems at Waseca over this 8-week period. In Winona Co., soil NO_3-N increased in the top foot from preplant (late April) to V2 (early June) but did not change over the next four weeks (V6 stage). Soil NO_3-N changes in the 1-2' layer were small and inconsistent.

Waseca

Soil NO_3 amounts in October 1989 are given in Tables 3 and 5. Main effects showed significantly higher residual NO_3-N with the 100-lb N rate and with P3732 compared to DK547 but no effect of tillage. The significant tillage x N rate interaction indicates a greater effect of N with the MP system compared to NT. Larger differences between the amount of residual NO_3 after P3732 compared to DK547 with the MP system resulted in the significant tillage x hybrid interaction. Proportionately more NO_3 remained after the P3732 hybrid especially when fertilizer N was not applied. When N was applied there was less relative difference between hybrids. These results may have been unduly affected by the poor crop at this site in 1988.

Winona Co.

Fall total profile NO_3-N values shown in Table 4 show a substantial and highly significant effect of tillage, N rate, and hybrid on residual NO_3 (Table 5). The highly significant tillage x N rate interaction shows very low residual soil NO_3 except when 100 lb N/A was applied to the MP system. This high level of residual NO_3 reflects carryover of the fertilizer N which was not needed by the corn because of adequate N being supplied by mineralization of the N in the moldboard plowed alfalfa system. Almost 2X as much residual NO_3 was found after P3732 compared to DK547. This may have been due to slightly higher yields with DK547.

Table 1. Soil nitrate-N in April, 1989 following 1 year of corn after alfalfa.

	Waseca				Winona Co.			
Tillage:	Moldboard		No till		Moldboard		No till	
Profile depth / N rate:	0	100	0	100	0	100	0	100
feet	lb NO_3-N/A							
0 - 1	37.8	69.4	39.3	45.5	49.3	112.2	41.1	70.1
1 - 2	72.3	104.7	57.6	117.2	43.7	83.1	27.9	63.8
2 - 3	51.9	55.0	46.9	57.6	21.4	30.0	14.4	23.6
3 - 4	17.3	32.1	26.2	23.8	11.4	12.5	9.5	11.0
4 - 5	6.7	13.1	12.7	10.0	6.5	9.8	7.1	10.9
Total in 5-foot profile								
April, 1989	186	274	183	254	132	248	100	117
Oct., 1988	170	235	184	236	178	302	136	182

Table 2. Soil NO_3-N concentration at the preplant, V2 and V6 stages as influenced by tillage.

Soil	Moldboard			No tillage		
depth	Preplant	V2	V6	Preplant	V2	V6
feet	NO_3-N, ppm					
			Waseca Co.			
0 - 1	9.5	-	12.3	9.8	-	13.6
1 - 2	18.1	-	13.8	14.4	-	14.2
			Winona Co.			
0 - 1	17.5	21.8	21.4	10.3	12.9	12.9
1 - 2	16.0	14.2	15.6	7.0	7.9	7.5

Table 5. Means for main effects and interactions for total residual soil nitrate-N (0-5') after harvest at Waseca and Winona Co. in October, 1989.

Treatment		Location Waseca	 Winona Co.
		——— lb NO_3-N/A ———	
Tillage			
Moldboard		107	138
No-tillage		97	57
P >F		0.23	0.01
N Rate (lb/A)			
0		54	47
100		150	148
P > F		0.01	0.01
Hybrid			
P3732		114	128
DK547		89	66
P > F		0.01	0.01
Tillage X N Rate Interaction			
Moldboard	0	50	56
	100	164	219
No-tillage	0	58	38
	100	137	77
P> F		0.01	0.01
Tillage X Hybrid Interaction			
Moldboard	P3732	128	180
	DK547	86	96
No-tillage	P3732	101	77
	DK547	94	38
P> F		0.01	0.16
N Rate X Hybrid Interaction			
0	P3732	62	60
	DK547	46	34
100	P3732	167	197
	DK547	133	99
P> F		0.04	0.03
Tillage X N Rate X Hybrid Interaction			
P> F		0.01	0.72
CV (%):		11.4	45.

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). 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), where 50 lb N/A optimized yields. 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. Yields from the residual manure treatments (manure applied in 1987 and 1988) were equal to yields from the 150-lb fertilizer N rate. However, NO_3-N concentrations in the water at 5' still remained very high (38 to 79 mg/L). When profitability was highest, NO_3-N concentrations at 5' averaged about 15 mg/L. 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 1989 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 6.5 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 1989. 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 November 3, 1988. Spring N fertilizer treatments were applied on May 3 and again on June 29, 1989. Liquid hog manure was not applied in 1989. All plots except the no-till treatment were disked on May 8.

Corn (Pioneer 3737) was planted on May 15 at 30,200 plants/A. Lasso (3 lb/A) and atrazine (2.5 lb/A) were applied preemergence. Force was applied in the furrow at a rate of 8 oz/1000' of row to control rootworms. All chisel plow plots were cultivated on June 22.

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 (Oct. 4). All samples were weighed, dried, ground and analyzed for total N.

Soil samples were obtained from each plot on April 18 and Nov. 6 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).

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

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 May 12, June 7, July 26, and September 12.

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 May 3 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 7.5' depths were used to extract soil water. Grain and stover yields were taken at physiological maturity (PM).

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 1989. 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 October 31, 1988. Anhydrous ammonia was applied preplant on May 9. All chisel plots were disked on May 12.

Corn (Pioneer 3772) was planted at 30,200 plants/A on May 16. Lasso (4 lb/A) and Bladex (2.5 lb/A) was applied preemergence. Force was applied (8 oz/1000 ft) 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 21) and 8 to 9-leaf stage (June 29).

Plant sampling procedures at silking and at PM were essentially the same as at the Olmsted Co. site except that grain yields were determined by combine harvesting two rows per plot. Soil sampling to the 8-foot depth on May 3 and November 10 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 May 3, June 21, July 20, and Sept. 11 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 1989. Twelve N treatments were established for a total of 48 plots. Each plot measures 20' wide by 65' long.

Fall chiseling was conducted on October 31, 1988. The preplant anhydrous ammonia treatments were applied on May 4. A field cultivator was used as secondary tillage just prior to planting.

Corn (Pioneer 3772) was planted at 30,200 plants/A on May 15. Lasso (3 lb/A) and Bladex (2.5 lb/A) were applied preemergence. Force (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-leaf stage (June 20) and the 8 to 9-leaf stage (June 29).

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 May 16, June 15, Aug. 3, and Sept. 12 to determine NO_3 and pesticide concentrations in the extracted soil water.

RESULTS AND DISCUSSION

Olmsted Co.

Corn grain yields in 1989 were increased significantly by both the fertilizer and previous manure N treatments (Table 1). The addition of 75 lb N/A increased yield by 86 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 with the two hog manure treatments were not significantly different than 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 3-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 1989 corn 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	1989	1987-89	5'	7.5'
		lb N/A		---- bu/A ----		--- mg/L ---	
1	Chisel	0	------	69.0	86.1	1	3
2	Chisel	75	Spr., preplant	155.2	159.1	7	7
3	Chisel	150	Spr., preplant	181.4	178.4	15	7
4	Chisel	225	Spr., preplant	174.6	170.7	28	9
5	Chisel	150	Fall, post tillage	183.1	177.6	17	-
6	Chisel	150+NI[1]	Fall, post tillage	180.8	176.3	15	-
7	Chisel	150- Split	50% Spr., preplant 50% SD, 8-leaf	174.0	173.2	-	-
8	No tillage	150	Spr., preplant	178.8	177.4	-	-
9	Chisel	315[2]	Spr., disked in	186.6	185.2	38	13
10	Chisel	490[2]	Spr., disked in	181.2	183.9	79	6
	Significance level (%)		:	99			
	BLSD (.05)		:	13.1			
	CV (%)		:	6.0			

1) N-Serve

2) Liquid swine manure was applied annually at an average rate of 6050 and 9200 gal/A, respectively, in 1987 and 1988. No manure was applied in 1989. Total N rates were 315 and 490 lb N/A or approximately 175 and 265 lb "available" N/A.

3) September 12, 1989

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. Contrary to 1988, fall applications of N, regardless of the inclusion of N-Serve, showed similar NO_3-N concentrations as the spring preplant 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 three growing seasons probably because of the dry conditions in both 1988 and 1989. 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 greatly influenced by tillage (Table 2). The yields with the MP system were significantly higher than those from either the ridge till (RT) or NT systems with yields from CP being intermediate. A slight weed infestation in the RT and NT systems may have competed for soil water in this dry year, thus reducing corn yields.

Table 2. Effect of tillage treatments on the 1989 corn yields in Olmsted Co.

Tillage	Grain Yield	
	1989	1987-89 Avg.
	---- bu/A ----	
Moldboard plow	180.1	174.0
Chisel plow	169.1	170.1
Ridge till	156.5	160.7
No tillage	158.8	157.4
Significance level (%):	98	
BLSD (.05) :	15.7	
CV (%) :	5.5	

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. There was no significant difference between the two tillage systems except when no N was applied. Under these conditions yields were better with the CP system. None of the split and sidedress treatments enhanced yields over the spring PP anhydrous applications. Benefits were not obtained by including N-Serve with the anhydrous ammonia.

Three-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 (3) 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. 11 varied considerably and did not relate closely 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 concentration in the soil water at 5′ as affected by N treatments in Goodhue Co. in 1989.

No.	Treatment			Grain Yield		Nitrate-N[3] Conc. in Water at
	Tillage[1]	N rate	Time/Method	1989	1987-89	5′
		lb N/A		---- bu/A ----		mg/L
1	Chisel	0	--------	55.2	87.1	11
2	Chisel	50	Spr., preplant (PP)	111.9	129.8	-
3	Chisel	100	Spr., preplant (PP)	139.2	146.3	11*
4	Chisel	150	Spr., preplant (PP)	146.4	148.4	33
5	Chisel	200	Spr., preplant (PP)	137.9	148.6	-
6	No tillage	0	--------	38.2	73.8	-
7	No tillage	100	Spr., preplant (PP)	128.8	142.9	8
8	No tillage	150	Spr., preplant (PP)	139.4	148.3	16
9	No tillage	200	Spr., preplant (PP)	126.6	144.5	-
10	Chisel	50+50	Spr. PP + SD 9-lf	135.6	142.3	-
11	Chisel	50+100	Spr. PP + SD 9-lf	142.2	147.0	-
12	Chisel	100+50	Spr. PP + SD 9-lf	142.8	148.7	-
13	Chisel	100	SD 6-lf	138.5	141.8	-
14	Chisel	150	SD 6-lf	136.7	147.0	32
15	Chisel	150+NI[2]	Spr. PP	138.1	152.1	-
16	Chisel	150+NI	SD 6-lf	144.0	148.0	-
	Significance level (%) :			99		
	BLSD (.05) :			11.8		
	CV (%) :			7.4		

1) Chiseling was done in Oct., 1988.
2) NI = N-Serve
3) Sept. 11, 1989
* Average of only 2 samples

Winona Co.

Corn grain yields were improved over the 0-lb control by about 45 bu/A with all of the N treatments (Table 4). Yields were optimized by the 50-lb N rate applied preplant. Higher rates of N and split or sidedress applications showed no additional yield advantage. No difference was observed between the two tillage systems.

Three-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 three years of experimentation still are at 19 mg/L where no N has been used. Concentrations ranged between 39 and 73 mg NO_3-N/L for the treatments that received fertilizer N, with a positive relationship to N rate. These high values must be a result of the previous alfalfa crop which received manure in 1985 and the very dry conditions in 1988 that limited yields and N uptake by the crop severely.

Table 4. Effect of N treatments on the corn grain yield and NO_3-N concentrations in the soil water at 5′ and 7.5′ in Winona County in 1989.

Treatment				Grain Yield		Nitrate-N^2 Conc. in Water	
No.	Tillage^1	N rate	Time/Method	1989	1987-89	5′	7.5′
		lb N/A		---- bu/A ----		--- mg/L ---	
1	Chisel	0	------	131.9	129.9	19*	-
2	Chisel	50	Spr., preplant	175.1	146.2	-	-
3	Chisel	100	Spr., preplant	174.6	148.3	44	21*
4	Chisel	150	Spr., preplant	173.4	149.7	44	-
5	Chisel	200	Spr., preplant	175.2	154.8	73	42
6	No tillage	0	------	137.0	131.7	-	-
7	No tillage	100	Spr., preplant	174.6	148.2	39*	-
8	No tillage	150	Spr., preplant	171.7	141.8	-	34
9	No tillage	200	Spr., preplant	167.6	146.2	62	36
10	Chisel	50+50	Spr. PP + SD 9-lf	170.7	149.2	-	-
11	Chisel	50+100	Spr. PP + SD 9-lf	177.3	152.0	-	23
12	Chisel	150	SD 6-lf	162.0	142.4	61*	-
	Significance level (%) :			99			
	BLSD (.05) :			12.4			
	CV (%) :			5.5			

1) Chiseling was done in October, 1988.
2) Sept. 12, 1989
* - Average of two samples

SUMMARY

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

1) N rates for continuous corn were optimized at 150 lb/A at one site, 100 lb/A at another, and at 50 N lb/A at the site with an alfalfa and manure history (1983-85).
2) No apparent yield advantages were found with split or sidedress applications of N at any of the three sites.
3) There was no yield difference between the no tillage and chisel tillage systems at any of the three sites except when no N was applied.
4) Previous crop and manure history apparently still impacts corn yield and N management at the Winona Co. site.
5) 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.
6) 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.
7) Highest NO_3-N concentrations in the soil water obtained by suction lysimeter were associated with the 1987 and 1988 manure treatments. Concentrations also related very closely to the rate of fertilizer N applied.

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 analysis in previous years.

TILLAGE SYSTEMS FOR CORN AND SOYBEAN CROP SEQUENCES

Waseca, 1989

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 1989 were quite variable due to moisture stress and the presence of soybean cyst nematode. Corn yields were not influenced by tillage. On the other hand, soybean yields were 9 and 24% higher with MP and CP tillage compared to NT. Corn and soybeans in rotation yielded 14 and 42% 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, 1988 after stalk chopping all corn plots. Spring secondary tillage consisted of disking the CP plots and field cultivating the MP and CP plots on May 11.

Nitrogen was broadcast applied as ammonium nitrate prior to secondary tillage to all 1989 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 12 at a rate of 29,700 ppA with a John Deere Max-Emerge II 4-row planter equipped with bubble coulters. Furadan (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 23. Row cultivation was performed on June 21 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 24. Weeds were controlled with a preemergence application of Lasso (3½ qts/A) + Amiben (6 qts/A) on May 31. The MP and CP soybean plots were cultivated on June 21.

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.

Results and Discussion

Corn yields were below normal and quite variable due to the dry conditions throughout most of the growing season (Table 1). When averaged over crop sequence, there was not a significant difference

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[1/] Soil scientist and assistant scientist, Southern Experiment Station and Professor, Department of Soil Science.

at the P = 90% level in yield among the tillage systems. Crop sequence significantly influenced corn yield. Corn following soybeans yielded 14% higher than continuous corn. There was no tillage x crop sequence interaction. Grain moisture was significantly higher with NT compared to the MP and CP systems but was not influenced by cropping sequence (Table 1).

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

Tillage	Crop Sequence	Grain Yield	Grain Moisture
		bu/A	%
MP	C-C	119.1	14.0
"	C-Sb	142.8	14.0
CP	C-C	129.2	14.2
"	C-Sb	145.1	13.9
NT	C-C	120.0	15.5
"	C-Sb	130.6	14.8
FACTORIAL COMPARISONS			
Tillage			
MP		131.0	14.0
CP		137.2	14.0
NT		125.3	15.1
Signif. Level (%):1/		75	99
BLSD (.05) :			0.8
Crop Sequence			
C-C		122.8	14.6
C-Sb		139.5	14.2
Signif. Level (%):1/		94	91
Tillage x Sequence Interaction			
Signif. Level (%):1/		21	60
CV (%) :		14.	3.4

1/ Probability level of significance.

Soybean yields were also highly variable (Table 2). Highly significant yield differences occurred among the three tillage systems. When averaged over crop sequence, yields with the MP and CP systems were 9 and 24% higher than with the NT system. A severe infestation of soybean cyst nematode became evident in 1989. This was especially true on some of the MP plots that were in continuous soybeans. Consequently, yields for the MP system were lower than expected. The lower yields with no tillage resulted primarily from poor broadleaf weed control in some plots. Lambsquarter and red root pigweed pressures have continued to increase over the years with continuous NT. Continuous soybeans yielded 30% lower than the Sb-C sequence. A significant tillage x crop sequence interaction was not found. Seed moisture at harvest was not influenced by tillage or crop sequence.

FOUR-YEAR SUMMARY

Corn yields from this completely weed-free site were 8 to 12 bu/A higher for NT compared to either MP or CP regardless of crop sequence (Table 3). Corn yields following soybeans averaged 14% higher than continuous corn for the MP system and 9% higher for the CP and NT systems. Soybean yields were not affected by tillage system. Soybeans following corn yielded 15, 22, and 25% higher than continuous corn for the MP, CP and NT systems, respectively.

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	31.7	8.3
"	Sb-C	43.1	8.4
CP	Sb-Sb	36.8	8.4
"	Sb-C	48.2	8.4
NT	Sb-Sb	25.8	8.4
"	Sb-C	42.8	8.4
FACTORIAL COMPARISONS			
Tillage			
MP		37.4	8.3
CP		42.5	8.4
NT		34.3	8.4
Signif. Level (%):		99	78
Crop Sequence			
Sb-Sb		31.4	8.4
Sb-C		44.7	8.4
Signif. Level (%):		99	79
BLSD (.05) :		3.2	-
Tillage x Sequence Interaction			
Signif. Level (%):		50	14
CV (%) :		14.	1.1

Table 3. Four-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	128.0	-
"	Corn-Soybean	145.6	47.4
"	Cont. Soybean	-	41.1
CP	Cont. Corn	131.7	-
"	Corn-Soybean	143.2	50.1
"	Cont. Soybean	-	41.1
NT	Cont. Corn	140.6	-
"	Corn-Soybean	153.8	49.4
"	Cont. Soybean	-	39.5

CONSERVATION TILLAGE FOR CORN AND SOYBEAN PRODUCTION[1/]

Waseca, 1989

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

ABSTRACT: This was the 15th year of a study to evaluate five primary tillage systems for corn and soybean production on a Nicollet-Webster soil complex. Because of extremely high weed pressure with the NT system in previous years, all weed growth was eliminated by an aggressive herbicide program in 1989. Surface residue amounts ranged from 8% with MP tillage to 99% with NT. Soybean yields were unaffected by tillage systems under these conditions.

With increasing emphasis on controlling erosion and minimizing energy requirements (time, labor, and fuel), tillage practices have changed markedly over the last decade. Many tillage practices have come to be known as "conservation tillage". To fit this definition, a tillage practice must leave 30% of the soil surface covered with residue after planting.

EXPERIMENTAL PROCEDURES

To evaluate some of these conservation tillage practices an experiment was started in 1975 with continuous corn grown on a Webster clay loam at the Southern Experiment Station. Five tillage treatments [no tillage (NT), fall moldboard plow (MP), fall chisel plow (CP), ridge-plant (RP) 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 (SD) (20" disk blade) treatment (Table 1). Because of increased pressure of the grass weeds in the NT 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.

Ridges for the RP treatment in 1989 were built in June, 1988. After the 1988 corn harvest stalks were chopped and the MP and CP treatments were performed. On May 30 the MP and CP treatments were field cultivated once with the chiseled plots receiving a prior disking. The SD treatment was disked twice. Ridges for 1990 corn were prepared on July 24.

Soybeans (Hardin) were planted in 30" rows at a rate of 160,000 plants/A on May 31. All treatments except RP were planted with a John Deere 7300 planter equipped with bubble coulters. B&H ridge cleaners were attached to a JD 7100 planter for the RP treatment. No starter fertilizer was used. Broadcast P and K were not applied for the 1989 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. Because of extraordinarily high weed pressures associated with the NT treatments over the last 8 years, and the increasing weed pressure with the CP and SD systems, weed control methods to "eradicate" weeds were employed in 1989. Roundup (2 qts/A) was applied to all NT plots on June 2. Lasso (3.5 qts/A) + Amiben (3 lb/A) were applied broadcast to all plots on June 2. All plots except NT were cultivated with a Hiniker 5000 cultivator on June 30. Poast (0.35 lb/A) was applied broadcast with 1 qt of crop oil concentrate/A to all plots on July 4. This same rate of Poast + oil was applied to the NT, CP, and SD treatments on July 24 and again to the NT plots on August 8. As a result of this chemical arsenal plus cultivation, weed control was perfect.

Surface residue coverage was measured by the line-transect method on April 11 prior to spring tillage. Yields were taken by combine harvesting the center two rows from each plot.

RESULTS

Surface residue amounts prior to planting were highly related to tillage system with the following ranking NT > SD > RP > CP > MP (Table 1).

[1/] Funding provided by the Southern Experiment Station, Waseca.

[2/] Professors, Southern Experiment Station and Department of Soil Science, respectively.

Table 1. Influence of tillage methods for soybeans after corn on surface residue before spring tillage at Waseca in 1989.

Treatment	Surface Residue Coverage
	%
No tillage	99
Fall plow	8
Fall chisel	36
Ridge plant	55
Spring disk (2x)	84
Significance Level (%):	99
BLSD (.05) :	10
CV (%) :	13.

Seed yield and moisture were not affected by the tillage systems in 1989 (Table 2). This was in sharp contrast to previous years where yields with NT were severely depressed. However, even though surface residue accumulations were very high, soybean yields were not affected when weeds were completely removed from the system.

Table 2. Influence of tillage method on soybean production at Waseca in 1989.

	Seed	
Tillage	Moisture	Yield
	%	bu/A
No tillage	10.1	39.2
Fall plow	10.1	41.5
Fall chisel	10.0	41.1
Ridge plant	10.2	40.4
Spring disk (2x)	10.0	41.3
Significance Level (%)[1/] :	45	80
CV (%) :	1.2	3.4

[1/] Probability level of significant difference between means.

SUMMARY - 1989

This was the fourth crop of soybeans grown following corn in this long-term study with continuous corn from 1975 through 1982 and soybeans in 1983, 1985, and 1987. Surface residues prior to planting were greater than 50% with the NT, RP, and SD tillage. Weeds were completely eliminated from the plots with an aggressive chemical and cultivation program. As a result, soybean yields and moisture content at harvest were not affected by tillage.

FOURTEEN-YEAR YIELD SUMMARY (Not including 1989)

Grain yields from the five tillage systems where starter fertilizer was used from 1975-1982 are shown in Table 3. 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 3). 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 3. 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	137.5
"	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]

1989

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 declined by about 15% at Waseca and 20% at Morris. Soil test K did not change at Waseca but increased about 20% at Morris. Corn yields were increased 10 to 16% over the long-term control plots at the two sites when soil test Bray P_1 was greater than 30 lb/A. Highest yields occurred at both locations when both P and K were applied to these high testing soils. There appeared to be little effect of soil test K on corn yield at Waseca.

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.

Table 1. Experimental procedures for corn on the high P and K rate study at the two branch stations in 1989.

	Location	
Variable	Morris	Waseca
Planting date	5/10	5/15
Row spacing	30"	30"
Planting rate (plants/A)	32,000	30,000
Variety	Dekalb 461	Pioneer 3732
Herbicide	3# Lasso + 2.2# Bladex/A(Bdct)	3.5# Lasso + 3# Bladex/A(Bdct)
Harvest date	10/3	10/12
Soil type	Aastad clay loam	Webster clay loam

The P and K materials (0-46-0 and 0-0-60) were broadcast on the soil surface and incorporated by chisel plowing the corn residue in the fall of 1988. Specific experimental procedures used for corn 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.

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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-year 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 12 to 110 lb/A (Table 2). Soil test P declined slightly compared to 1988, but soil test K did not. Corn yields were increased significantly by P but plateaued at soil P levels higher than 45 lb/A.

At Morris, Bray P_1 ranged from 13 to 70 lb/A while Olsen's $NaHCO_3$ test ranged from 8 to 44 lb P/A (Table 3). Soil test P values declined about 20% at Morris, while soil K values increased about 20%. Grain yields were increased and grain moisture was decreased significantly by the P treatments.

Table 2. Soil test values, grain moisture, and grain yield as influenced by 16 years' application of P and K at Waseca.

	P and K Treatments						
	Total		Soil Test[2]			Corn	
No.	1973-84	1985-88[1]	pH	P	K	Moisture	Yield
	---- lb P_2O_5 + K_2O/A ----			--- lb/A ---		%	bu/A
2	0 + 1200	0 + 100	6.8	12	306	20.1	140.0
3	600 + 1200	0 + 100	6.4	43	304	19.6	163.3
4	1200 + 1200	0 + 100	6.6	72	290	19.3	167.1
5	600 + 1200	100 + 100	6.6	74	295	19.1	178.4
6	1200 + 0	100 + 0	6.7	110	245	19.2	172.7
7	1200 + 600	100 + 0	6.6	100	231	18.8	166.4
	Signif. Level (%)	:	44	99	99	93	99
	BLSD (.05)	:	-	11	46	-	12.5
	CV (%)	:	3.6	9.8	8.7	2.4	4.2

1. Treatments applied each fall. P was discontinued for treatments 6 & 7 in 1988.
2. Samples were taken in October before 1989 treatments were applied.

Table 3. Soil test values, grain moisture, and grain yield as influenced by 16 years' application of P and K at Morris.

	P and K Treatments							
	Total		Soil Test[2]				Corn	
No.	1973-84	1985-88[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	13	8	533	21.8	135.1
3	600 + 1200	0 + 100	7.7	32	21	454	20.8	151.1
4	1200 + 1200	0 + 100	7.8	52	34	473	20.8	149.7
5	600 + 1200	100 + 100	7.6	70	44	446	20.4	173.7
	Signif. Level (%)	:	95	99	99	99	99	99
	BLSD (.05)	:	0.1	22	13	53	0.7	17.7
	CV (%)	:	1.0	33.	31.	6.5	2.1	7.0

1. Treatments applied each fall.
2. Samples were taken in October before 1989 treatments were applied.

CONCLUSIONS

Long term (12-yr) additions to these two soils created a wide range in soil test P levels. Corn 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. At Morris, corn yields were significantly improved with the higher soil test P levels. It is interesting to note that the highest yield at each site was produced with the 100 + 100 treatment even though soil tests were already high. Soil test P declined by about 15% at Waseca and 20% at Morris. Soil test K was not changed at Waseca but increased by about 20% at Morris. 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 1989 [1]

Large and Small plot phases

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

Abstract: The objective of the **small plot** water quality research phase is to evaluate and quantify the impact of a variety of agricultural practices on crop nitrogen utilization efficiency and the potential impact on water quality. Currently agricultural 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. There was no significant difference in corn grain or soybeans yields utilizing a traditional chisel-plow tillage systems than ridge-till systems. Early N applications provided higher yields than split or late N applications in 1989. Use of a nitrification inhibitor increased yields. A significant inhibitor x method of application interaction indicates that the greatest response to inhibitor is when N is applied at 8-leaf. Nitrogen rates in excess of 105 #/A 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.

The objective of the **large plot** groundwater phase is to monitor the movement of nitrate-N through the soil profile into the underlying aquifer and to quantify subsequent impact on groundwater quality. Experimentation utilizes several sampling devices, including suction lysimeters, glass blocks, sheet metal (pan) containers, wick samplers, and wells established at three different levels in the aquifer. Three treatments replicated twice were established in 1987. Each plot area is in excess of one acre and the treatments include continuous corn at a moderate (160 # N/A) and high (215 # N/A) rate of N, and a corn-soybean rotation at the moderate N rate. Corn grain yields were not increased by the high N rate in 1987,1988 and 1989.

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. The large and small plot phases are reported here, the lysimeter phase will be reported separately.

The soil at the Rosholt farm is an Estherville sandy loam with 15-30 inches 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 these phases 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

Small Plot N Management/Crop Production Phase:

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 in 1987. In 1988 the entire experiment was planted to corn and in 1989 soybeans

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[2] Associate Professor and Asst. Scientist respectively, Dept. of Soil Science, and Associate Professor and Research Asst. respectively, Dept. Agricultural Engineering, University of MN.

were planted in the corn-soybean rotation. The 25 N treatments within each sub-plot consisted of a control (zero N) plus four N rates (60, 120, 180, and 240 kg N/ha -- these will be reported as 50, 105 160, and 215 # N/A), 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 0.5 #/A active ingredient.

Soil samples were taken from 0-1 and 1-2 ft depth from 13 of the 25 treatments of Experiment 1 on April 19th before planting and on October 30th after harvest. The soil samples were analyzed for ammonium and nitrate concentration and the data is reported in tables 3 and 4. Only spring samples were taken on soybeans following corn.

Experiment 2 consisted of 16 N treatments randomized within a split plot design with three replications. The main plot variable was tillage (ridge till and chisel plow). The 16 N treatments within each sub-plot consisted of two N rates (105 and 160 #/A), 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 0.5 #/A 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 6 inches and positioned approximately 6 inches away from the row similar to the anhydrous ammonia treatments.

Experiments 1, and 2: Corn (Pioneer 3902 - 90 day R.M.) was planted on May 12 in 30 inch rows at a population of 29,900 seeds/A using a four-row Buffalo planter. Starter fertilizer was applied to the corn plots at the rate of 10 gal/A of 7-22-5 as a band below the seed and Lorsban 15G was banded over the row at planting. Lasso (3 #/A) and AAtrex 90 DF (1#/A) was applied on May 18th for weed control in the corn. Soybeans were planted on May 20 at the rate of 63 #/A. A tank mix of Basagran (1 qt/A), Blazer (0.5 pt/A), Poast (1.5 pt/A) and oil concentrate (1 qt) applied June 8th at the rate of 20 gal/A. For additional weed control the experiments were cultivated twice. The first cultivation was on June 16th, and second on July 1st, ridges were also built on July 1st. Nitrogen treatments were applied on June 13th (early-4 leaf) and on June 28th (late-8 leaf). The irrigation program (traveling boom) was started on June 23rd and continued through August 6th with 7 inches of water being applied through irrigation. An additional 15.36 inches of water was obtained during the growing season as rainfall.

Soybean yields were taken October 8th with a plot combine harvesting two 50 ft rows. Corn grain yields were obtained on October 25th by hand harvesting 100 ft^2 of plot area. All corn grain yields were adjusted to 15.5% moisture and soybeans to 13%. Grain yields and N composition are reported on tables 1 and 2.

Large Plot Groundwater Phase:

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 215 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, and in 1989 all treatments were planted to corn. Nitrogen was applied as anhydrous ammonia in split application of two-thirds of the N rate with a nitrification inhibitor (N-Serve) at an early growth stage 4-leaf (June 14), and one-third at the 8-leaf growth stage (June 28). 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 #/A a.i.

Corn (Pioneer 3902 - 90 day R.M.) was planted on May 12 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. Lorsban 15G was banded over the row at planting. Lasso (3.0 #/A) and AAtrex 90 DF (1#/A) were sprayed on May 18th and Dicamba (0.25 #/A) on June 6th for weed control on corn.

The irrigation program (traveling boom) was started on June 23rd and continued through August 6th with 7.0 inches of water being applied through irrigation and an additional 15.36 inches of water coming through rainfall during the growing season.

Grain yields were obtained on October 25th by hand harvesting 800 ft^2 of plot area. Corn grain yields were adjusted to 15.5% moisture. Grain yields results are presented in table 6.

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, pan sheet metal, wick samplers, and wells. The wells were installed by the United States Geological Survey. Data from the wells and suction lysimeters will not be presented at this time. The glass blocks did not collect enough water in 1989 to present the data in tabular form.

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 soil surface for sampling. This type of sampler allows for the collection of soil water samples at the aforementioned depths.

Pan sheet metal samplers consist of 18-gauge 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 facilitate extraction of the water collected.

Wick samplers are 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 length 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 pan sheet metal and wick samplers were installed at approximately the same depth as the glass blocks.

General Results

Small Plot N Management/Crop Production Phase:

Experiment 1 When no fertilizer N was applied corn yields were about 95 bu/A and soybeans yields were about 45 bu/A. Across the entire experiment corn and soybean grain yields were essentially the same utilizing a chisel system of tillage or the ridge tillage for corn following corn and beans following corn.

Yield increases were obtained with fertilizer N up to rates of 215 #/A although 85% of the yield increase was obtained with the first 50 # N/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 and 1989 highest yields were obtained when the fertilizer was applied early (4-leaf) rather than in split or 8-leaf applications. The lack of a yield response when the timing of fertilizer N was delayed would indicate that N losses during the growing season were not large in 1988 or 1989 growing seasons. A significant yield increase (4 bu/A) was obtained with the use of N-Serve on corn. 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 both 1988 and 1989, the reason for a response is not well understood at this time. Previous N management practices had no influence on soybean yields.

The soil nitrate-N concentration following harvest were generally lower than that found before planting. This reduced concentration of nitrate-N may be due to either efficient utilization of the N by the plant or movement of the N below the 0-2 ft 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. Nitrate-N concentrations in the spring soil sampling following soybeans were higher with the chisel plow tillage system than with the ridge till system (table 4). The NO_3-N concentration of water collected in the pan lysimeters tended to be higher in the continuous corn plots than in the corn following soybean plots (table 5). Water samples collected by the wick lysimeters had higher NO_3-N concentrations than the water collected in the pan lysimeters.

Experiment 2 The fertilizer N rate of 105 #/A was at or above the necessary rate to obtain optimum yields. Differences between various fertilizer N management options were therefore minimal. There were no treatment effects due to tillage, N source, N rate, or time of application.

Large Plot Groundwater Phase:

Results displayed in table 6 suggest that there was no yield advantage to the application of fertilizer N over 160 lbs/A in 1989 which corresponded to the results that were obtained in both 1987 and 1988. Corn yields following soybeans were higher than yields following corn. Application of more fertilizer N did not compensate for these differences. Higher rates of fertilizer N resulted in higher concentrations of NO_3-N in the water samples collected in the pan and wick samples (table 7). Concentration of NO_3-N was higher in the corn-soybean rotation than the respective corn-corn rotation. The pan samplers provided lower estimates of the concentration of the NO_3-N in the soil water than the wick samplers.

Table 1. Influence of N-rate, nitrification inhibitors, method of application and tillage on **continuous corn** grain yields, N-concentration, and N removal. Influence of treatments applied in 1988 on soybean yields (soybeans following corn). Westport, MN. 1989

Total N-Rate	Early N	Inh.	Late N	Tillage	Corn Grain Yield	N-content	N-removal	Soybean Yield
#/A	#/A		#/A		Bu/A	%	#/A	Bu/A
Control	----	--	----	C	96.1	1.13	51.29	44.9
50	50	--	----	C	137.3	1.36	88.34	46.9
50	----	--	50	C	134.3	1.37	87.05	44.8
50	35	--	15	C	128.6	1.54	93.44	47.1
50	50	NS	----	C	141.0	1.34	89.01	44.3
50	----	NS	50	C	142.1	1.29	86.93	46.3
50	35	NS	15	C	124.5	1.39	82.14	45.5
105	105	--	----	C	132.7	1.40	87.92	46.9
105	----	--	105	C	123.2	1.36	79.18	46.6
105	70	--	35	C	141.0	1.46	97.34	46.3
105	105	NS	----	C	126.3	1.44	86.23	44.4
105	----	NS	105	C	142.7	1.42	95.95	47.5
105	70	NS	35	C	138.9	1.48	97.03	45.2
160	160	--	----	C	141.0	1.44	96.36	45.6
160	----	--	160	C	126.8	1.52	90.00	50.6
160	105	--	55	C	142.7	1.48	100.01	48.0
160	160	NS	----	C	143.6	1.51	102.84	46.0
160	----	NS	160	C	143.5	1.54	104.48	47.9
160	105	NS	55	C	122.4	1.49	86.36	44.6
215	215	--	----	C	133.6	1.53	96.70	46.2
215	----	--	215	C	141.4	1.46	97.54	40.5
215	145	--	70	C	131.1	1.53	94.95	48.5
215	215	NS	----	C	148.1	1.46	101.91	46.4
215	----	NS	215	C	144.6	1.51	103.09	48.3
215	145	NS	70	C	148.5	1.49	105.05	46.6
Control	----	--	----	R	94.8	1.17	52.44	43.7
50	50	--	----	R	131.9	1.42	88.78	43.1
50	----	--	50	R	126.2	1.39	83.23	45.6
50	35	--	15	R	126.6	1.32	78.95	46.5
50	50	NS	----	R	144.6	1.42	97.07	48.1
50	----	NS	50	R	129.7	1.47	90.06	44.5
50	35	NS	15	R	130.2	1.52	93.47	42.5
105	105	--	----	R	151.0	1.51	107.44	46.8
105	----	--	105	R	105.9	1.34	67.24	44.6
105	70	--	35	R	135.8	1.57	100.70	47.2
105	105	NS	----	R	126.6	1.44	86.59	47.0
105	----	NS	105	R	140.7	1.44	95.86	41.5
105	70	NS	35	R	136.3	1.55	99.61	49.4
160	160	--	----	R	141.5	1.45	96.87	48.1
160	----	--	160	R	139.3	1.50	98.75	43.4
160	105	--	55	R	137.5	1.51	97.98	45.2
160	106	NS	----	R	128.1	1.44	87.35	48.7
160	----	NS	160	R	142.2	1.41	94.63	50.4
160	105	NS	55	R	143.5	1.54	104.13	46.7
215	215	--	----	R	146.7	1.49	103.41	47.5
215	----	--	215	R	134.6	1.56	99.29	40.8
215	145	--	70	R	132.2	1.53	95.44	47.2
215	215	NS	----	R	142.7	1.52	102.35	47.3
215	----	NS	215	R	142.1	1.47	98.81	47.2
215	145	NS	70	R	139.6	1.58	104.45	47.6

Table 1. continued. Continuous Corn Split Plot Statistical Analysis
Corn Soybean Rotation Split Plot Statistical Analysis

	Corn Grain			Soybean
	Yield	N-Content	N-Removal	Yield
	Bu/A	%	#/A	Bu/A
Tillage				
Chisel	136.6	1.45	93.7	46.3
Ridge Till	135.6	1.47	94.7	46.1
P-Value	34	83	59	18
N-Rate X Method X Inhibitor				
N-Rate #/A				
50	133.1	1.40	88.21	45.4
105	133.4	1.45	91.76	46.1
160	137.7	1.48	96.64	47.1
215	140.4	1.51	100.25	46.2
P-Value	99	99	99	78
BLSD (.05)	3.5	0.03	2.42	
Method				
1. 4 leaf	138.5	1.45	94.95	46.4
2. 8 leaf	135.0	1.44	92.00	45.7
3. Split 2/3 1/3	135.0	1.50	95.69	46.5
P-Value	96	99	99	62
BLSD (.05)	3.4	0.32	2.31	
Inhibitor				
None	134.3	1.46	92.79	46.0
N-Serve	138.0	1.46	95.64	46.4
P-Value	99	28	99	54
N-Rate X Method	99	64	99	81
N-Rate X Inhibitor	86	15	66	71
Method X Inhibitor	99	14	99	93
N-Rate X Method X Inhibitor	99	31	99	82
N-Rate X Method X Inhibitor X Tillage				
N-Rate X Tillage	43	76	15	7
Method X Tillage	87	13	91	92
Inhibitor X Tillage	38	63	15	87
N-Rate X Method X Tillage	99	86	99	54
N-Rate X Inhibitor X Tillage	57	98	99	61
Method X Inhibitor X Tillage	98	88	99	28
N-Rate X Method X Inhibitor X Tillage	99	79	99	86

Table 2. Influence of N-rates, N-forms, nitrification inhibitors, time of application and two tillage systems on corn grain yields at Westport, MN. 1989

					---------Corn Grain----------		
N-Rate	N-Form	Inh.	Time	Tillage	Yield	N-Content	N-Removal
#/A					bu/A	%	#/A
105	AA	---	1	C	129.5	1.57	96.15
105	AA	NS	1	C	121.0	1.69	96.78
105	UREA	---	1	C	130.6	1.68	103.81
105	UREA	DCD	1	C	115.0	1.57	84.77
105	AA	---	2	C	123.1	1.41	82.02
105	AA	NS	2	C	130.5	1.46	89.16
105	UREA	---	2	C	125.3	1.61	95.78
105	UREA	DCD	2	C	128.4	1.45	88.19
160	AA	---	1	C	121.8	1.63	93.59
160	AA	NS	1	C	131.7	1.59	98.76
160	UREA	---	1	C	101.8	1.72	82.53
160	UREA	DCD	1	C	135.6	1.54	97.96
160	AA	---	2	C	118.5	1.51	84.07
160	AA	NS	2	C	125.7	1.60	94.63
160	UREA	---	2	C	128.0	1.51	91.12
160	UREA	DCD	2	C	128.6	1.68	102.33
105	AA	---	1	R	136.8	1.61	103.74
105	AA	NS	1	R	143.5	1.55	104.80
105	UREA	---	1	R	143.8	1.49	101.50
105	UREA	DCD	1	R	147.0	1.56	108.61
105	AA	---	1	R	138.5	1.59	104.67
105	AA	NS	2	R	140.1	1.59	104.36
105	UREA	---	2	R	141.0	1.53	101.46
105	UREA	DCD	2	R	152.2	1.45	104.47
160	AA	---	2	R	134.7	1.76	111.95
160	AA	NS	1	R	121.8	1.58	91.29
160	UREA	---	1	R	142.7	1.55	104.15
160	UREA	DCD	1	R	140.6	1.58	105.10
160	AA	---	1	R	129.9	1.69	102.91
160	AA	NS	2	R	142.8	1.56	105.14
160	UREA	---	2	R	129.6	1.65	101.21
160	UREA	DCD	2	R	144.8	1.58	108.97

Table 2. continued. Split Plot Statistical Analysis

	Grain		
	Yield	N-Content	N-Removal
Tillage	Bu/A	%	#/A
Chisel	124.7	1.57	92.60
Ridge Till	139.3	1.58	104.02
P-Value	83	11	98
N-Form X Inh. X Time X N-Rate			
N-Form			
Anhydrous Ammonia	130.6	1.58	97.75
Urea	133.4	1.57	98.87
P-Value	67	51	46
Inhibitor			
Without	129.7	1.59	97.54
With	134.3	1.56	99.08
P-Value	89	88	60
Time			
1. 4 leaf	131.1	1.60	99.09
2. 8 leaf	132.9	1.55	97.53
P-Value	47	99	40
N-Rate #/A			
105	134.1	1.55	98.1
160	129.9	1.60	98.5
P-Value	85	99	15
N-Form X N-Rate	8	1	12
N-Form X Time	22	68	61
N-Rate X Time	10	86	77
N-Form X N-Rate X Time	10	34	28
N-Form X Inhibitor	41	40	35
N-Rate X Inhibitor	77	32	84
N-Form X N-Rate X Inhibitor	54	93	97
Inhibitor X Time	66	50	86
N-Form X Inhibitor X Time	37	24	58
N-Rate X Inhibitor X Time	49	96	47
N-Form X N-Rate X Inhibitor X Time	76	61	66
N-Form X Inhibitor X Time X N-Rate X Tillage			
N-Form X Tillage	82	99	13
N-Rate X Tillage	66	62	30
N-Form X N-Rate X Tillage	4	35	40
Time X Tillage	22	98	68
N-Form X Time X Tillage	76	35	93
N-Rate X Time X Tillage	13	71	43
N-Form X N-Rate X Time X Tillage	74	86	24
Inhibitor X Tillage	4	74	56
N-Form X Inhibitor X Tillage	23	99	96
N-Rate X Inhibitor X Tillage	89	83	99
N-Form X N-Rate X Inhibitor X Tillage	37	40	66
Inhibitor X Time X Tillage	69	89	14
N-Form X Inhibitor X Time X Tillage	51	93	37
N-Rate X Inhibitor X Time X Tillage	98	93	93
N-Form X N-Rate X Inhibitor X Time X Tillage	19	37	4

Table 3. Influence of N-rates, nitrification inhibitors, method of application and tillage in **continuous corn** on soil ammonium and soil nitrate from spring and fall soil samples depth 1 (0-1 ft) and depth 2 (1-2 ft) Westport, MN 1989.

Total	Early		Late			Ammonium		Nitrate	
N-Rate	N	Inh.	N	Tillage	Depth	Spring	Fall	Spring	Fall
#/A	#/A		#/A			-----ppm-----		-----ppm-----	
Control	---	---	---	C	1	2.2	2.4	6.2	5.0
					2	2.0	2.0	3.4	2.0
50	50	---	---	C	1	3.5	2.4	6.9	6.1
					2	2.7	2.4	5.3	3.7
50	---	---	50	C	1	2.7	2.6	9.1	6.3
					2	2.4	2.4	5.4	3.2
105	105	---	---	C	1	2.3	2.9	7.8	7.9
					2	1.9	2.1	5.2	5.9
105	---	---	105	C	1	2.5	2.5	6.6	9.1
					2	2.0	2.2	5.3	6.0
160	160	---	---	C	1	3.2	2.8	10.3	9.1
					2	2.6	2.0	9.4	6.9
160	---	---	160	C	1	3.1	3.1	9.7	11.0
					2	2.2	6.3	11.6	11.1
160	105	---	50	C	1	2.6	2.9	8.7	7.0
					2	2.4	1.7	5.9	3.7
160	160	NS	---	C	1	4.1	4.0	11.8	12.2
					2	2.9	2.4	10.1	7.5
160	---	NS	160	C	1	2.3	11.3	8.8	13.8
					2	1.9	4.4	6.6	16.9
160	105	NS	50	C	1	2.3	2.6	7.4	6.5
					2	2.3	2.3	6.4	4.4
215	215	---	---	C	1	4.1	5.2	15.5	13.3
					2	3.6	3.4	19.3	9.5
215	---	---	215	C	1	2.3	4.1	8.9	23.3
					2	1.9	2.6	8.7	23.0
Control	---	---	---	R	1	2.2	2.2	7.0	5.4
					2	3.5	2.1	6.3	1.5
50	50	---	---	R	1	2.3	2.8	7.7	7.2
					2	2.5	2.6	3.2	2.8
50	---	---	50	R	1	2.6	2.4	7.5	6.7
					2	2.3	2.4	5.2	2.4
105	105	---	---	R	1	3.5	2.0	9.0	9.5
					2	3.3	2.3	5.4	3.1
105	---	---	105	R	1	2.5	3.7	8.0	6.2
					2	2.0	2.6	6.1	3.0
160	160	---	---	R	1	2.7	3.1	12.5	9.4
					2	2.2	2.0	9.2	5.8
160	---	---	160	R	1	4.6	2.6	12.8	8.2
					2	3.9	2.5	14.8	7.1
160	105	---	50	R	1	3.0	2.7	12.5	9.1
					2	2.6	2.4	9.2	4.2
160	160	NS	---	R	1	2.5	2.6	12.3	10.5
					2	2.0	2.6	9.8	8.2
160	---	NS	160	R	1	2.7	2.8	11.3	9.8
					2	2.3	2.5	8.0	7.4
160	105	NS	50	R	1	3.0	2.7	8.4	8.2
					2	2.3	2.6	5.6	3.9
215	215	---	---	R	1	3.9	3.8	15.7	10.4
					2	3.2	2.2	8.5	7.2
215	---	---	215	R	1	3.2	2.2	14.9	10.9
					2	3.3	2.7	29.1	9.3

Table 4. Influence of N-rate, nitrification inhibitors, methods of application and tillage in **soybeans following corn** on soil ammonium and soil nitrate from spring soil samples depth 1 (0-1 ft) and depth 2 (1-2 ft) Westport, MN 1989.

Total	Early		Late			Ammonium		Nitrate	
N-Rate	N	Inh.	N	Tillage	Depth	Spring	Fall	Spring	Fall
#/A	#/A		#/A			-----ppm-----		-----ppm------	
Control	---	---	---	C	1	3.0	1.6	6.7	7.5
					2	2.7	1.8	7.7	4.4
50	50	---	---	C	1	2.7		9.9	
					2	2.4		12.7	
50	---	---	50	C	1	2.6		5.7	
					2	2.6		3.8	
105	105	---	---	C	1	2.4		9.1	
					2	2.1		12.9	
105	---	---	105	C	1	2.5		6.0	
					2	1.8		7.4	
160	160	---	---	C	1	2.7		13.5	
					2	2.5		12.0	
160	---	---	160	C	1	2.2		9.6	
					2	2.3		9.8	
160	105	---	50	C	1	2.6		7.0	
					2	2.2		6.0	
160	160	NS	---	C	1	2.8		10.5	
					2	2.4		9.4	
160	---	NS	160	C	1	2.2		7.9	
					2	2.1		7.0	
160	105	NS	50	C	1	2.5		11.7	
					2	2.6		5.0	
215	215	---	---	C	1	2.8		11.3	
					2	2.6		9.2	
215	---	---	215	C	1	3.1		17.6	
					2	2.3		22.4	
Control	---	---	---	R	1	3.3	2.1	10.7	7.2
					2	2.5	1.7	7.7	3.7
50	50	---	---	R	1	3.0		5.9	
					2	2.6		8.4	
50	---	---	50	R	1	3.5		8.0	
					2	3.1		6.0	
105	105	---	---	R	1	2.6		10.7	
					2	2.6		7.7	
105	---	---	105	R	1	2.9		8.3	
					2	2.6		5.8	
160	160	---	---	R	1	3.0		9.7	
					2	2.5		8.3	
160	---	---	160	R	1	5.7		16.1	
					2	2.5		8.0	
160	105	---	50	R	1	2.7		8.1	
					2	2.6		4.4	
160	160	NS	---	R	1	4.3		8.7	
					2	5.7		6.7	
160	---	NS	160	R	1	2.7		10.9	
					2	2.3		9.2	
160	105	NS	50	R	1	2.8		8.2	
					2	2.8		6.4	
215	215	---	---	R	1	2.4		5.0	
					2	2.1		3.3	
215	---	---	215	R	1	2.8		9.0	
					2	2.9		8.7	

Table 5. Nitrate-N concentration of water collected in pan and wick lysimeters in the small plot area, Westport, MN 1989.

		Pan		Wick	
N rate		corn-corn	corn-beans	corn-corn	corn-beans
#/A		ppm NO_3-N			
0		1.7	2.3	-	0.9
105	early	0.6	0.8	-	5.7
105	late	18.4	1.4	40.9	-
215	early	5.7	3.6	-	40.5
215	late	3.8	0.3	-	13.5

Table 6. Corn grain yields from large plot area Westport, MN 1989.

				Grain		
Total N-Rate	Early N	Late N	Crop Rotation	Yield	N-Content	N-Removal
#/A	#/A	#/A		Bu/A	%	#/A
160	105	55	Corn-Corn	143.1	1.53	103.5
215	140	75	Corn-Corn	144.2	1.50	105.6
160	105	55	Corn-Soybeans	150.4	1.49	106.4

Table 7. Nitrate-N concentration of water collected from the pan and wick lysimeters in large plot area, Westport, MN 1989.

Pan N rate	Rotation	NO_3-N
lb N/A		ppm
160	corn-corn	1.7
215	corn-corn	15.5
160	corn-beans	26.4
Wick		
160	corn-corn	44.1
215	corn-corn	51.9
160	corn-beans	80.4

THE IMPACT OF RESIDUAL FERTILIZER TREATMENTS AND TILLAGE ON SOYBEAN YIELDS AND NO_3^- LEACHING[1]

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

Abstract: Coarse textured soils in central Minnesota are frequently irrigated and fertilized with N to obtain maximum corn yields. The objective of this study was to investigate the impact of tillage, nitrification inhibitor (DCD), and N rates on crop yields, and water and NO_3 leaching under an irrigated corn-corn-soybean rotation in central Minnesota. During the first two years of the study: (i) N rate increased corn yields and the concentration of NO_3 in the percolating water; and (ii) treatment of urea with DCD reduced the NO_3 concentration in the percolating water. In the third year of the study (reported here) tillage or fertilizer treatments applied during the first two years of the study did not impact soybean yields or water and NO_3 movement.

In central Minnesota coarse 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 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 study was to investigate the impact of tillage, nitrification inhibitor treated fertilizer, and N rates on crop yields, and water and NO_3 leaching under an irrigated corn-corn-soybean rotation 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 Hapludoll) and was used to fill the lysimeters by depth.

Prior to the initiation of this experiment the site had been cropped with dryland no-till soybeans (Glycine max) for 2 years (1985 and 1986). 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 soybeans. Water was pumped through the irrigation system at 13.8 KPa pressure. The emission rate for each dripper was 0.35 gal/h. Each lysimeter contained 4 drippers. Irrigation water was applied when less than 2 inches of water were available in the soil profile. Irrigation water was metered through 3 main irrigation lines.

Soybeans (Pioneer 9061) were planted in the spring of 1989 at a density of 63 lbs/A, while corn (Pioneer 3790) had been planted in 1987 and 1988 at a density of 27,000 seeds/A. Soil temperature, wind speed, air temperature, and rainfall were measured at regular intervals during the 3 growing seasons. The third year of research will be reported at this time.

Treatments consisted of a factorial arrangement of 2 tillage treatments (rototillage and no-tillage), 3 N rates (0,70, and 140 lbs N/A) applied in 1987 and 1988, and 3 blocks. Dicyandiamide (DCD) was an additional treatment in 1987 and 1988, and was applied at rates of 0 or 10% of the applied N in the high N treatments.

Soybeans were harvested from a 30 ft row at maturity in 1989. Subsamples from the beans were analyzed for water content. Yield was adjusted to 13% moisture.

Following rainfall events, water that had collected on the bottom of the lysimeters was removed, the volume quantified and the concentration of NO_3-N determined.

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[1] Funding provided by the Center for the Impact of Agricultural Practices on Water Quality.

[2] Adj. Asst. Professor, South Dakota State University; Associate Professor and Associate Professor respectively, Dept. of Soil Science, University of Minnesota.

Results and Discussion

Rainfall was 2.3, 2.2, 1.0, 8.0 and 1.8 inches during May, June, July, August, and September , respectively. Five inches of supplemental irrigation was applied between 12 July and 11 August.

Soybean yields ranged from 40 to 50 bu/A and were not influenced by tillage or previous N rates (table 2).

Water percolated through the lysimeters during the spring (April and May) and fall (August). During spring the amount of water percolating through the lysimeters ranged from 4 to 6 inches and was not influenced by field treatments. The NO_3-N concentration ranged from 3 to 5 ppm and also was not influenced by field treatment (table 2).

The amount of water percolating through the lysimeters in August ranged from 1.6 to 3.3 inches and was not influenced by field treatments. The NO_3-N concentration of the percolating water ranged from 3.7 to 8.5 ppm and also was not influenced by field treatment. The concentration of NO_3-N in the percolate was slightly higher in the fall than in the spring.

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. Soybean yields and water and NO_3-N percolation through the soil profile during the 1989 growing season.

		Soybean	Spring			Fall		
Tillage	N rate	Yield	H_2O	N	NO_3-N	H_2O	N	NO_3-N
	lb/A	bu/A	in.	lb/A	ppm	in.	lb/A	ppm
Roto-till	0	47.2	4.7	1.73	3.05	2.5	1.33	5.8
	70	46.3	6.2	2.30	3.14	3.0	1.12	4.41
	140	40.5	5.3	2.10	3.46	2.2	1.35	5.52
	140 DCD	47.9	5.7	1.68	3.09	1.6	1.46	8.50
No-till	0	45.6	4.6	1.78	3.12	2.9	1.24	3.76
	70	49.2	6.0	2.21	3.29	2.7	1.35	4.23
	140	44.6	4.8	2.48	4.74	3.2	1.11	3.89
	140 DCD	42.5	5.1	2.42	3.29	2.0	1.31	6.75
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
					Tillage			
Roto-till		45.5	5.5	1.95	3.19	2.3	1.32	6.06
No-till		45.5	5.1	2.22	3.61	2.7	1.25	4.66
LSD (0.05)		NS	NS	NS	NS	NS	NS	NS
					N rate			
	0	46.4	4.7	1.76	3.09	2.8	1.29	4.78
	70	47.7	6.1	2.26	3.22	2.8	1.24	4.32
	140	42.6	4.7	2.29	4.10	2.7	1.23	4.71
	140 DCD	45.2	5.4	2.05	3.19	1.8	1.39	7.63
LSD (0.05)		NS	NS	NS	NS	NS	NS	NS

LAND TREATMENT OF SEWAGE SLUDGE INCINERATOR ASH[1]

C. Rosen, R. Polta, L. America, P. Bierman, and G. Korbel[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 and final grain yield significantly increased with both ash and fertilizer compared to the control. The Olsen P soil test seemed to predict response to the ash amended soils better than the Bray P1 or Nitric acid extractants. Tissue analysis revealed that both P sources increased P levels in the plant; however, at equivalent P rates, tissue P concentrations were 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 third year of a four 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 two years ago (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 1988. 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 broadcast 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 May 13, 1989 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 were installed in all treatments in reps 1 and 3 on May 23 at a depth of 18". Water samples were collected on June 19, July 18, and September 6 approximately 3 or 4 days after at least 1" of rainfall or irrigation was supplied. On June 19, 8 whole plants were sampled from each plot at the ends of the two middle rows. At this sampling, plant development corresponded to the 6-8 leaf stage. The entire plot was sidedressed with 34-0-0 (295 lbs/A) with a Gandy on June 19. Ear leaf samples were collected from each plot at the mid-silking stage (July 31). Plots (20' from the middle two rows) were harvested for grain plus cob and stover yields on September 26. Subsamples of stover and grain plus cob were

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[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.

collected for moisture determinations, shelling percentages, 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 20 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. For phosphorus and all heavy metals, concentrations were generally below detection limits of the ICP spectrophotometer. Other elements such as Cu, Zn and B were at background levels. One exception was zinc at the second sampling date and at the highest ash rate, which was nearly 3 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 linearly increased with ash application, but was not affected by P fertilizer application. Ammonium acetate and nitric acid extractable Na increased slightly with increasing ash rates. All nitric acid extracted elements except K and Co increased with ash applications. Of particular interest are the DTPA or 'plant available' metals. Ash amendments significantly increased DTPA extractable Zn, Cu, Pb, and Cd and decreased extractable Mn 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 and nitric acid extractable Zn tended to increase with ash application. Nitric acid extractable S increased with both ash and fertilizer application.

In the 12 - 24" depth, Bray and Olsen extractable P tended to increase with both amendments (Table 4a) with no differences in nitric acid extractable P (Table 4b). Nitric acid extractable Zn and Cu increased with increasing ash rates. These results indicate that Zn and Cu are moving to some extent through the soil profile. There was also a slight trend for Cr to increase with increasing ash application.

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. For the first time in three years at this site, there was a significant increase in grain yield with ash and fertilizer application compared to the check. Reasons for this increase were due to optimum rainfall and irrigation coupled with a gradual depletion of P from the nonfertilized plots. Stover yield was unaffected by treatment. These results clearly indicate that application of ash does not detrimentally affect yield, but may improve yields if soil P is limiting.

Tissue Analyses. Fertilizer and ash treatments increased tissue P concentrations in corn sampled at the 6 - 8 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 triple super phosphate was superior to the ash 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 or at levels below the detection limit of the ICP. 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 triple super phosphate plots than with the ash plots. Phosphate fertilizer increased tissue Mn, but decreased 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 when fertilizer or ash were applied. Levels of Zn and Cu in the stover were greater with ash application compared to P fertilizer application. Fertilizer application increased P levels in the cob, while there was no effect due to ash application (Table 9). Cob Zn significantly decreased when P fertilizer was applied. Levels of P, K, Mg, and Mn in grain increased with fertilizer and ash treatments compared to those in the control plots (Table 10). Grain Zn linearly decreased with increasing P fertilizer application. 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

The positive yield response from both ash and fertilizer application indicate that the ash can serve as a source of P for plant growth. From tissue analysis results, phosphate availability at equivalent rates does not appear to be as good from the ash source as from the 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 substantiate the positive yield response and to evaluate longer term effects of incinerator ash on element movement in the soil profile and uptake by the plant.

Table 1. Elemental composition of lysimeter water as affected by fertilizer or ash treatment 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 19		ppm														
control	--	<0.53	5.8	307	80	0.31	<0.02	7	0.04	0.05	<0.01	0.03	<0.12	<0.05	<0.01	<0.01
70	Fert.	<0.53	5.7	594	146	0.35	<0.01	13	0.15	0.09	<0.01	0.02	<0.12	<0.09	<0.01	<0.01
140	Fert.	<0.53	3.4	390	101	0.35	<0.02	13	0.07	<0.02	<0.01	0.04	<0.12	<0.05	<0.01	<0.01
280	Fert.	<0.53	5.7	300	75	0.38	<0.01	8	0.10	0.02	<0.01	0.03	<0.12	0.24	<0.01	<0.01
70	Ash	<0.53	6.4	416	104	0.41	<0.01	11	0.07	0.02	<0.01	0.04	<0.12	<0.06	<0.01	<0.01
140	Ash	<0.53	5.2	306	80	0.31	0.02	10	0.03	0.04	<0.01	0.03	<0.12	<0.11	<0.01	<0.01
280	Ash	<0.53	2.8	145	41	0.24	<0.01	10	0.02	<0.01	<0.01	0.02	<0.12	<0.05	<0.01	<0.01
July 18																
control	--	<0.53	4.9	300	79	0.31	<0.01	7	0.03	0.05	<0.01	0.04	<0.12	<0.05	<0.01	<0.02
70	Fert.	<0.53	5.5	596	151	0.33	0.01	13	0.14	0.11	<0.01	0.04	<0.13	<0.08	<0.01	<0.02
140	Fert.	<0.53	4.9	416	110	0.31	<0.01	11	0.07	0.06	<0.01	0.05	<0.12	<0.05	<0.01	<0.01
280	Fert.	<0.53	7.1	312	80	0.39	<0.01	8	0.06	0.05	<0.01	0.04	<0.12	0.14	<0.01	<0.03
70	Ash	<0.53	29.1	520	132	0.37	<0.01	9	0.06	0.04	<0.01	0.05	<0.12	<0.05	<0.01	<0.02
140	Ash	<0.53	6.1	367	99	0.34	<0.01	9	<0.02	0.05	<0.01	0.05	<0.12	<0.05	<0.01	<0.02
280	Ash	<0.67	5.0	169	46	0.18	<0.01	13	0.05	0.15	<0.01	0.05	<0.12	<0.05	<0.01	<0.01
September 6																
control	--	<0.53	4.2	464	122	0.40	0.02	11	0.01	0.07	<0.01	0.04	<0.12	<0.05	<0.02	<0.01
70	Fert.	<0.53	4.4	776	195	0.31	0.02	16	0.15	0.07	<0.01	0.03	<0.12	<0.05	<0.01	<0.01
140	Fert.	<0.53	4.2	456	118	0.39	<0.01	11	0.04	0.05	<0.01	0.04	<0.12	<0.05	<0.02	<0.01
280	Fert.	<0.53	6.3	379	95	0.45	0.01	11	0.05	0.03	<0.01	0.04	<0.13	<0.09	<0.01	<0.01
70	Ash	<0.54	5.3	849	216	0.25	<0.01	13	0.02	0.05	<0.01	0.04	<0.12	<0.05	<0.02	<0.01
140	Ash	<0.53	4.5	395	105	0.40	0.02	10	0.01	0.06	0.02	0.04	<0.12	<0.06	<0.01	<0.01
280	Ash	<0.53	3.3	202	57	0.31	0.01	10	<0.01	0.03	<0.01	0.03	<0.12	<0.05	<0.01	<0.01

Table 2a. Effect of sludge ash and phosphate fertilizer on soil pH, Bray P1, Olsen P, Ammonium Acetate extractable cations, and DTPA extractable micro elements (0-6" 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_2O_5/A									ppm							
Control	-	5.5	12.8	6.0	132	1772	248	5.1	88.0	50.3	1.3	1.03	1.29	2.26	0.06	0.12
70	Fert.	5.5	41.0	19.8	131	1812	250	6.8	91.0	52.8	1.4	1.01	1.21	2.37	0.09	0.14
140	Fert.	5.4	69.0	32.3	136	1794	249	6.6	86.1	51.1	1.4	1.03	1.23	2.36	0.07	0.12
280	Fert.	5.6	108.4	48.0	123	1805	248	6.0	83.0	46.0	1.4	1.00	1.15	2.47	0.07	0.11
70	Ash	5.5	43.3	18.9	142	1787	250	6.6	86.1	44.9	2.1	1.85	1.31	2.39	0.07	0.17
140	Ash	5.7	66.3	21.8	135	1848	273	6.9	79.0	38.3	2.7	2.73	1.46	2.22	0.05	0.19
280	Ash	5.8	156.6	38.8	134	1926	298	8.6	81.3	33.2	4.4	5.02	1.63	2.41	0.06	0.32
Significance		**	**	**	NS	NS	NS	*	NS	*	**	**	*	NS	NS	**
BLSD(0.05)		0.2	37.9	9.7	-	-	--	1.7	--	13.3	0.6	0.60	0.35	-	-	0.04
Contrasts																
Ctrl vs Rest		NS	**	**	NS	NS	NS	**	NS	NS	**	**	NS	NS	NS	**
Fert vs Ash		**	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
Linear Ash		**	**	**	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 2b. Effect of sludge ash and phosphate fertilizer on 1N nitric acid extractable elements (0-6" depth).

Treatment	P Source	1 N Nitric Acid Extractable																			
		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	As	Ba	Co	Mo	S
lb P_2O_5/A											ppm										
Control	-	66	170	2715	444	1693	372	11.8	141	5.1	3.4	1.3	5.27	4.36	0.97	0.29	1.68	98	0.80	0.62	18
70	Fert	113	173	2879	463	1847	433	13.8	163	5.7	3.7	1.4	5.92	4.92	1.09	0.32	1.83	108	0.89	0.68	20
140	Fert	157	174	2749	441	1818	444	13.3	170	5.4	3.6	1.3	5.69	4.86	1.11	0.32	1.76	102	0.91	0.59	20
280	Fert	226	164	2892	472	1939	501	13.6	171	5.9	3.7	1.4	6.01	5.06	1.21	0.33	1.87	108	0.87	0.63	22
70	Ash	151	178	2760	439	1776	409	14.0	152	6.9	6.0	1.3	5.97	4.71	1.28	0.42	1.76	103	0.82	0.59	20
140	Ash	242	173	3020	495	1951	483	16.5	162	9.4	9.4	1.4	6.89	4.83	1.88	0.59	1.89	107	0.86	0.68	21
280	Ash	528	182	3451	564	2178	578	21.5	172	15.7	18.6	1.6	8.48	5.52	3.17	1.00	2.04	119	0.85	0.71	22
Significance		**	NS	**	*	**	**	**	NS	**	**	**	**	*	**	**	**	*	NS	NS	NS
BLSD (0.05)		81	-	366	94	151	69	2.2	25	1.5	2.0	0.1	0.73	0.62	0.30	0.10	0.14	11	-	0.16	4
Contrasts																					
Ctrl. vs Rest		**	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	*
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Linear Ash		**	NS	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	NS	*	**
Quad Ash		NS	NS	NS	NS	NS	NS	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 extractable cations, and DTPA extractable microelements (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_2O_5/A					ppm											
Control	-	6.0	3.5	1.8	50	1581	247	6.2	26.6	10.1	0.3	0.77	0.48	1.16	<0.03	<0.02
70	Fert.	5.8	6.8	2.0	58	1797	271	8.2	34.5	11.7	0.5	0.84	0.59	1.41	<0.04	<0.04
140	Fert.	5.9	8.3	3.5	63	1740	263	7.8	34.4	12.8	0.5	0.87	0.51	1.37	<0.04	<0.03
280	Fert.	5.9	8.0	4.5	59	1641	246	7.5	33.9	12.3	0.5	0.72	0.55	1.56	<0.04	<0.03
70	Ash	5.9	5.3	2.5	55	1730	264	7.3	31.0	11.4	0.4	0.86	0.52	1.33	<0.03	<0.03
140	Ash	5.9	6.8	2.3	52	1589	242	6.8	30.0	11.1	0.4	0.78	0.42	1.08	<0.02	<0.03
280	Ash	5.9	8.0	3.5	59	1776	275	9.0	30.8	12.7	0.5	0.87	0.51	1.28	<0.04	0.03
Significance		NS	*	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-
BLSD (0.05)		-	3.7	1.6	-	-	-	-	-	-	-	-	-	-	-	-
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	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	-	-
Linear Ash		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	Source	1 N Nitric Acid Extractable																			
		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	As	Ba	Co	Mo	S
lb. P_2O_5/A		ppm																			
Control	-	48	56	2172	564	1591	608	13	53	4.1	2.7	0.8	4.00	3.29	1.35	0.21	1.6	68	0.41	0.53	9.4
70	Fert.	34	63	2507	612	1792	630	15	65	4.9	3.2	1.0	4.65	3.67	1.45	0.24	1.8	89	0.50	0.63	13.0
140	Fert.	49	64	2361	564	1668	603	14	67	4.6	3.0	0.9	4.47	3.77	1.36	0.22	1.7	78	0.48	0.56	12.6
280	Fert.	46	72	2306	563	1679	622	16	64	4.7	2.8	1.0	4.48	4.16	1.38	0.22	1.7	79	0.46	0.57	13.8
70	Ash	45	63	2311	578	1692	628	15	57	4.5	3.0	1.0	4.47	3.56	1.40	0.24	1.8	77	0.47	0.57	11.4
140	Ash	57	58	2157	547	1657	646	14	64	4.5	2.8	0.9	4.21	3.17	1.39	0.23	1.6	74	0.42	0.55	12.9
280	Ash	50	63	2401	639	1816	743	16	62	5.2	3.3	0.9	4.61	3.45	1.60	0.25	1.8	83	0.43	0.60	13.1
Significance		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)		-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.2
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	NS	NS	NS	NS	NS	NS	NS
Linear Fert.		NS	**	NS	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	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	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 extractable cations, and DTPA extractable micro elements (12-24" 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_2O_5/A		ppm														
Control	-	6.7	3.0	1.3	42	982	159	3.4	16.7	13.9	0.24	0.62	<0.33	0.82	<0.03	<0.02
70	Fert.	6.7	4.3	1.5	45	1121	175	4.0	18.3	14.3	0.26	0.85	<0.37	0.89	<0.03	<0.03
140	Fert.	7.1	4.3	2.8	48	1328	168	<3.5	16.4	14.9	0.26	0.93	<0.31	0.93	<0.03	<0.03
280	Fert	7.1	5.0	2.5	44	1343	174	3.6	15.5	15.0	0.21	0.86	<0.35	0.88	<0.05	<0.02
70	Ash	6.9	4.0	2.0	38	1059	152	2.6	15.7	14.4	0.26	0.66	<0.24	0.83	<0.03	<0.03
140	Ash	7.1	4.8	2.0	38	1299	163	3.0	15.6	12.3	0.24	0.80	<0.26	0.77	<0.02	<0.07
280	Ash	6.8	7.8	2.8	43	1289	179	<3.8	18.2	17.4	0.28	0.80	<0.34	0.85	<0.04	<0.03
Significance		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	-	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	-	-
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	As	Ba	Co	Mo	S
lb. P_2O_5/A		ppm																			
Control	-	114	52	2663	1014	967	717	11	65	3.0	2.1	0.7	2.79	3.80	1.10	0.19	1.3	39	0.24	0.39	6.7
70	Fert.	98	54	3406	1086	1016	696	11	69	3.1	2.5	0.7	2.94	4.35	1.15	0.19	1.4	47	0.29	0.41	7.7
140	Fert.	109	51	4618	1601	900	727	11	74	3.0	2.6	0.8	2.67	4.61	1.10	0.19	1.3	40	0.31	0.34	8.4
280	Fert.	117	54	6096	1970	867	742	13	79	3.0	2.8	0.9	2.88	6.20	1.15	0.22	1.4	43	0.35	0.36	11.0
70	Ash	121	52	5475	2070	881	757	12	77	3.1	2.5	0.9	3.03	4.63	1.14	0.23	1.5	42	0.35	0.38	9.5
140	Ash	136	50	8001	2804	1042	876	14	85	3.7	2.9	1.0	3.44	3.81	1.38	0.26	1.6	40	0.37	0.61	13.4
280	Ash	145	55	6587	2169	1064	916	12	86	3.8	3.0	1.0	3.04	4.23	1.31	<0.25	1.5	50	0.24	0.40	12.1
Significance		NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	-	NS	NS	NS	*	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	0.7	0.5	-	-	-	-	-	-	-	-	0.17	-
Contrasts																					
Crtl vs Rest		NS	NS	NS	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	NS	*	NS
Linear Fert.		NS	NS	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	-	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	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), and 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	-	4.29	130.1	2.80
70	Fert.	5.77	141.1	2.90
140	Fert.	7.77	147.9	2.78
280	Fert.	8.91	145.7	3.08
70	Ash	5.28	145.7	3.01
140	Ash	6.31	150.9	2.90
280	Ash	6.78	149.3	2.92
Significance		**	**	NS
BLSD (0.05)		1.73	9.36	-
Contrasts				
Control vs Rest		**	**	NS
Fert. vs Ash		*	NS	NS
Linear Fert.		**	**	NS
Quad. Fert.		NS	*	NS
Linear Ash		**	**	NS
Quad. Ash		NS	**	NS

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

Table 6. Effect of sludge ash and phosphate fertilizer on 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				%								ppm					
Control	-	3.77	0.27	3.55	0.60	0.38	427	376	35	104	35	7.6	8.4	<1.2	0.78	1.4	<0.24
70	Fert.	3.86	0.28	3.80	0.64	0.34	441	391	38	110	41	6.1	8.1	<1.3	1.03	1.4	0.32
140	Fert.	3.98	0.31	3.98	0.65	0.32	394	367	27	114	30	5.3	9.3	<1.2	<0.96	1.4	<0.27
280	Fert.	4.06	0.38	3.92	0.68	0.33	488	450	43	139	28	4.5	8.1	<1.2	<1.07	1.7	0.61
70	Ash	3.79	0.28	3.68	0.62	0.33	578	481	44	119	39	7.2	8.3	<1.2	0.86	1.5	<0.20
140	Ash	3.87	0.29	3.87	0.57	0.34	403	364	30	104	41	7.8	8.6	<1.4	1.12	1.7	0.44
280	Ash	3.94	0.31	3.85	0.56	0.33	444	395	32	96	43	8.0	7.8	<1.3	<0.96	1.4	0.37
Significance		NS	**	NS	*	NS	NS	NS	NS	**	NS	**	NS	-	-	NS	-
BLSD (0.05)		-	0.03	-	0.08	-	-	-	-	19	-	0.8	-	-	-	-	-
Contrasts																	
Ctrl vs Rest		NS	**	*	NS	*	NS	NS	NS	NS	NS	**	NS	-	-	NS	-
Fert vs Ash		NS	**	NS	**	NS	NS	NS	NS	**	*	**	NS	-	-	NS	-
Linear Fert.		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	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 7. Effect of sludge ash and phosphate fertilizer on the elemental composition of 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	-	3.08	0.24	2.05	0.46	0.31	20	274	19	98	38	10	9.9	<1.1	<0.5	0.24	<0.17
70	Fert.	2.96	0.25	2.06	0.54	0.33	21	252	22	126	34	8	10.2	<1.1	<0.5	0.28	<0.19
140	Fert.	2.90	0.28	2.07	0.58	0.34	24	269	19	127	27	7	10.0	<1.1	<0.5	0.27	0.24
280	Fert.	2.81	0.34	1.94	0.61	0.36	25	262	24	143	20	4	8.8	<1.1	<0.5	0.29	<0.18
70	Ash	3.02	0.26	2.11	0.51	0.30	22	259	18	134	45	9	10.9	<1.1	<0.5	0.23	<0.19
140	Ash	3.00	0.26	2.05	0.50	0.32	22	284	18	100	41	8	9.7	<1.1	<0.5	0.25	<0.14
280	Ash	2.94	0.26	2.04	0.55	0.35	27	273	23	101	42	9	10.0	<1.1	<0.5	0.27	<0.19
Significance		**	**	NS	**	NS	NS	NS	NS	*	**	**	NS	-	-	NS	-
BLSD (0.05)		0.11	0.01	-	0.04	-	-	-	-	29	5	1	-	-	-	-	-
<u>Contrasts</u>																	
Ctrl vs Rest		**	**	NS	**	NS	NS	NS	NS	*	NS	**	NS	-	-	NS	-
Fert. vs Ash		**	**	NS	**	NS	NS	NS	NS	*	**	**	NS	-	-	NS	-
Linear Fert.		*	**	NS	**	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	-
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	-	-	NS	-

NS = Nonsignificant, * = 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	-	0.68	1.47	0.31	0.31	396	62	117	15	77	20	7	4.8	<1.1	<0.5	0.36	<0.09
70	Fert.	0.74	1.74	0.36	0.27	414	75	122	14	79	16	7	4.8	<1.4	0.8	0.30	<0.12
140	Fert.	0.75	1.96	0.37	0.26	609	82	128	15	85	11	6	4.8	<1.4	<0.8	0.33	<0.10
280	Fert.	0.91	1.59	0.40	0.25	1030	74	141	16	90	9	5	4.9	<1.8	<0.6	0.41	<0.12
70	Ash	0.64	1.78	0.33	0.26	390	60	112	15	88	20	7	5.1	<1.1	<0.6	0.24	<0.10
140	Ash	0.71	1.63	0.32	0.28	398	61	111	14	69	25	7	4.6	<1.7	<0.6	0.34	<0.13
280	Ash	0.78	1.77	0.36	0.29	449	71	126	14	71	19	7	4.9	2.0	<0.7	0.33	<0.11
Significance		NS	*	**	NS	**	NS	NS	NS	NS	*	**	NS	-	-	NS	-
BLSD (0.05)		-	0.26	0.05	-	148	-	-	-	-	9	1	-	-	-	-	-
<u>Contrasts</u>																	
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	-
Quad Fert.		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	-
Quad Ash		NS	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	-	0.40	0.48	306	116	504	2.0	15	<3.3	13	40	13	2.6	<2.3	1.03	<0.11	<0.16
70	Fert.	0.35	0.45	292	108	471	1.3	14	<2.7	13	32	11	2.1	<2.0	0.90	<0.11	0.24
140	Fert.	0.38	0.46	353	107	462	1.4	14	<2.3	13	25	11	2.2	<1.5	0.86	<0.11	<0.15
280	Fert.	0.37	0.42	430	110	409	1.7	13	<2.6	14	16	9	2.0	<1.5	0.64	<0.13	<0.18
70	Ash	0.37	0.44	294	103	472	<1.5	14	<3.2	12	39	13	2.3	<1.9	0.65	<0.11	<0.08
140	Ash	0.33	0.46	266	93	455	1.2	14	<2.4	11	36	13	2.1	2.5	0.92	<0.11	<0.13
280	Ash	0.35	0.45	309	95	441	1.3	14	<2.4	11	38	12	2.3	<15.8	0.72	<0.11	<0.16
Significance		NS	NS	**	NS	NS	-	NS	-	NS	**	NS	NS	-	NS	-	-
BLSD (0.05)		0.07	-	84	-	-	-	-	-	4	6	-	0.5	-	-	-	-
Contrasts																	
Ctrl vs Rest		*	NS	NS	NS	NS	-	NS	-	NS	**	NS	**	-	NS	-	-
Fert. vs Ash		NS	NS	**	NS	NS	-	NS	-	*	**	NS	NS	-	NS	-	-
Linear Fert.		NS	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 = 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	-	1.43	0.20	0.32	36	1147	<0.5	22	<4.4	6.5	22	1.4	2.0	<1.1	<0.5	<0.1	<0.2
70	Fert.	1.44	0.25	0.33	38	1270	<0.5	23	<1.9	7.5	22	0.9	2.1	<1.1	<0.5	<0.1	<0.2
140	Fert.	1.54	0.32	0.38	35	1481	<1.6	24	<4.3	8.8	21	<0.6	2.1	<1.1	<0.5	<0.1	<0.1
280	Fert.	1.53	0.36	0.40	34	1576	<0.9	25	<2.2	9.5	18	<0.3	2.0	<1.1	<0.5	<0.1	<0.1
70	Ash	1.42	0.25	0.34	37	1271	<0.8	23	<2.6	7.4	23	1.3	2.1	<1.1	<0.5	<0.1	<0.1
140	Ash	1.43	0.27	0.35	36	1326	0.7	23	<4.6	7.2	23	1.2	2.1	<1.1	<0.5	<0.1	<0.1
280	Ash	1.43	0.27	0.36	37	1352	<1.4	23	<1.9	7.3	23	1.3	2.2	<1.1	<0.5	<0.1	<0.1
Significance		*	**	**	NS	**	-	NS	-	**	**	-	NS	-	-	-	-
BLSD (0.05)		0.09	0.02	0.02	-	109	-	4	-	0.9	2	-	-	-	-	-	-
Contrasts																	
Ctrl vs Rest		NS	**	**	NS	**	-	NS	-	**	NS	-	NS	-	-	-	-
Fert. vs Ash		**	**	*	NS	**	-	NS	-	**	**	-	NS	-	-	-	-
Linear Fert.		*	**	**	NS	**	-	*	-	**	**	-	NS	-	-	-	-
Quad Fert.		NS	**	NS	NS	*	-	NS	-	NS	NS	-	NS	-	-	-	-
Linear Ash		NS	**	**	NS	**	-	NS	-	NS	NS	-	NS	-	-	-	-
Quad Ash		NS	**	NS	NS	NS	-	NS	-	NS	NS	-	NS	-	-	-	-

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

UREA MANAGEMENT--RATE AND TIME OF APPLICATION AND NITRIFICATION INHIBITORS--FOR CORN PRODUCTION

M.A. Schmitt, R.H. Beck, and W. Connolly[1]

ABSTRACT: A field trial was established in 1986 to study the effects of urea management on continuous corn production on coarse-textured, nonirrigated soils. The results from 1989 show that fall applications of urea, regardless of rate or inhibitor treatment, were inferior to spring or sidedress treatments. However, within all application dates, there were yield differences due to nitrogen rate and nitrification inhibitors. The effect of the inhibitors were more pronounced with the lower rate of nitrogen.

Nitrogen (N) management is continually under scrutiny due to its overall effect on yields and profitability. In recent years the concern regarding groundwater quality has added to this scrutiny--especially in "sensitive" areas. Western Wisconsin and eastern Minnesota can be characterized as "sensitive" due to its coarse-textured soils.

Nitrogen product selection can be difficult for producers in this area. While anhydrous ammonia is the cheapest, its inconvenience is sometimes a drawback. Liquid UAN-28 is very convenient, especially for sidedress applications that are sometimes warranted with these soils, but UAN-28 is relatively expensive. Urea prices fluctuate between these other two product's prices and can therefore be quite attractive since handling a granular product is not necessarily a disadvantage.

The objectives of this project are to examine the effects of: urea application timing, urea N rate, nitrification inhibitor use with urea, and the possible interaction of N management and hybrid selection.

MATERIALS AND METHODS

The field site used in River Falls, Wisconsin is at the University of Wisconsin-River Falls. Soil texture is sandy loam with 2.1% organic matter and the drainage class is well-drained. The pH was 6.7 and the P and K soil tests were in the 'very high' category. The field has been continuous corn for the past 4 years.

Granular urea was the N source for the entire project. For treatments including dicyandiamide (dcd.), urea which had dcd. added in the melt at the Agrico plant in 1985 was used. This was a 5% dcd. N/urea N ratio. The N-Serve treatments had nitrapyrin impregnated at a 2 lbs./A rate equivalent. The N treatments consisted of 2 rates of N (60 and 120 lbs N/A), 3 stabilizer treatments (none, dicyandiamide, and N-Serve), and 3 application times (fall, spring, and sidedress).

All the fall treatments were applied on November 17, 1988. The spring applications were made on April 22, 1989, with all treatment combinations. The urea was incorporated immediately after application was a disk. Sidedress applications were made on June 9, 1989, when the corn was in the V6 stage of growth. At this time, the fertilizer was applied down each row using a drop spreader and then incorporated with a cultivator.

Corn was planted on May 4 at a depth of 2 inches with a band of starter fertilizer in a 2x2 inch placement away from the seed. The starter fertilizer supplied 18 lbs. N, 46 lbs. P_2O_5, and 60 lbs K_2O per acre. The seed was planted in 30-inch rows at a population of 28,200 plants/A.

Three corn hybrids were used in this study. These were selected on the basis of the most widely grown hybrids for the area when the study was initiated. These included Pioneer 3790 and Pioneer 3737, and Cenex 2100 95- and 100-day and 100-day relative maturity hybrids, respectively.

Above-ground plant samples were taken for total N when the corn was in the V4, V9, and R1 stages of growth (on June 9, June 29, and July 21, respectively). Yields were measured by harvesting 40 feet of row and adjusting to a 15.5% bushel per acre equivalent.

Soil samples were taken to a depth of 6 inches and 12 inches in each plot at the same time plant samples were taken. The samples were frozen and then analyzed for ammonium-N and nitrate-N. After harvest, each plot had a soil core removed to a depth of 4 feet. The core was split into one-foot sections and these samples were frozen and analyzed for ammonium-N and nitrate-N.

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The experimental design for this experiment is a split-plot of a randomized complete block, with hybrids being the factor using the split plots. The main plot treatments were determined by using a 3-factor factorial treatment design. The factors were N application date, N application rate, and N stabilizers.

RESULTS AND DISCUSSION

The 1989 growing season was relatively dry in terms of total precipitation; however, the timeliness of the rains did provide for good growing conditions and yields. The springtime conditions did put stress on the corn plants due to a combination of cool and dry soil conditions along with some herbicide injury that did occur. As a result, the phenological uniformity of the stand was not as good as desired.

Plant N and yield

The main effects of N application date, application rate, and hybrid grown had consistent, statistically significant results (Table 1). There were very few interactions of these main effects that were significant. Grain yields were depressed with the fall N applications as well as with the lower rate of N with the spring application (Table 2). Even though the sidedress application of the low N rate equaled the spring application with the high N rate in 1989, the long term results of this study show that sidedress applications are not more efficient than spring applications.

The yield differences with the inhibitor treatments were not statistically different. Although the nitrification inhibitors appeared to have the same effect averaged across all other treatments (Table 3), the yields from the DCD-amended plots were better with the fall and spring treatments while the N-Serve plots were superior with the sidedress treatments (Table 2). Some of these differences may be explained in impregnation and volatilization differences each of these products encounter when used with urea.

Hybrid differences were statistically different for all parameters measured--exemplifying the genetic differences between the hybrids. Since there was a relative maturity difference among the hybrids, the grain moisture differences were expected. Yields were different as well as the N uptake patterns of the plants in the early portion of the season (Table 3). Although the hybrids N contents were a function of the available N in the soil (time and rate effects), the relative amounts were always genetically regulated by the specific hybrid. While the N uptake and use may vary by the hybrid, there is no indication of a hybrid by N rate yield response interaction.

Soil Nitrogen

Virtually every main effect and interaction had a significant effect on the concentration of ammonium-N and nitrate-N in the top 6 and 12 inches in the soil (Table 4). The two depths of soil were selected since the urea was applied and incorporated to a depth no greater than 6 inches. On the June 9th sampling, the sidedress treatments were no applied before the samples were taken so the values are representative of background N levels (Table 5). The fall treatments were significantly higher for both depths than sidedress ("control" at this date) yet lower than the spring application for nitrates. Since no significant ammonium-N differences were noted between the fall and spring applications, nitrification had converted all of the urea (ammonium) to nitrate-N.

At the June 29 and July 20 sampling dates, there was a major influence of the sidedress application on the amount of nitrate found in the soil (Table 5). The ammonium differences were not noticeable with the main effect means. The effect of N rate was consistent across all sampling dates for nitrate. The more N applied, the more nitrate was found in the soil. Ammonium levels were not as affected by N rate.

Nitrate concentrations in the soil peaked on the June 29 sampling and were declining by the July 20 sampling. While nitrification of the fertilizer N created an increase up until this point, it is predicted that the plant demand for N was high during July and this caused the decrease. Whereas the ammonium concentration followed the same pattern, the effect of the nitrification inhibitors did not retain more measured ammonium-N at the sampling dates to alter this pattern.

SUMMARY

The results from this study indicate that the yield response to N management strategies can be interpreted by examining soil N levels. Those strategies that result in low soil N during the season will result in lower yields. While this study did not attempt to calibrate the plant response and soil N concentrations, the correlation holds true.

Table 1. Significance[1] of main effects and interactions based on whole plant N concentrations and grain moisture and yield, River Falls, 1989.

	Plant Sampling Date			Grain	
	June 9	June 29	July 20	Moisture	Yield
Application Date (D)	**	**	**	NS	**
Application Rate (R)	**	**	**	**	**
D x R	NS	NS	**	NS	NS
N Stablizer (S)	*	NS	NS	NS	NS
S x D	**	NS	NS	NS	NS
S x R	NS	NS	NS	NS	NS
S x D x R	NS	NS	NS	*	NS
Hybrids (H)	**	**	**	**	**
H x D	NS	*	**	NS	NS
H x R	NS	NS	NS	**	NS
H x D x R	NS	NS	NS	NS	NS
H x S	NS	NS	NS	NS	NS
H x S x D	NS	NS	**	NS	NS
H x S x R	NS	NS	NS	NS	NS
H x S x D x R	NS	NS	*	NS	NS

[1] **, *, and NS represent probabilities of larger F values of >0.05, >0.10, and <0.10, respectively.

Table 2. Corn grain yields as affected by N application date and rate, and nitrification inhibitors, River Falls, 1989.

Application Date	N Rate	Nitrification Inhibitor	Hybrids Average
	lbs N/A		- - bu/A - -
Fall	78	None	107.4
		DCD	123.2
		N-Serve	121.7
	138	None	147.0
		DCD	147.7
		N-Serve	133.4
Spring	78	None	132.2
		DCD	159.0
		N-Serve	136.3
	138	None	154.7
		DCD	150.2
		N-Serve	148.5
Sidedress	78	None	153.1
		DCD	143.0
		N-Serve	161.6
	138	None	143.0
		DCD	152.4
		N-Serve	171.1

Table 3. Mean plant N concentrations at each sampling date as affected by treatment main effects, River Falls, 1989.

	Plant Sampling Date			Grain	
	June 9	June 29	July 20	Moisture	Yield
	- - - - - - - - % N - - - - - - - -			- - % - -	bu/A
Time of Application					
Fall	4.68	3.03	1.60	24.6	130.1
Spring	4.85	3.11	1.65	24.4	146.8
Summer	4.55	3.23	2.07	24.5	152.8
N Rate					
60	4.61	3.05	1.66	24.0	136.6
120	4.77	3.19	1.89	25.0	149.8
Stablizer					
None	4.61	3.12	1.79	24.7	139.6
DCD	4.69	3.12	1.80	24.2	144.6
N-Serve	4.77	3.12	1.73	24.5	145.4
Hybrids					
Pio. 3790	4.35	2.88	1.60	21.4	139.5
Cenex 2100	4.80	3.28	1.93	28.1	136.1
Pio. 3737	4.92	3.21	1.79	23.9	154.0

Table 4. Significance[1] of main effects and interactions based on soil ammonium-N and nitrate-N concentrations, River Falls, 1989.

	June 9		June 27		July 20	
NO_3-N	0-6"	0-12"	0-6"	0-12"	0-6"	0-12"
Application Date (D)	**	**	**	**	**	**
Application Rate (R)	**	**	**	**	**	**
D x R	**	**	**	**	**	NS
N Inhibitor (I)	**	**	NS	**	**	*
I x D	**	*	**	**	**	NS
I x R	**	NS	**	NS	**	**
I x D x R	**	**	NS	**	**	NS
NH_4-N						
Application Date (D)	**	NS	**	**	**	NS
Application Rate (R)	NS	NS	NS	NS	*	*
D x R	**	**	**	**	**	**
N Inhibitor (I)	*	NS	**	NS	*	NS
I x D	NS	**	**	**	**	**
I x R	*	**	NS	*	**	NS
I x D x R	**	**	**	**	**	**

Table 5. Soil ammonium-N and nitrate-N means as affected by treatment factors and date of sampling, River Falls, 1989.

NO_3-N	June 9		June 29		July 20	
Time of Application	0-6	0-12	0-6	0-12	0-6	0-12
Fall	18.2	21.1	23.4	14.2	17.4	20.5
Spring	27.0	23.6	31.1	14.9	18.1	25.1
Sidedress	13.1	13.9	48.6	24.9	35.9	34.4
N Inhibitor						
None	20.7	20.2	33.7	16.3	21.6	27.1
Dcd	18.8	17.8	33.7	19.5	26.1	25.1
N-Serve	18.9	20.4	35.7	18.1	23.8	27.8
N Rate						
78	17.0	17.3	27.8	15.3	18.4	22.7
138	22.0	21.8	40.9	20.7	29.2	30.7
NH_4-N						
Time of Application						
Fall	1.72	2.04	2.72	1.48	1.33	1.28
Spring	2.24	1.82	1.86	1.46	0.94	1.43
Sidedress	1.33	1.74	1.84	1.84	1.16	1.34
N Inhibitor						
None	1.96	2.01	2.27	1.63	1.08	1.50
DCD	1.82	2.01	2.63	1.73	1.07	1.29
N-Serve	1.52	1.60	1.51	1.41	1.28	1.27
N Rate						
78	1.82	1.74	2.20	1.63	1.07	1.26
138	1.72	2.00	2.08	1.56	1.22	1.45

INFLUENCE OF NITROGEN AND POTASSIUM FERTILIZATION ON THE YIELD AND NUTRIENT ACCUMULATION OF FOUR DIFFERENT CORN HYBRIDS--1989 [1]

G.L. Malzer, G.W. Randall and T.J. Graff [2]

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 objectives of this experiment are to evaluate the N accumulation patterns 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 between hybrid with N and K and nitrification inhibitors treatments would suggest that management treatments 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 environment, and 2. Evaluate the impact of N, and K, and 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. Nitrogen and hybrid treatments were randomized within the main plots. A modified factorial arrangement consisting of four corn hybrids (Pioneer 3615, Pioneer 3737, LH74 x LH85, and DeKalb 485), 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 27th, 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 28th and one cultivation on May 30. Nitrogen treatments were applied as anhydrous ammonia on June 7th (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.

Plant and soil samples were taken four times during the growing season. Plant samples were taken on July 19th, August 8th, August 22th, and September 20th. These dates corresponded to the tasseling, milk stage R3, dent stage R5, 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 harvest total dry matter production was determined and subsamples collected for N concentration and determination of total N uptake. Plant samples obtained during the second, 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 3615 and LH74 x LH85). 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.

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

The irrigation program began on June 16th and continued through August 25th with a total of 13.05 inches being applied through an overhead solid set irrigation system. An additional 14.45 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 4 treatments were evaluated. The experimental design was a split plot with four replications. Treatments included a factorial combination of four hybrids (Pioneer 3615, Pioneer 3475, LH74 X LH51, AND LH74 X LH82), 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 were included, both with no fertilizer N but one with K and one without.

Potassium treatments were applied in the fall of 1988. The four corn hybrids were planted on May 9th 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 17 and cultivation on June 14th. Nitrogen treatments were applied as anhydrous ammonia on June 23rd using procedures similar to that used at Becker. Rainfall accumulation over the growing season was 12.49 inches.

Plant and soil samples were taken four times (July 27th, August 16th, August 30th, and September 28th), 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 3615 and LH74 x LH82) at each plant sampling.

General Results

The results from the Becker location are presented in tables 1-14, and a summary of the results from Waseca are presented in tables 15-28. 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: Due to a suitable growing season in 1989 yields were "good", with the top treatments yielding above 220 bu/A. Yields obtained from the four hybrids were significantly different. At physiological maturity DeKalb 485 was the highest yielding hybrid, P-3737 was intermediate a P-3615 and LH74 X LH85 were the lowest yielding of the four hybrids tested. A significant yiel increase of 18 bu/A was obtained when the fertilizer N rate was increased from 80 to 160 lbs/A. There were significant N management hybrid interactions when the final yield was determined. A significant hybrid x N-rate interaction in 1989 suggests that DeKalb 485 and P-3615 were more responsive to higher rates of fertilizer N than were the other two hybrids examined. There was a significant N-rate x K-rate interaction. Although increased K rate tended to decrease yields, reductions were more prominent at the low N rate.

Waseca: Although 1989 was a dry growing season, yields were average or above average at this site. Final grain yields were significantly different between hybrids when there was no K applied, with LH74 x LH82 having the lowest yield, P-3475 being intermediate, and both LH74 x LH51 and P-3615 having the highest overall yields. When fertilizer K was applied hybrids did not vary in yield, but the general response was a reduced yield or no positive yield increase. The P-3615 and LH74 x LH51 hybrids also tended to have the highest yield when no fertilizer N was applied. A yield response to increasing N-rate was observed through the 80 #/A N-rate. The main effect of nitrification inhibitor was significant as the use of N-serve tended to reduce yields. A significant N-rate x K-rate interaction indicated that at the low N-rate K tended to reduce yield, but at the high N-rate additional K increased yields.

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 at **silking**. Becker, MN 1989.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant Silking Stover		
#/A			#/A	T/A	% N	#/A
80	Pioneer 3615	---	---	3.68	1.42	104.5
80		NS	---	3.74	1.73	129.2
80		---	100	3.47	1.89	131.2
80		NS	100	3.66	1.43	104.1
80		---	200	3.50	1.79	125.6
80		NS	200	3.78	1.64	123.3
160		---	200	3.45	1.67	114.2
160		NS	200	3.85	1.55	118.5
240		---	---	3.65	1.95	142.4
240		NS	---	3.38	1.90	128.9
240		---	100	3.62	1.94	140.5
240		NS	100	4.02	2.06	165.8
240		---	200	3.34	1.98	132.4
240		NS	200	3.58	1.85	132.7
80	Pioneer 3737	---	---	3.74	1.94	143.1
80		NS	---	3.81	1.75	132.5
80		---	100	3.68	1.75	129.0
80		NS	100	3.41	1.70	115.3
80		---	200	3.84	1.57	120.1
80		NS	200	3.65	1.40	101.6
160		---	200	3.79	2.10	159.4
160		NS	200	4.07	2.11	173.1
240		---	---	3.57	2.09	148.2
240		NS	---	3.80	2.12	159.6
240		---	100	4.09	1.95	159.3
240		NS	100	3.48	2.17	150.9
240		---	200	3.31	2.16	140.7
240		NS	200	3.88	1.89	144.9
80	LH74 X LH85	---	---	3.46	1.65	112.9
80		NS	---	3.60	1.55	110.7
80		---	100	3.65	1.64	117.1
80		NS	100	3.68	1.68	122.5
80		---	200	3.81	1.64	125.1
80		NS	200	3.37	1.64	110.4
160		---	200	3.72	1.78	130.8
160		NS	200	3.77	1.71	128.9
240		---	---	4.02	2.16	172.0
240		NS	---	3.86	1.93	149.0
240		---	100	3.91	2.14	166.5
240		NS	100	3.64	1.86	133.7
240		---	200	3.92	2.07	162.0
240		NS	200	3.90	1.93	150.6
80	DeKalb 485	---	---	3.68	1.76	129.3
80		NS	---	3.77	1.76	132.2
80		---	100	3.89	1.72	133.6
80		NS	100	3.97	1.97	156.2
80		---	200	3.64	1.75	127.5
80		NS	200	3.87	1.72	133.3
160		---	200	4.05	1.71	138.6
160		NS	200	3.45	1.87	128.8
240		---	---	3.83	1.86	142.1
240		NS	---	4.01	1.65	132.1
240		---	100	3.60	2.04	146.5
240		NS	100	3.75	1.94	145.5
240		---	200	3.98	1.82	145.1
240		NS	200	3.44	1.98	135.6

Table 2. Influence of N-rate, K-rate and nitrification inhibitors on grain yields and dry matter production on four corn hybrids at **milk stage R3**. Becker, MN 1989.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	--------------T/A--------------			
80	Pioneer 3615	---	---	35.7	0.84	4.29	0.63	5.76
80		NS	---	46.9	1.11	4.25	0.68	6.04
80		---	100	42.8	1.01	4.60	0.65	6.26
80		NS	100	32.4	0.77	4.27	0.56	5.60
80		---	200	30.6	0.72	4.44	0.57	5.74
80		NS	200	43.3	1.02	4.65	0.60	6.27
160		---	200	42.6	1.01	4.46	0.73	6.20
160		NS	200	41.1	0.97	5.12	0.76	6.85
240		---	---	46.1	1.09	4.06	0.70	5.84
240		NS	---	50.9	1.20	4.50	0.74	6.44
240		---	100	33.5	0.79	4.08	0.69	5.57
240		NS	100	41.4	0.98	4.55	0.72	6.25
240		---	200	42.0	0.99	4.63	0.69	6.31
240		NS	200	34.0	0.80	4.15	0.64	5.59
80	Pioneer 3737	---	---	62.9	1.49	4.20	0.65	6.34
80		NS	---	68.9	1.63	4.44	0.64	6.71
80		---	100	55.4	1.31	3.73	0.55	5.60
80		NS	100	52.6	1.25	4.18	0.70	6.13
80		---	200	66.7	1.58	4.32	0.65	6.55
80		NS	200	57.6	1.36	3.78	0.53	5.67
160		---	200	61.9	1.46	3.55	0.67	5.68
160		NS	200	65.5	1.55	4.05	0.64	6.24
240		---	---	52.6	1.24	3.58	0.58	5.40
240		NS	---	67.2	1.59	4.30	0.77	6.66
240		---	100	64.5	1.53	4.22	0.69	6.44
240		NS	100	58.2	1.38	4.08	0.76	6.22
240		---	200	55.6	1.32	3.83	0.68	5.83
240		NS	200	65.8	1.56	4.24	0.68	6.48
80	LH74 X LH85	---	---	72.7	1.72	4.36	0.75	6.83
80		NS	---	61.8	1.46	3.68	0.67	5.81
80		---	100	57.9	1.37	4.01	0.76	6.14
80		NS	100	67.7	1.60	4.05	0.73	6.38
80		---	200	70.4	1.66	4.09	0.71	6.47
80		NS	200	57.6	1.36	4.02	0.64	6.03
160		---	200	73.9	1.75	4.18	0.76	6.69
160		NS	200	67.1	1.59	4.13	0.77	6.49
240		---	---	72.6	1.72	4.38	0.73	6.83
240		NS	---	69.3	1.64	4.05	0.72	6.42
240		---	100	72.8	1.72	4.18	0.75	6.65
240		NS	100	66.6	1.58	4.27	0.73	6.58
240		---	200	72.5	1.72	4.39	0.80	6.91
240		NS	200	75.0	1.77	4.39	0.75	6.92
80	DeKalb 485	---	---	66.4	1.57	4.58	0.75	6.90
80		NS	---	64.1	1.52	4.27	0.69	6.47
80		---	100	64.2	1.52	4.39	0.71	6.62
80		NS	100	64.1	1.52	4.42	0.70	6.64
80		---	200	52.9	1.25	4.36	0.65	6.27
80		NS	200	61.9	1.47	4.30	0.75	6.51
160		---	200	68.2	1.61	4.41	0.74	6.77
160		NS	200	64.1	1.52	4.64	0.75	6.92
240		---	---	69.9	1.65	4.35	0.74	6.74
240		NS	---	72.6	1.72	4.53	0.76	7.01
240		---	100	57.1	1.35	3.99	0.78	6.12
240		NS	100	61.9	1.47	4.29	0.80	6.55
240		---	200	58.2	1.38	4.18	0.60	6.16
240		NS	200	68.0	1.61	4.47	0.79	6.87

Table 3. Influence of N-rate, K-rate and nitrification inhibitors on N content and total N removal on four corn hybrids at **milk stage R3**. Becker, MN 1989.

				N-Concentration			N-Removal			
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Cob	Stover	Grain	Cob	Total
#/A			#/A	%			#/A			
80	Pioneer 3615	---	---	0.92	1.96	1.01	79.3	32.6	12.6	124.5
80		NS	---	1.11	1.85	1.04	94.5	39.9	14.1	148.5
80		---	100	0.92	1.89	1.07	83.3	38.3	13.9	135.5
80		NS	100	0.99	1.84	1.03	84.0	28.3	11.6	123.9
80		---	200	0.87	1.88	1.06	77.2	27.1	12.1	116.3
80		NS	200	0.88	1.79	1.04	81.7	36.7	12.4	130.8
160		---	200	1.11	1.88	1.03	98.2	38.4	14.9	151.5
160		NS	200	1.18	1.87	1.08	120.5	35.8	16.4	172.6
240		---	---	1.31	1.93	1.03	106.3	41.5	14.2	162.1
240		NS	---	1.35	2.02	0.98	120.9	47.9	14.5	183.2
240		---	100	1.34	2.02	0.99	109.6	31.9	13.7	155.2
240		NS	100	1.39	1.93	1.04	125.5	37.3	15.0	177.8
240		---	200	1.36	1.93	1.06	125.4	38.0	14.6	177.9
240		NS	200	1.62	1.98	1.04	133.5	31.7	13.3	178.5
80	Pioneer 3737	---	---	0.94	1.62	0.83	78.6	48.2	10.7	137.5
80		NS	---	1.27	1.63	0.86	108.2	52.8	10.8	171.7
80		---	100	1.23	1.65	0.95	92.1	43.1	10.5	145.7
80		NS	100	1.12	1.66	0.82	94.3	41.0	11.8	147.2
80		---	200	1.01	1.58	0.85	86.8	49.5	11.1	147.5
80		NS	200	0.97	1.55	0.77	72.1	42.5	8.2	122.8
160		---	200	1.34	1.82	0.95	95.5	53.2	12.6	161.3
160		NS	200	1.57	1.66	0.89	127.0	51.3	11.4	189.7
240		---	---	1.39	1.82	0.85	98.9	44.6	9.9	153.4
240		NS	---	1.49	1.75	0.91	126.4	54.9	14.0	195.3
240		---	100	1.49	1.71	0.86	125.2	52.1	11.8	189.1
240		NS	100	1.40	1.77	0.86	114.2	48.5	13.2	175.8
240		---	200	1.63	1.77	0.89	125.2	46.5	12.1	183.9
240		NS	200	1.67	1.76	0.82	141.5	54.6	11.1	207.2
80	LH74 X LH85	---	---	1.05	1.70	0.78	90.8	58.5	11.7	161.0
80		NS	---	1.09	1.76	0.71	79.9	51.3	9.5	140.6
80		---	100	1.51	1.71	0.71	121.5	46.1	10.6	178.2
80		NS	100	0.93	1.68	0.75	75.4	54.1	10.8	140.2
80		---	200	1.06	1.64	0.70	86.4	54.7	9.9	151.0
80		NS	200	1.08	1.65	0.83	86.0	44.5	10.6	141.2
160		---	200	1.30	1.84	0.70	109.4	64.3	10.6	184.3
160		NS	200	1.34	1.76	0.80	110.7	55.9	12.2	178.8
240		---	---	1.38	1.74	0.80	120.9	59.5	11.7	192.1
240		NS	---	1.38	1.73	0.76	113.0	56.5	10.9	180.4
240		---	100	1.55	1.84	0.81	131.1	63.3	12.1	206.4
240		NS	100	1.37	1.81	0.76	116.9	56.9	11.0	184.8
240		---	200	1.33	1.81	0.83	118.0	62.2	13.3	193.6
240		NS	200	1.48	1.84	0.80	129.0	65.5	12.0	206.5
80	DeKalb 485	---	---	1.03	1.59	0.75	94.2	49.7	11.2	155.0
80		NS	---	1.26	1.62	0.79	109.1	49.0	10.8	168.9
80		---	100	0.93	1.48	0.85	81.4	45.6	11.9	138.9
80		NS	100	1.42	1.50	0.80	126.3	45.4	11.2	182.8
80		---	200	1.26	1.59	0.84	109.4	39.2	10.9	159.5
80		NS	200	1.16	1.61	0.80	99.7	47.2	12.1	159.0
160		---	200	1.42	1.65	0.80	125.8	53.5	11.9	191.1
160		NS	200	1.52	1.68	0.81	141.4	50.9	12.2	204.6
240		---	---	1.17	1.70	0.74	100.2	56.3	10.8	167.3
240		NS	---	1.37	1.76	0.76	124.2	60.5	11.5	196.2
240		---	100	1.22	1.71	0.79	96.6	46.2	12.0	154.8
240		NS	100	1.37	1.75	0.83	117.6	51.3	13.3	182.3
240		---	200	1.53	1.69	0.86	126.8	46.5	9.9	183.2
240		NS	200	1.60	1.76	0.82	142.8	56.7	12.9	212.4

Table 4. Influence of N-rate, K-rate and nitrification inhibitors on grain yields and dry matter production on four corn hybrids at **dent stage R5**. Becker, MN 1989.

					Dry Matter Production			
N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Grain	Stover	Cob	Total
#/A			#/A	Bu/A	T/A			
80	Pioneer 3615	---	---	113.5	2.69	3.73	0.68	7.09
80		NS	---	120.2	2.84	4.15	0.89	7.88
80		---	100	99.3	2.35	3.71	0.63	6.69
80		NS	100	108.1	2.56	4.03	0.69	7.28
80		---	200	98.6	2.33	3.94	0.63	6.91
80		NS	200	114.3	2.70	3.86	0.64	7.20
160		---	200	122.4	2.89	4.47	0.80	8.17
160		NS	200	117.7	2.78	4.30	0.78	7.86
240		---	---	129.5	3.06	4.00	0.78	7.85
240		NS	---	114.9	2.72	3.95	0.76	7.43
240		---	100	123.0	2.91	4.39	0.81	8.12
240		NS	100	118.1	2.80	4.30	0.81	7.91
240		---	200	120.2	2.84	4.25	0.78	7.87
240		NS	200	121.2	2.87	4.40	0.82	8.09
80	Pioneer 3737	---	---	142.0	3.36	3.81	0.58	7.75
80		NS	---	158.9	3.76	3.98	0.67	8.42
80		---	100	137.1	3.24	3.63	0.54	7.41
80		NS	100	139.2	3.29	3.60	0.55	7.44
80		---	200	136.2	3.22	3.66	0.47	7.36
80		NS	200	162.1	3.84	3.92	0.55	8.31
160		---	200	140.4	3.32	3.71	0.61	7.64
160		NS	200	159.2	3.77	3.98	0.62	8.37
240		---	---	150.4	3.56	4.15	0.62	8.32
240		NS	---	156.4	3.70	4.29	0.64	8.63
240		---	100	134.9	3.19	3.38	0.53	7.10
240		NS	100	136.9	3.24	3.68	0.56	7.48
240		---	200	149.3	3.53	3.95	0.64	8.13
240		NS	200	153.6	3.63	3.77	0.61	8.01
80	LH74 X LH85	---	---	143.0	3.38	4.06	0.68	8.12
80		NS	---	143.0	3.38	4.03	0.75	8.17
80		---	100	131.5	3.11	3.51	0.70	7.32
80		NS	100	140.9	3.33	3.93	0.70	7.96
80		---	200	134.1	3.17	4.02	0.73	7.93
80		NS	200	137.7	3.26	3.56	0.69	7.50
160		---	200	144.1	3.41	3.89	0.80	8.09
160		NS	200	141.7	3.35	3.90	0.75	8.00
240		---	---	140.8	3.33	4.10	0.83	8.26
240		NS	---	143.4	3.39	3.95	0.73	8.08
240		---	100	149.7	3.54	4.27	0.81	8.62
240		NS	100	149.2	3.53	3.85	0.75	8.13
240		---	200	142.7	3.38	4.07	0.71	8.15
240		NS	200	149.2	3.53	3.90	0.73	8.16
80	DeKalb 485	---	---	160.9	3.81	4.12	0.79	8.72
80		NS	---	140.6	3.33	3.78	0.72	7.83
80		---	100	161.2	3.81	3.97	0.73	8.51
80		NS	100	136.7	3.24	4.06	0.63	7.92
80		---	200	127.3	3.01	3.54	0.59	7.14
80		NS	200	150.5	3.56	4.03	0.68	8.27
160		---	200	156.8	3.71	4.40	0.72	8.84
160		NS	200	149.1	3.53	3.95	0.69	8.17
240		---	---	166.3	3.93	4.24	0.76	8.93
240		NS	---	159.1	3.76	4.36	0.72	8.84
240		---	100	142.4	3.37	3.67	0.66	7.70
240		NS	100	149.1	3.53	4.12	0.71	8.36
240		---	200	149.9	3.55	3.98	0.72	8.24
240		NS	200	155.6	3.68	4.10	0.76	8.55

Table 5. Influence of N-rate, K-rate and nitrification inhibitors on N content and total N removal on four corn hybrids at dent stage R5. Becker, MN 1989.

				N-Concentration			N-Removal			
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Cob	Stover	Grain	Cob	Total
#/A			#/A	-----------%----------			----------------#/A------------			
80	Pioneer 3615	---	---	1.13	1.30	0.78	84.1	69.4	10.5	164.0
80		NS	---	1.06	1.40	0.76	88.2	79.9	13.4	181.5
80		---	100	0.94	1.32	0.87	69.4	61.8	10.9	142.1
80		NS	100	1.02	1.40	0.75	82.9	71.0	10.3	164.3
80		---	200	0.94	1.31	0.75	74.7	61.1	9.4	145.2
80		NS	200	1.16	1.32	0.80	89.1	71.5	10.3	170.8
160		---	200	0.97	1.46	0.82	86.0	83.8	13.1	182.9
160		NS	200	1.52	1.52	0.82	131.0	84.6	12.8	228.5
240		---	---	1.06	1.43	0.72	84.1	87.0	11.2	182.3
240		NS	---	1.39	1.50	0.70	108.8	81.4	10.5	200.7
240		---	100	1.15	1.54	0.83	100.9	89.8	13.5	204.3
240		NS	100	1.33	1.44	0.86	114.6	80.6	13.9	209.1
240		---	200	1.34	1.54	0.75	113.7	86.4	11.6	211.8
240		NS	200	1.28	1.48	0.82	112.6	84.6	13.4	210.6
80	Pioneer 3737	---	---	1.15	1.32	0.55	89.3	88.4	6.5	184.3
80		NS	---	1.14	1.37	0.54	91.0	102.9	7.3	201.3
80		---	100	0.87	1.31	0.54	62.0	84.8	5.8	152.5
80		NS	100	1.13	1.29	0.56	81.9	84.4	6.2	172.5
80		---	200	1.20	1.33	0.54	86.8	85.6	5.1	177.5
80		NS	200	1.21	1.21	0.56	95.4	92.4	6.1	193.9
160		---	200	1.22	1.41	0.61	89.4	93.4	7.4	190.1
160		NS	200	1.40	1.36	0.63	111.1	101.8	7.8	220.7
240		---	---	1.38	1.38	0.65	113.2	98.2	7.9	219.3
240		NS	---	1.49	1.44	0.62	127.9	106.6	8.0	242.5
240		---	100	0.99	1.44	0.54	67.2	91.2	5.7	164.1
240		NS	100	1.67	1.39	0.65	122.7	89.4	7.3	219.5
240		---	200	1.34	1.48	0.60	106.0	103.8	7.6	217.4
240		NS	200	1.15	1.37	0.59	86.5	98.9	7.1	192.5
80	LH74 X LH85	---	---	1.03	1.42	0.64	83.6	95.6	8.6	187.7
80		NS	---	1.20	1.41	0.61	96.8	94.9	9.2	200.8
80		---	100	0.86	1.31	0.64	60.5	81.1	8.9	150.4
80		NS	100	0.96	1.37	0.56	74.4	91.6	7.8	173.8
80		---	200	1.04	1.33	0.66	83.4	85.2	9.7	178.3
80		NS	200	0.86	1.30	0.66	60.0	85.0	9.1	154.2
160		---	200	1.10	1.46	0.56	85.3	99.4	9.0	193.8
160		NS	200	1.23	1.51	0.56	95.7	101.4	8.4	205.5
240		---	---	1.08	1.39	0.64	88.3	92.3	10.5	191.0
240		NS	---	0.95	1.52	0.62	75.3	103.3	9.1	187.6
240		---	100	1.19	1.54	0.58	101.5	107.9	9.4	218.8
240		NS	100	1.05	1.49	0.66	80.7	104.6	9.9	195.2
240		---	200	1.33	1.48	0.57	107.2	100.2	8.1	215.5
240		NS	200	1.37	1.49	0.69	106.0	105.3	10.1	221.4
80	DeKalb 485	---	---	1.14	1.21	0.63	94.5	91.7	9.8	196.0
80		NS	---	1.48	1.20	0.63	111.8	80.6	9.0	201.4
80		---	100	1.08	1.14	0.62	86.3	87.2	8.9	182.4
80		NS	100	1.26	1.20	0.65	101.2	77.5	8.1	186.8
80		---	200	0.93	1.06	0.51	66.0	64.4	6.0	136.4
80		NS	200	1.41	1.20	0.62	112.5	85.5	8.4	206.4
160		---	200	1.52	1.30	0.60	133.8	96.4	8.7	238.9
160		NS	200	1.44	1.29	0.64	113.4	91.0	8.8	213.2
240		---	---	1.24	1.34	0.61	105.3	105.2	9.3	219.8
240		NS	---	1.22	1.33	0.64	105.9	100.2	9.2	215.3
240		---	100	1.11	1.30	0.62	81.0	87.2	8.1	176.3
240		NS	100	1.50	1.33	0.58	122.9	93.5	8.1	224.5
240		---	200	1.44	1.36	0.57	114.8	96.1	8.2	219.0
240		NS	200	1.27	1.32	0.65	104.1	97.4	9.9	211.4

Table 6. Influence of N-rate, K-rate and nitrification inhibitors on grain yields and dry matter production on four corn hybrids at **physiological maturity**. Becker, MN 1989.

				Grain	Dry Matter Production		
N-Rate	Hybrid	Inh.	K-Rate	Yields	Grain	Stover	Total
#/A			#/A	Bu/A	-------------T/A---------------		
80	Pioneer 3615	---	---	195.2	4.62	4.28	8.90
80		NS	---	203.0	4.80	4.45	9.25
80		---	100	177.7	4.21	4.27	8.47
80		NS	100	187.2	4.43	4.29	8.71
80		---	200	174.5	4.13	4.03	8.15
80		NS	200	184.9	4.37	4.24	8.61
160		---	200	202.1	4.78	4.23	9.01
160		NS	200	204.3	4.83	4.48	9.31
240		---	---	221.7	5.25	4.55	9.80
240		NS	---	206.4	4.88	4.50	9.38
240		---	100	208.8	4.94	4.47	9.41
240		NS	100	212.1	5.02	4.66	9.68
240		---	200	205.2	4.86	4.43	9.29
240		NS	200	207.3	4.91	4.54	9.44
80	Pioneer 3737	---	---	207.9	4.92	4.19	9.11
80		NS	---	219.9	5.20	4.33	9.53
80		---	100	199.1	4.71	3.57	8.28
80		NS	100	200.7	4.75	3.91	8.66
80		---	200	199.5	4.72	4.03	8.75
80		NS	200	193.2	4.57	3.83	8.40
160		---	200	206.2	4.88	3.89	8.77
160		NS	200	216.2	5.12	3.94	9.05
240		---	---	214.0	5.06	4.17	9.23
240		NS	---	205.4	4.86	3.87	8.73
240		---	100	210.2	4.97	3.90	8.87
240		NS	100	206.9	4.90	3.94	8.84
240		---	200	214.1	5.07	3.93	8.99
240		NS	200	203.1	4.81	4.00	8.80
80	LH74 X LH85	---	---	195.3	4.62	4.30	8.92
80		NS	---	197.7	4.68	4.20	8.87
80		---	100	178.5	4.22	3.91	8.13
80		NS	100	183.6	4.34	4.19	8.54
80		---	200	194.4	4.60	4.16	8.76
80		NS	200	178.3	4.22	3.93	8.15
160		---	200	202.1	4.78	4.24	9.02
160		NS	200	195.2	4.62	4.43	9.05
240		---	---	197.2	4.67	4.34	9.01
240		NS	---	195.0	4.61	4.25	8.86
240		---	100	191.2	4.52	4.22	8.74
240		NS	100	194.5	4.60	4.22	8.82
240		---	200	199.8	4.73	4.52	9.25
240		NS	200	207.2	4.90	4.31	9.22
80	DeKalb 485	---	---	201.8	4.78	4.25	9.03
80		NS	---	206.1	4.88	4.24	9.12
80		---	100	203.4	4.81	4.21	9.02
80		NS	100	205.2	4.85	4.11	8.97
80		---	200	189.3	4.48	3.83	8.31
80		NS	200	205.2	4.86	4.26	9.11
160		---	200	226.8	5.37	4.33	9.70
160		NS	200	215.5	5.10	4.38	9.48
240		---	---	223.3	5.28	4.44	9.72
240		NS	---	226.7	5.36	4.70	10.06
240		---	100	220.4	5.22	4.29	9.50
240		NS	100	222.1	5.25	4.20	9.45
240		---	200	212.4	5.03	4.15	9.18
240		NS	200	219.0	5.18	4.35	9.53

Table 7. Influence of N-rate, K-rate and nitrification inhibitors on stover and grain N content and total N removal on four corn hybrids at **physiological maturity**. Becker, MN 1989.

				N-Concentration		N-Removal		
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Stover	Grain	Total
#/A			#/A	-------%--------		-----------#/A---------		
80	Pioneer 3615	---	---	0.61	1.25	52.2	115.4	167.5
80		NS	---	0.65	1.38	57.6	133.0	190.6
80		---	100	0.68	1.20	58.2	100.6	158.8
80		NS	100	0.63	1.20	53.6	106.6	160.2
80		---	200	0.56	1.26	45.4	103.6	149.0
80		NS	200	0.68	1.32	57.7	115.5	173.3
160		---	200	0.77	1.44	64.8	137.8	202.7
160		NS	200	0.83	1.48	74.5	142.8	217.4
240		---	---	0.82	1.43	74.9	149.7	224.6
240		NS	---	0.80	1.49	71.4	144.7	216.0
240		---	100	0.84	1.38	74.6	135.8	210.4
240		NS	100	0.90	1.46	83.6	145.5	229.1
240		---	200	0.80	1.45	70.5	139.9	210.4
240		NS	200	0.85	1.51	76.9	148.0	224.9
80	Pioneer 3737	---	---	0.70	1.24	58.3	122.4	180.6
80		NS	---	0.75	1.39	65.3	144.5	209.8
80		---	100	0.67	1.19	47.3	112.0	159.3
80		NS	100	0.76	1.26	58.5	119.8	178.3
80		---	200	0.75	1.32	60.4	124.8	185.1
80		NS	200	0.67	1.32	50.5	121.0	171.5
160		---	200	0.88	1.39	68.7	135.8	204.5
160		NS	200	0.86	1.48	67.4	150.7	218.1
240		---	---	0.93	1.42	77.9	143.3	221.2
240		NS	---	0.87	1.44	67.2	139.7	206.9
240		---	100	0.88	1.35	68.6	134.0	202.6
240		NS	100	1.06	1.48	83.0	144.9	227.9
240		---	200	0.87	1.44	68.3	146.1	214.4
240		NS	200	0.93	1.51	73.7	145.4	219.1
80	LH74 X LH85	---	---	0.66	1.30	56.5	119.7	176.2
80		NS	---	0.78	1.31	65.8	122.5	188.3
80		---	100	0.74	1.33	58.0	112.2	170.2
80		NS	100	0.72	1.31	60.8	114.0	174.8
80		---	200	0.73	1.34	60.7	123.7	184.4
80		NS	200	0.71	1.30	55.1	109.5	164.6
160		---	200	0.87	1.57	73.4	150.0	223.4
160		NS	200	0.89	1.42	79.2	131.1	210.3
240		---	---	0.95	1.45	82.1	135.3	217.4
240		NS	---	0.87	1.43	74.1	131.6	205.7
240		---	100	0.95	1.43	80.4	128.9	209.3
240		NS	100	0.97	1.44	81.5	132.8	214.3
240		---	200	0.88	1.44	79.8	136.1	215.9
240		NS	200	0.99	1.49	85.5	145.6	231.1
80	DeKalb 485	---	---	0.74	1.13	62.5	107.7	170.3
80		NS	---	0.70	1.17	59.0	114.0	173.0
80		---	100	0.66	1.14	55.4	109.9	165.2
80		NS	100	0.73	1.17	59.9	113.7	173.6
80		---	200	0.60	1.07	45.9	95.4	141.3
80		NS	200	0.67	1.19	56.6	115.9	172.5
160		---	200	0.78	1.30	68.0	139.4	207.3
160		NS	200	0.86	1.39	75.0	142.0	217.0
240		---	---	0.95	1.30	83.2	137.7	220.9
240		NS	---	0.93	1.46	87.3	156.9	244.2
240		---	100	0.93	1.29	79.7	134.2	213.9
240		NS	100	0.91	1.28	76.0	134.4	210.4
240		---	200	0.87	1.44	72.5	144.3	216.8
240		NS	200	0.97	1.37	84.1	141.9	226.0

Table 8. Continued from table 1.

200 # K-Rate only (Hybrid X N-Rate X Inhibitor)	Whole Plant Silking Stover		
Hybrids	T/A	% N	#/A
Pioneer 3615	3.58	1.74	124.4
Pioneer 3737	3.75	1.87	139.9
LH74 X LH85	3.75	1.79	134.6
DeKalb 485	3.74	1.81	134.8
P-Value	73	78	95
BLSD (.05)			12.5
N-Rate			
80	3.68	1.64	120.8
160	3.77	1.81	136.5
240	3.67	1.95	142.9
P-Value	52	99	99
BLSD (.05)		0.09	9.0
Inhibitor			
None	3.69	1.83	135.1
N-Serve	3.71	1.77	131.8
P-Value	24	85	60
Hybrid X N-Rate	65	99	99
Hybrid X Inhibitor	99	82	21
N-Rate X Inhibitor	14	34	36
Hybrid X N-Rate X Inh.	95	13	26
Split Plot without the 160# N-Rate			
K-Rate			
0	3.72	1.84	135.5
100	3.71	1.86	138.6
200	3.67	1.80	131.9
P-Value	8	73	69
BLSD(.05)			
Hybrid X N-Rate X Inhibitor			
Hybrid			
Pioneer 3615	3.61	1.79	130.0
Pioneer 3737	3.68	1.87	137.1
LH74 X LH85	3.73	1.82	136.0
DeKalb 485	3.78	1.83	138.2
P-Value	11	79	92
BLSD(.05)			
N-Rate			
80	3.68	1.68	123.7
240	3.73	1.97	146.9
P-Value	63	99	99
Inhibitor			
None	3.70	1.85	137.3
N-Serve	3.71	1.79	133.3
P-Value	8	98	90
Hybrid X N-Rate	76	30	99
Hybrid X Inhibitor	60	63	90
N-Rate X Inhibitor	32	36	52
Hybrid X N-Rate X Inhibitor	33	92	98
Hybrid X N-Rate X Inhibitor X K-Rate			
Hybrid X K-Rate	3	99	94
N-Rate X K-Rate	28	99	13
Hybrid X N-Rate X K-Rate	81	83	89
Inhibitor X K-Rate	17	34	14
Hybrid X Inhibitor X K-Rate	89	97	17
N-Rate X Inhibitor X K-Rate	27	61	61
Hybrid X N-Rate X Inhibitor X K-Rate	84	99	62

Table 9. Continued from table 2. **Milk Stage R3**

	Grain	Dry Matter Production			
200 # K-Rate only RCB (Hybrid X N-Rate X Inh.)	Yields	Grain	Stover	Cob	Total
Hybrids	Bu/A	-------------T/A---------------			
Pioneer 3615	38.9	0.92	4.57	0.66	6.15
Pioneer 3737	62.2	1.47	3.96	0.64	6.07
LH74 X LH85	69.4	1.64	4.20	0.74	6.58
DeKalb 485	62.2	1.47	4.39	0.71	6.58
P-Value	99	99	99	99	99
BLSD (.05)	4.6	0.11	0.24	0.05	0.36
N-Rate					
80	55.1	1.30	4.24	0.63	6.18
160	60.5	1.43	4.31	0.72	6.47
240	58.8	1.39	4.28	0.70	6.38
P-Value	95	95	19	99	84
BLSD (.05)	4.8	0.11		0.04	
Inhibitor					
None	57.9	1.37	4.23	0.68	6.29
N-Serve	58.4	1.38	4.32	0.69	6.40
P-Value	22	22	68	7	60
Hybrid X N-Rate	76	76	12	96	56
Hybrid X Inhibitor	57	57	87	27	62
N-Rate X Inhibitor	95	95	84	58	95
Hybrid X N-Rate X Inh.					
Split Plot without the 160# N-Rate					
K-Rate					
0	61.2	1.45	4.23	0.69	6.38
100	55.8	1.32	4.20	0.70	6.23
200	57.0	1.34	4.26	0.67	6.28
P-Value	34	34	8	59	13
BLSD(.05)					
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	39.9	0.94	4.37	0.65	5.97
Pioneer 3737	60.6	1.43	4.07	0.65	6.16
LH74 X LH85	68.0	1.61	4.15	0.72	6.49
DeKalb 485	63.4	1.50	4.34	0.72	6.57
P-Value	99	99	99	99	99
BLSD(.05)	3.0	0.07	0.18	0.03	0.22
N-Rate					
80	56.5	1.33	4.23	0.66	6.23
240	59.5	1.40	4.23	0.72	6.36
P-Value	99	99	2	99	86
Inhibitor					
None	57.3	1.35	4.21	0.68	6.26
N-Serve	58.7	1.39	4.25	0.69	6.34
P-Value	76	76	43	56	66
Hybrid X N-Rate	75	75	80	42	79
Hybrid X Inhibitor	86	86	69	91	91
N-Rate X Inhibitor	75	75	95	90	97
Hybrid X N-Rate X Inhibitor	56	56	6	18	22
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	55	55	19	14	12
N-Rate X K-Rate	11	11	12	35	18
Hybrid X N-Rate X K-Rate	93	93	41	34	73
Inhibitor X K-Rate	49	49	34	14	14
Hybrid X Inhibitor X K-Rate	95	95	72	97	93
N-Rate X Inhibitor X K-Rate	13	13	47	35	45
Hybrid X N-Rate X Inhibitor X K-Rate	99	99	92	49	99

Table 10. Continued from table 3. **Milk Stage R3**

	N-Contration			N-Removal			
	Stover	Grain	Cob	Stover	Grain	Cob	Total
	---------%---------			-------------#/A----------			
200 # K-Rate only RCB (Hybrid X N-Rate X Inh.)							
Hybrids							
Pioneer 3615	1.17	1.88	1.05	106.0	34.5	13.9	154.5
Pioneer 3737	1.36	1.68	0.86	108.0	49.6	11.0	168.7
LH74 X LH85	1.26	1.75	0.77	106.5	57.8	11.4	175.8
DeKalb 485	1.41	1.66	0.82	124.3	49.0	11.6	184.9
P-Value	99	99	99	99	99	99	99
BLSD (.05)	0.09	0.05	0.05	9.2	3.9	1.1	10.9
N-Rate							
80	1.03	1.65	0.86	87.4	42.6	10.9	140.9
160	1.34	1.76	0.88	116.0	50.4	12.7	179.2
240	1.52	1.81	0.89	130.2	50.2	12.3	192.8
P-Value	99	99	51	99	99	99	99
BLSD (.05)	0.07	0.04		7.3	3.5	0.9	8.9
Inhibitor							
None	1.26	1.75	0.87	107.0	47.7	11.9	166.7
N-Serve	1.33	1.74	0.87	115.4	47.7	12.0	175.3
P-Value	96	45	19	99	2	11	96
Hybrid X N-Rate	98	43	56	62	49	77	26
Hybrid X Inhibitor	17	63	87	16	85	95	41
N-Rate X Inhibitor	88	81	60	99	86	29	94
Hybrid X N-Rate X Inh.	36	16	12	42	91	57	71
Split Plot without the 160# N-Rate							
K-Rate							
0	1.21	1.75	0.84	102.8	50.2	11.8	164.8
100	1.26	1.74	0.86	105.9	45.5	12.1	163.6
200	1.28	1.73	0.87	108.8	46.4	11.6	166.9
P-Value	54	19	52	40	42	20	6
BLSD(.05)							
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3615	1.17	1.91	1.03	101.7	35.9	13.4	151.1
Pioneer 3737	1.29	1.68	0.85	105.2	48.2	11.2	164.7
LH74 X LH85	1.26	1.74	0.77	105.7	56.0	11.1	172.9
DeKalb 485	1.27	1.64	0.80	110.6	49.4	11.5	171.6
P-Value	99	99	99	92	99	99	99
BLSD(.05)	0.07	0.78	0.03		2.3	0.7	7.3
N-Rate							
80	1.08	1.68	0.86	91.3	44.3	11.2	147.0
240	1.42	1.81	0.86	120.3	50.4	12.4	183.2
P-Value	99	99	49	99	99	99	99
Inhibitor							
None	1.22	1.74	0.87	102.7	46.7	11.8	161.2
N-Serve	1.28	1.74	0.85	109.0	48.1	11.9	169.0
P-Value	98	12	59	99	87	33	99
Hybrid X N-Rate	99	62	59	99	82	45	97
Hybrid X Inhibitor	99	56	10	99	93	62	99
N-Rate X Inhibitor	28	67	2	88	86	83	95
Hybrid X N-Rate X Inhibitor	60	45	55	18	43	60	8
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	89	39	54	65	75	37	57
N-Rate X K-Rate	99	82	40	99	48	37	99
Hybrid X N-Rate X K-Rate	48	76	1	29	95	8	21
Inhibitor X K-Rate	98	10	23	88	65	28	92
Hybrid X Inhibitor X K-Rate	99	7	62	99	93	93	99
N-Rate X Inhibitor X K-Rate	92	17	58	68	17	36	58
Hybrid X N-Rate X Inhibitor X K-Rate	68	20	17	76	99	59	87

Table 11. Continued from table 4. **Dent Stage R5**

	Grain Yields	Dry Matter Production			
		Grain	Stover	Cob	Total
	Bu/A	T/A			
200 # K-Rate only RCB (Hybrid X N-Rate X Inh.)					
Hybrids					
Pioneer 3615	115.6	2.73	4.20	0.74	7.68
Pioneer 3737	150.1	3.55	3.83	0.58	7.96
LH74 X LH85	141.5	3.34	3.88	0.73	7.97
DeKalb 485	148.2	3.50	3.99	0.69	8.20
P-Value	99	99	96	99	79
BLSD (.05)	8.2	0.19	0.30	0.04	
N-Rate					
80	132.5	3.13	3.81	0.62	7.57
160	141.4	3.34	4.07	0.72	8.14
240	142.6	3.37	4.05	0.72	8.14
P-Value	98	98	95	99	99
BLSD (.05)	8.1	0.19	0.25	0.03	0.41
Iinhibitor					
None	135.1	3.19	3.98	0.68	7.87
N-Serve	142.6	3.37	3.97	0.69	8.04
P-Value	98	98	16	50	68
Hybrid X N-Rate	12	12	17	78	16
Hybrid X Inhibitor	57	57	35	35	47
N-Rate X Inhibitor	90	90	15	60	62
Hybrid X N-Rate X Inh.	23	23	61	27	49
Split Plot without the 160# N-Rate					
K-Rate					
0	142.6	3.37	4.04	0.72	8.14
100	134.8	3.19	3.88	0.67	7.74
200	137.6	3.25	3.96	0.67	7.86
P-Value	36	36	44	80	44
BLSD(.05)					
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	115.0	2.72	4.05	0.74	7.52
Pioneer 3737	146.4	3.46	3.81	0.58	7.86
LH74 X LH85	142.0	3.36	3.96	0.73	8.03
DeKalb 485	149.9	3.54	3.99	0.70	8.24
P-Value	99	99	95	99	99
BLSD(.05)	5.0	0.11	0.20	0.02	1.87
N-Rate					
80	134.8	3.19	3.85	0.66	7.71
240	141.8	3.35	4.04	0.71	8.12
P-Value	99	99	99	99	99
Inhibitor					
None	136.8	3.23	3.92	0.68	7.84
N-Serve	139.9	3.31	3.98	0.69	7.99
P-Value	88	88	66	84	84
Hybrid X N-Rate	72	72	30	88	62
Hybrid X Inhibitor	80	80	63	90	46
N-Rate X Inhibitor	79	79	48	92	73
Hybrid X N-Rate X Inhibitor	87	87	31	81	67
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	81	81	85	44	78
N-Rate X K-Rate	44	44	15	99	45
Hybrid X N-Rate X K-Rate	61	61	72	99	77
Inhibitor X K-Rate	97	97	27	47	40
Hybrid X Inhibitor X K-Rate	54	54	21	69	42
N-Rate X Inhibitor X K-Rate	67	67	6	96	15
Hybrid X N-Rate X Inhibitor X K-Rate	56	56	78	88	82

Table 12. Continued from table 5. **Dent Stage R5**

	N-Concentration			N-Removal			
	Stover	Grain	Cob	Stover	Grain	Cob	Total
	---------%----------			-----------#/A-------------			
<u>200 # K-Rate only RCB (Hybrid X N-Rate X Inh.)</u>							
<u>Hybrid</u>							
Pioneer3615	1.25	1.35	0.79	101.1	78.6	11.7	191.6
Pioneer 3737	1.25	1.35	0.58	95.8	95.9	6.8	198.7
LH74 X LH85	1.15	1.42	0.61	89.6	96.0	9.0	194.7
DeKalb 485	1.33	1.25	0.59	107.4	88.4	8.3	204.2
P-Value	99	99	99	99	99	99	81
BLSD (.05)	0.08	0.04	0.03	7.9	5.6	0.7	
<u>N-Rate</u>							
80	1.09	1.25	0.63	83.4	78.8	8.0	170.3
160	1.30	1.41	0.65	105.7	93.9	9.5	209.2
240	1.31	1.43	0.65	106.3	96.5	9.4	212.4
P-Value	99	99	50	99	99	99	99
BLSD (.05)	0.7	0.04		6.4	4.7	0.6	9.3
<u>Inhibitor</u>							
None	1.19	1.37	0.62	95.6	87.9	8.6	192.2
N-Serve	1.27	1.36	0.66	101.4	91.6	9.3	202.4
P-Value	99	49	99	96	90	98	98
Hybrid X N-Rate	98	6	98	99	16	98	92
Hybrid X Inhibitor	97	91	53	97	5	46	79
N-Rate X Inhibitor	99	59	68	99	84	82	99
Hybrid X N-Rate X Inh.	99	44	38	99	72	99	99
<u>Split Plot without the 160# N-Rate</u>							
<u>K-Rate</u>							
0	1.19	1.37	0.64	96.7	92.3	9.3	198.4
100	1.13	1.36	0.65	88.1	86.4	8.9	183.5
200	1.20	1.34	0.64	94.9	87.7	8.7	191.3
P-Value	92	41	13	81	46	73	64
BLSD(.05)							
<u>Hybrid X N-Rate X Inhibitor</u>							
<u>Hybrid</u>							
Pioneer 3615	1.14	1.41	0.78	93.5	77.0	11.5	182.2
Pioneer 3737	1.22	1.35	0.57	94.1	93.8	6.7	194.7
LH74 X LH85	1.07	1.41	0.62	84.8	95.5	9.1	189.5
DeKalb 485	1.25	1.24	0.61	100.5	88.8	8.5	197.9
P-Value	99	99	99	99	99	99	99
BLSD(.05)	0.05	0.03	0.02	5.7	3.5	0.4	8.3
<u>N-Rate</u>							
80	1.09	1.29	0.64	84.4	82.2	8.5	175.1
240	1.26	1.42	0.65	102.1	95.4	9.4	207.0
P-Value	99	99	80	99	99	99	99
<u>Inhibitor</u>							
None	1.12	1.35	0.64	88.4	87.5	8.8	184.8
N-Serve	1.23	1.36	0.65	98.0	90.1	9.2	197.4
P-Value	99	51	85	99	93	97	99
Hybrid X N-Rate	91	43	84	85	78	84	73
Hybrid X Inhibitor	99	69	25	99	17	44	94
N-Rate X Inhibitor	72	83	91	75	92	7	91
Hybrid X N-Rate X Inhibitor	99	68	77	81	87	40	20
<u>Hybrid X N-Rate X Inhibitor X K-Rate</u>							
Hybrid X K-Rate	45	7	97	94	79	94	96
N-Rate X K-Rate	99	99	12	99	96	92	99
Hybrid X N-Rate X K-Rate	99	11	74	99	77	99	99
Inhibitor X K-Rate	99	95	96	99	57	94	75
Hybrid X Inhibitor X K-Rate	99	76	63	92	88	76	92
N-Rate X Inhibitor X K-Rate	99	84	63	96	53	97	93
Hybrid X N-Rate X Inh. X K-Rate 99	47	34	99	86	84	99	

Table 13. Continued from table 6. **Physiological Maturity**

	Grain Yields	Dry Matter Production Grain	Stover	Total
	Bu/A	----------T/A----------		
200 # K-Rate only RCB (Hybrid X N-Rate X Inh)				
Hybrids				
Pioneer 3615	196.4	4.64	4.32	8.96
Pioneer 3737	205.3	4.86	3.93	8.79
LH74 X LH85	196.1	4.64	4.26	8.90
DeKalb 485	211.3	5.00	4.21	9.21
P-Value	99	99	99	99
BLSD (.05)	6.1	0.14	0.12	0.26
N-Rate				
80	189.9	4.49	4.03	8.53
160	208.5	4.93	4.23	9.17
240	208.5	4.93	4.27	4.93
P-Value	99	99	99	99
BLSD (.05)	5.1	0.12	0.10	0.19
Inhibitor				
None	202.2	4.78	4.14	8.92
N-Serve	202.4	4.79	4.22	9.01
P-Value	9	9	89	65
Hybrid X N-Rate	55	55	76	67
Hybrid X Inhibitor	65	65	94	91
N-Rate X Inhibitor	12	12	29	1
Hybrid X N-Rate X Inh.	97	97	76	97
Split Plot without the 160# N-Rate				
K-Rate				
0	207.2	4.90	4.31	9.22
100	200.1	4.73	4.14	8.88
200	199.2	4.71	4.15	8.87
P-Value	91	91	80	88
BLSD(.05)				
Hybrid X N-Rate X Inhibitor				
Hybrid				
Pioneer 3615	198.6	4.70	4.39	9.09
Pioneer 3737	206.1	4.87	3.97	8.84
LH74 X LH85	192.7	4.56	4.21	8.77
DeKalb 485	211.2	4.99	4.25	9.24
P-Value	99	99	99	99
BLSD(.05)	4.0	0.09	0.09	0.17
N-Rate				
80	195.0	4.61	4.12	8.73
240	209.3	4.92	4.28	9.24
P-Value	99	99	99	99
Inhibitor				
None	201.4	4.76	4.18	8.94
N-Serve	202.9	4.80	4.23	9.03
P-Value	65	65	77	77
Hybrid X N-Rate	99	99	93	99
Hybrid X Inhibitor	71	71	66	73
N-Rate X Inhibitor	89	89	60	89
Hybrid X N-Rate X Inhibitor	82	82	11	41
Hybrid X N-Rate X Inhibitor X K-Rate				
Hybrid X K-Rate	88	88	74	71
N-Rate X K-Rate	99	99	80	97
Hybrid X N-Rate X K-Rate	50	50	70	70
Inhibitor X K-Rate	19	19	35	32
Hybrid X Inhibitor X K-Rate	64	64	87	80
N-Rate X Inhibitor X K-Rate	76	76	14	48
Hybrid X N-Rate X Inhibitor X K-Rate	37	37	73	58

Table 14. Continued from table 7. **Physiological Maturity**

	N-Concentration		N-Removal		
	Stover	Grain	Stover	Grain	Total
	-------%-------		----------#/A------------		
200 # K-Rate only RCB (Hybrid X N-Rate X Inh.)					
Hybrids					
Pioneer 3615	0.74	1.40	65.0	131.3	196.2
Pioneer 3737	0.82	1.40	64.8	137.3	202.1
LH74 X LH85	0.84	1.42	72.2	132.6	204.9
DeKalb 485	0.79	1.29	67.0	129.8	196.8
P-Value	99	99	99	85	78
BLSD (.05)	0.04	0.04	4.7		
N-Rate					
80	0.69	1.26	54.0	113.6	167.7
160	0.84	1.43	71.3	141.2	212.5
240	0.89	1.45	76.4	143.4	219.8
P-Value	99	99	99	99	99
BLSD (.05)	0.03	0.03	3.6	5.2	7.5
Inhibitor					
None	0.77	1.37	64.8	131.4	196.2
N-Serve	0.82	1.39	69.6	134.1	203.8
P-Value	99	85	99	74	97
Hybrid X N-Rate	31	65	42	52	57
Hybrid X Inhibitor	85	87	97	92	96
N-Rate X Inhibitor	65	12	60	13	22
Hybrid X N-Rate X Inh.	37	90	49	96	85
Split Plot without the 160# N-Rate					
K-Rate					
0	0.79	1.34	68.4	132.3	200.8
100	0.81	1.30	67.4	123.7	191.1
200	0.78	1.35	65.2	128.5	193.7
P-Value	11	93	58	86	86
BLSD(.05)					
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.73	1.35	64.7	128.2	192.9
Pioneer 3737	0.81	1.36	64.9	133.1	198.0
LH74 X LH85	0.82	1.37	70.0	125.9	196.0
DeKalb 485	0.80	1.25	68.5	125.4	194.0
P-Value	99	99	99	99	78
BLSD(.05)	0.02	0.02	2.7	4.0	
N-Rate					
80	0.68	1.25	56.7	115.7	172.4
240	0.90	1.42	77.3	140.7	218.0
P-Value	99	99	99	99	99
Inhibitor					
None	0.78	1.31	65.5	125.5	191.0
N-Serve	0.81	1.36	68.5	130.8	199.4
P-Value	99	99	99	99	99
Hybrid X N-Rate	93	49	92	99	99
Hybrid X Inhibitor	7	92	33	82	84
N-Rate X Inhibitor	3	8	25	70	65
Hybrid X N-Rate X Inhibitor	17	21	5	70	27
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	35	57	89	57	57
N-Rate X K-Rate	67	55	89	98	99
Hybrid X N-Rate X K-Rate	15	84	65	90	96
Inhibitor X K-Rate	82	66	87	35	17
Hybrid X Inhibitor X K-Rate	94	27	99	54	95
N-Rate X Inhibitor X K-Rate	99	48	99	80	98
Hybrid X N-Rate X Inhibitor X K-Rate	92	54	99	99	99

Table 15. Influence of N-rate, K-rate and nitrification on stover dry matter production, N content and total N removal on four corn hybrids at silking. Waseca 1989.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant Silking Stover		
#/A			#/A	T/A	% N	#/A
0	Pioneer 3615	---	---	4.07	1.37	111.4
0		---	100	3.75	1.01	74.6
80		---	---	4.12	1.50	123.3
80		NS	---	3.82	1.56	119.6
80		---	100	4.16	1.49	123.7
80		NS	100	4.13	1.50	122.6
160		---	---	3.67	1.53	112.0
160		NS	---	3.90	1.64	128.1
160		---	100	3.98	1.55	123.1
160		NS	100	4.03	1.54	123.8
0	Pioneer 3475	---	---	3.82	1.15	87.5
0		---	100	4.36	0.87	75.2
80		---	---	4.55	1.45	132.0
80		NS	---	4.19	1.55	129.8
80		---	100	4.44	1.55	136.6
80		NS	100	4.33	1.44	125.0
160		---	---	4.54	1.73	157.1
160		NS	---	4.44	1.44	127.9
160		---	100	4.37	1.65	144.3
160		NS	100	3.98	1.44	114.8
0	LH74 X LH51	---	---	4.32	1.37	117.9
0		---	100	3.89	1.29	100.3
80		---	---	4.65	1.63	151.5
80		NS	---	4.29	1.56	134.0
80		---	100	4.26	1.64	138.1
80		NS	100	4.02	1.56	124.8
160		---	---	4.35	1.84	160.2
160		NS	---	4.16	1.60	132.7
160		---	100	4.61	1.59	146.6
160		NS	100	4.44	1.67	146.4
0	LH74 X LH82	---	---	3.33	1.18	78.2
0		---	100	4.04	1.31	104.7
80		---	---	3.61	1.65	119.0
80		NS	---	4.23	1.77	149.6
80		---	100	4.20	1.64	137.6
80		NS	100	4.31	1.59	136.6
160		---	---	4.02	1.80	144.6
160		NS	---	4.23	1.69	142.9
160		---	100	4.18	1.65	136.9
160		NS	100	4.79	1.74	165.2

Table 16. Influence of N-rate, K-rate and nitrification on grain yields and dry matter production on four corn hybrids at the **milk stage R3**. Waseca 1989.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production			
					Grain	Stover	Cob	Total
#/A			#/A	Bu/A	------------T/A------------			
0	Pioneer 3615	---	---	66.2	1.57	4.41	0.68	6.65
0		---	100	43.9	1.04	4.47	0.54	6.05
80		---	---	74.8	1.77	4.46	0.79	7.02
80		NS	---	65.4	1.55	4.34	0.77	6.66
80		---	100	63.3	1.50	4.64	0.73	6.87
80		NS	100	54.6	1.29	4.43	0.66	6.38
160		---	---	65.7	1.55	4.27	0.75	6.57
160		NS	---	66.9	1.58	4.28	0.77	6.63
160		---	100	57.0	1.35	4.47	0.72	6.54
160		NS	100	60.9	1.44	4.89	0.73	7.06
0	Pioneer 3475	---	---	48.9	1.16	4.12	0.57	5.85
0		---	100	37.8	0.89	4.67	0.57	6.13
80		---	---	69.5	1.64	4.96	0.84	7.45
80		NS	---	66.7	1.58	4.70	0.77	7.05
80		---	100	54.6	1.29	4.52	0.67	6.48
80		NS	100	51.7	1.22	4.49	0.64	6.36
160		---	---	66.4	1.57	5.01	0.80	7.38
160		NS	---	60.6	1.43	4.48	0.76	6.68
160		---	100	59.8	1.41	5.24	0.75	7.41
160		NS	100	53.7	1.27	4.89	0.70	6.86
0	LH74 X LH51	---	---	42.2	1.00	5.01	0.59	6.60
0		---	100	30.5	0.72	5.26	0.47	6.45
80		---	---	55.5	1.31	5.42	0.72	7.46
80		NS	---	49.2	1.16	5.17	0.63	6.96
80		---	100	44.5	1.05	5.31	0.65	7.02
80		NS	100	48.8	1.15	5.71	0.70	7.56
160		---	---	44.6	1.05	4.52	0.59	6.16
160		NS	---	50.9	1.20	5.01	0.64	6.85
160		---	100	43.2	1.02	5.56	0.66	7.24
160		NS	100	47.6	1.13	5.75	0.67	7.54
0	LH74 X LH82	---	---	59.7	1.41	3.61	0.50	5.52
0		---	100	51.9	1.23	4.04	0.51	5.77
80		---	---	76.3	1.80	3.78	0.67	6.25
80		NS	---	89.2	2.11	4.50	0.70	7.30
80		---	100	69.9	1.65	4.20	0.64	6.49
80		NS	100	71.7	1.70	4.68	0.72	7.10
160		---	---	80.9	1.92	3.98	0.68	6.58
160		NS	---	80.3	1.90	4.33	0.72	6.96
160		---	100	70.6	1.67	4.29	0.66	6.62
160		NS	100	76.8	1.82	4.60	0.72	7.14

Table 17. Influence of N-rate, K-rate and nitrification on N content and total N removal on four corn hybrids at the **milk stage R3**. Waseca 1989.

				N-Concentration			N-Removal			
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Cob	Stover	Grain	Cob	Total
#/A			#/A	%			#/A			
0	Pioneer 3615	---	---	0.90	1.54	0.76	79.1	48.0	10.3	137.4
0		---	100	0.62	1.65	0.86	55.7	34.4	9.1	99.2
80		---	---	1.07	1.78	0.76	95.9	62.6	12.0	170.5
80		NS	---	0.97	1.73	0.82	84.3	53.4	12.6	150.3
80		---	100	1.19	1.81	0.78	110.2	54.0	11.5	175.7
80		NS	100	1.04	1.81	0.84	91.7	46.8	11.2	149.7
160		---	---	1.05	1.80	0.80	89.8	55.7	12.0	157.5
160		NS	---	1.28	1.65	0.78	109.4	51.9	12.1	173.4
160		---	100	1.30	1.83	0.86	115.5	49.4	12.3	177.3
160		NS	100	1.25	1.79	0.81	122.5	51.5	11.7	185.8
0	Pioneer 3475	---	---	0.70	1.60	0.77	58.1	36.8	8.8	103.6
0		---	100	0.74	1.67	0.82	69.0	29.8	9.3	108.1
80		---	---	1.13	1.50	0.77	111.0	49.1	12.9	173.0
80		NS	---	1.03	1.57	0.83	95.8	49.2	12.7	157.8
80		---	100	1.24	1.61	0.85	111.7	41.5	11.4	164.5
80		NS	100	1.05	1.74	0.90	93.3	42.5	11.6	147.4
160		---	---	1.13	1.67	0.88	112.2	52.6	14.1	178.9
160		NS	---	1.06	1.64	0.88	95.1	47.1	13.4	155.6
160		---	100	1.28	1.57	0.92	135.1	44.5	13.7	193.4
160		NS	100	1.22	1.81	0.95	119.7	45.8	13.3	178.8
0	LH74 X LH51	---	---	0.84	1.71	0.68	85.6	34.1	7.9	127.5
0		---	100	0.70	1.74	0.75	73.7	25.2	7.0	105.9
80		---	---	1.34	1.93	0.75	144.5	50.0	10.8	205.2
80		NS	---	1.11	1.92	0.74	114.5	44.5	9.3	168.3
80		---	100	1.04	2.00	0.78	110.8	41.9	10.2	162.9
80		NS	100	1.13	1.85	0.80	129.3	42.8	11.2	183.2
160		---	---	1.26	1.95	0.76	113.4	41.2	9.0	163.6
160		NS	---	1.20	1.91	0.75	119.4	46.0	9.5	174.8
160		---	100	1.23	2.03	0.80	136.9	41.5	10.5	188.9
160		NS	100	1.17	2.00	0.83	135.5	44.7	11.0	191.1
0	LH74 X LH82	---	---	0.83	1.40	0.61	59.8	39.6	6.0	105.4
0		---	100	0.71	1.43	0.72	58.1	34.9	7.2	100.2
80		---	---	1.17	1.61	0.68	88.2	58.1	9.1	155.4
80		NS	---	1.25	1.60	0.70	112.0	67.4	9.7	189.0
80		---	100	1.09	1.64	0.75	90.9	54.1	9.6	154.5
80		NS	100	1.02	1.76	0.76	95.9	59.5	11.0	166.4
160		---	---	1.21	1.68	0.72	95.8	64.0	9.8	169.6
160		NS	---	1.15	1.63	0.68	99.6	61.8	9.8	171.2
160		---	100	1.23	1.70	0.71	105.5	56.6	9.3	171.3
160		NS	100	1.15	1.73	0.77	106.0	62.5	10.9	179.4

Table 18. Influence of N-rate, K-rate and nitrification on grain yield and dry matter production on four corn hybrids at the dent stage R5. Waseca 1989.

				Grain	Dry Matter Production			
N-Rate	Hybrid	Inh.	K-Rate	Yields	Grain	Stover	Cob	Total
#/A			#/A	Bu/A	-------------T/A--------------			
0	Pioneer 3615	---	---	135.8	3.21	3.52	0.66	7.39
0		---	100	104.5	2.47	3.34	0.56	6.37
80		---	---	156.5	3.70	3.89	0.76	8.36
80		NS	---	150.7	3.57	3.62	0.78	7.97
80		---	100	141.3	3.34	3.87	0.73	7.94
80		NS	100	134.8	3.19	3.63	0.71	7.53
160		---	---	139.4	3.30	3.19	0.65	7.14
160		NS	---	147.6	3.49	3.49	0.75	7.73
160		---	100	138.6	3.28	3.59	0.74	7.61
160		NS	100	138.3	3.27	3.79	0.72	7.79
0	Pioneer 3475	---	---	111.1	2.63	3.47	0.54	6.65
0		---	100	98.8	2.34	3.83	0.53	6.70
80		---	---	152.9	3.62	4.08	0.77	8.46
80		NS	---	148.4	3.51	3.84	0.71	8.07
80		---	100	126.5	2.99	4.03	0.60	7.63
80		NS	100	126.4	2.99	3.73	0.62	7.34
160		---	---	144.5	3.42	4.09	0.70	8.21
160		NS	---	139.7	3.31	3.27	0.66	7.24
160		---	100	127.6	3.02	3.70	0.67	7.39
160		NS	100	140.8	3.33	4.17	0.69	8.20
0	LH74 X LH51	---	---	114.1	2.70	4.24	0.57	7.51
0		---	100	103.5	2.45	4.78	0.53	7.75
80		---	---	131.2	3.10	4.23	0.63	7.97
80		NS	---	129.7	3.07	4.40	0.62	8.09
80		---	100	118.4	2.80	4.26	0.62	7.68
80		NS	100	120.0	2.84	4.37	0.62	7.83
160		---	---	131.4	3.11	4.11	0.59	7.81
160		NS	---	116.2	2.75	3.86	0.57	7.18
160		---	100	113.7	2.69	4.38	0.60	7.68
160		NS	100	132.2	3.13	5.15	0.68	8.96
0	LH74 X LH82	---	---	106.9	2.53	3.03	0.54	6.10
0		---	100	100.2	2.37	3.38	0.51	6.26
80		---	---	135.9	3.22	3.17	0.61	6.99
80		NS	---	148.0	3.50	3.47	0.65	7.62
80		---	100	137.7	3.26	3.92	0.66	7.83
80		NS	100	137.2	3.25	3.65	0.65	7.54
160		---	---	141.7	3.35	3.47	0.65	7.48
160		NS	---	142.9	3.38	3.35	0.65	7.38
160		---	100	144.8	3.43	3.97	0.69	8.09
160		NS	100	143.0	3.38	3.61	0.69	7.69

Table 19. Influence of N-rate, K-rate and nitrification on N content, and total N removal on four corn hybrids at the **dent stage R5**. Waseca 1989.

				N-Concentration			N-Removal			
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Cob	Stover	Grain	Cob	Total
#/A			#/A	-----------%----------			---------------#/A-------------			
0	Pioneer 3615	---	---	0.77	1.29	0.58	54.6	82.8	7.6	144.9
0		---	100	0.72	1.26	0.63	48.1	62.2	6.9	117.2
80		---	---	1.01	1.49	0.54	78.6	110.3	8.1	196.9
80		NS	---	0.94	1.46	0.60	68.0	103.6	9.4	181.0
80		---	100	0.84	1.40	0.56	64.8	93.6	8.1	166.5
80		NS	100	0.92	1.47	0.60	66.6	93.8	8.4	168.9
160		---	---	0.97	1.46	0.58	61.7	95.9	7.5	165.1
160		NS	---	1.03	1.54	0.56	72.1	107.6	8.4	188.1
160		---	100	0.96	1.53	0.57	68.6	99.8	8.5	176.9
160		NS	100	0.87	1.54	0.62	65.7	100.8	8.8	175.3
0	Pioneer 3475	---	---	0.63	1.14	0.58	43.5	59.8	6.2	109.5
0		---	100	0.58	1.18	0.56	44.2	55.4	5.9	105.5
80		---	---	1.00	1.42	0.61	80.2	102.0	9.2	191.4
80		NS	---	0.87	1.39	0.60	67.3	97.8	8.5	173.6
80		---	100	1.01	1.37	0.70	81.5	82.5	8.3	172.3
80		NS	100	0.89	1.46	0.64	66.7	87.0	7.9	161.6
160		---	---	0.95	1.47	0.62	77.5	100.7	8.7	186.9
160		NS	---	0.92	1.41	0.61	60.4	92.9	8.0	161.3
160		---	100	0.93	1.42	0.63	68.8	85.3	8.4	162.5
160		NS	100	0.92	1.44	0.65	76.2	95.7	8.9	180.8
0	LH74 X LH51	---	---	0.72	1.26	0.48	61.6	68.1	5.4	135.1
0		---	100	0.55	1.10	0.52	53.0	53.8	5.5	112.2
80		---	---	1.15	1.59	0.50	97.0	98.7	6.4	202.1
80		NS	---	1.00	1.43	0.55	88.2	87.6	6.8	182.6
80		---	100	0.91	1.44	0.53	78.0	80.6	6.5	165.1
80		NS	100	1.03	1.41	0.52	90.6	79.7	6.4	176.7
160		---	---	1.19	1.44	0.53	98.1	89.5	6.2	193.8
160		NS	---	1.14	1.51	0.61	88.3	82.8	6.9	178.0
160		---	100	1.01	1.53	0.57	88.5	82.4	6.9	177.8
160		NS	100	1.13	1.51	0.53	116.4	93.5	7.2	217.1
0	LH74 X LH82	---	---	0.63	1.18	0.58	38.1	59.6	6.3	104.0
0		---	100	0.54	1.16	0.64	36.7	55.2	6.4	98.3
80		---	---	0.90	1.45	0.59	57.0	93.6	7.2	157.8
80		NS	---	0.96	1.54	0.53	66.1	107.6	6.9	180.6
80		---	100	0.94	1.40	0.61	74.0	91.2	8.0	173.3
80		NS	100	1.00	1.41	0.50	72.1	90.8	6.5	169.4
160		---	---	0.97	1.55	0.65	67.8	103.6	8.4	179.9
160		NS	---	0.96	1.49	0.51	64.1	101.0	6.6	171.7
160		---	100	1.07	1.50	0.59	84.6	102.6	8.1	195.3
160		NS	100	1.04	1.43	0.66	75.4	96.5	9.1	181.0

Table 20. Influence of N-rate, K-rate and nitrification on grain yields and dry matter production on four corn hybrids at **physiological maturity**. Waseca 1989.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
#/A			#/A	Bu/A	----------T/A---------		
0	Pioneer 3615	---	---	166.9	3.95	3.76	7.71
0		---	100	134.1	3.17	3.74	6.91
80		---	---	185.3	4.38	3.88	8.26
80		NS	---	174.3	4.12	3.69	7.82
80		---	100	180.7	4.27	3.91	8.18
80		NS	100	171.4	4.05	3.88	7.93
160		---	---	185.6	4.39	3.74	8.13
160		NS	---	191.2	4.52	4.01	8.53
160		---	100	188.1	4.45	3.93	8.38
160		NS	100	184.5	4.37	3.92	8.29
0	Pioneer 3475	---	---	132.8	3.14	3.92	7.07
0		---	100	135.4	3.20	4.47	7.68
80		---	---	193.8	4.59	4.12	8.71
80		NS	---	185.2	4.38	4.20	8.58
80		---	100	175.5	4.15	4.35	8.51
80		NS	100	167.6	3.96	4.19	8.16
160		---	---	178.9	4.23	4.05	8.29
160		NS	---	180.8	4.28	4.11	8.39
160		---	100	177.3	4.20	4.16	8.36
160		NS	100	184.7	4.37	4.50	8.87
0	LH74 X LH51	---	---	165.2	3.91	4.35	8.26
0		---	100	133.5	3.16	4.36	7.51
80		---	---	185.6	4.39	4.35	8.74
80		NS	---	183.1	4.33	4.55	8.89
80		---	100	184.2	4.36	4.54	8.89
80		NS	100	166.4	3.94	4.23	8.16
160		---	---	180.3	4.27	4.51	8.77
160		NS	---	171.3	4.05	4.29	8.35
160		---	100	183.0	4.33	4.63	8.96
160		NS	100	174.2	4.12	4.55	8.67
0	LH74 X LH82	---	---	136.7	3.24	3.55	6.78
0		---	100	125.5	2.97	3.77	6.74
80		---	---	168.3	3.98	3.85	7.83
80		NS	---	173.6	4.11	3.98	8.08
80		---	100	175.5	4.15	4.26	8.41
80		NS	100	172.5	4.08	4.10	8.18
160		---	---	174.8	4.14	3.85	7.98
160		NS	---	175.5	4.15	4.04	8.19
160		---	100	179.3	4.24	4.02	8.26
160		NS	100	175.1	4.14	4.28	8.42

Table 21. Influence of N-rate, K-rate and nitrification on N content and total N removal on four corn hybrids at **physiological maturity**. Waseca 1989.

				N-Concentration		N-Removal		
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Stover	Grain	Total
#/A			#/A	-------%-------		----------#/A----------		
0	Pioneer 3615	---	---	0.39	1.21	29.4	96.1	125.5
0		---	100	0.32	1.26	24.1	79.7	103.8
80		---	---	0.47	1.39	36.6	122.0	158.6
80		NS	---	0.41	1.38	30.2	113.9	144.1
80		---	100	0.41	1.38	31.8	117.9	149.7
80		NS	100	0.47	1.41	36.2	113.8	150.0
160		---	---	0.49	1.41	36.6	124.2	160.8
160		NS	---	0.48	1.50	38.2	135.5	173.7
160		---	100	0.50	1.45	38.8	128.9	167.8
160		NS	100	0.46	1.48	36.0	129.1	165.1
0	Pioneer 3475	---	---	0.33	1.15	25.7	72.4	98.1
0		---	100	0.34	1.13	30.5	72.1	102.6
80		---	---	0.44	1.43	36.5	131.2	167.7
80		NS	---	0.46	1.47	38.6	127.8	166.4
80		---	100	0.47	1.38	41.0	114.1	155.1
80		NS	100	0.38	1.44	31.7	113.8	145.6
160		---	---	0.48	1.46	38.8	123.6	162.4
160		NS	---	0.50	1.37	40.7	116.9	157.6
160		---	100	0.49	1.41	40.4	117.9	158.4
160		NS	100	0.52	1.46	46.9	126.9	173.8
0	LH74 X LH51	---	---	0.39	1.17	33.8	91.3	125.1
0		---	100	0.31	1.10	26.9	69.1	95.9
80		---	---	0.49	1.28	42.2	112.3	154.5
80		NS	---	0.47	1.41	42.7	122.5	165.2
80		---	100	0.45	1.35	41.0	117.5	158.5
80		NS	100	0.38	1.34	32.1	105.2	137.3
160		---	---	0.52	1.36	47.1	115.5	162.6
160		NS	---	0.54	1.35	46.3	109.3	155.6
160		---	100	0.54	1.47	49.7	126.7	176.4
160		NS	100	0.53	1.38	48.3	113.2	161.5
0	LH74 X LH82	---	---	0.37	1.18	26.7	77.0	103.7
0		---	100	0.33	1.11	25.0	65.2	90.1
80		---	---	0.53	1.39	40.7	110.9	151.7
80		NS	---	0.54	1.46	42.6	119.3	162.0
80		---	100	0.48	1.37	41.2	113.5	154.7
80		NS	100	0.50	1.44	41.1	117.4	158.5
160		---	---	0.56	1.51	42.9	125.0	167.8
160		NS	---	0.54	1.53	43.3	127.2	170.5
160		---	100	0.56	1.58	44.8	133.5	178.4
160		NS	100	0.53	1.57	45.7	130.2	175.9

Table 22. Waseca 1989

	Whole Plant		
0 # K-Rate only RCB (Hybrid X N-Rate)	Tassling	Stover	N-Removal
Hybrids	% N	T/A	#/A
Pioneer 3615	1.46	3.95	115.6
Pioneer 3475	1.44	4.30	125.5
LH74 X LH51	1.61	4.43	143.1
LH74 X LH82	1.54	3.65	113.9
P-Value	99	99	99
BLSD (.05)	0.09	0.24	10.2
N-Rate			
0	1.26	3.88	98.7
80	1.55	4.23	131.4
160	1.72	4.14	143.4
P-Value	99	99	99
BLSD (.05)	0.07	0.02	8.5
Hybrid X N-Rate	99	99	99
100 # K-Rate only RCB			
Pioneer 3615	1.35	3.96	107.1
Pioneer 3475	1.35	4.39	118.7
LH74 X LH 51	1.50	4.25	128.3
LH74 X LH82	1.53	4.14	126.3
P-Value	99	84	99
BLSD (.05)	0.10		11.6
N-Rate			
0	1.11	4.01	88.6
80	1.57	4.02	133.9
160	1.61	4.28	137.7
P-Value	99	80	99
BLSD (.05)	0.08		9.0
Hybrid X N-Rate	99	22	77
Split Plot without the 0 # N-Rate			
K-Rate			
0	1.62	4.26	135.2
100	1.57	4.26	134.1
P-Value	60	55	47
Hybrid X N-Rate X Inhibitor			
Hybrid			
Pioneer 3615	1.53	3.97	122.0
Pioneer 3475	1.53	4.35	133.4
LH74 X LH51	1.63	4.34	141.7
LH74 X LH82	1.68	4.19	141.5
P-Value	99	99	99
BLSD (.05)	0.05	0.21	6.9
N-Rate			
80	1.56	4.20	131.4
160	1.63	4.23	137.9
P-Value	99	23	99
Inhibitor			
None	1.61	4.23	136.6
N-Serve	1.58	4.20	132.7
P-Value	91	25	86
Hybrid X N-Rate	3	66	62
Hybrid X Inhibitor	98	99	99
N-Rate X Inhibitor	91	54	42
Hybrid X N-Rate X Inhibitor	88	11	84
Hybrid X N-Rate X Inhibtor X K-Rate			
Hybrid X K-Rate	16	90	68
N-Rate X K-Rate	38	43	18
Hybrid X N-Rate X K-Rate	32	80	56
Inhibitor X K-Rate	10	4	15
Hybrid X Inhibitor X K-Rate	82	1	56
N-Rate X Inhibitor X K-Rate	99	10	93
Hybrid X N-Rate X Inhibitor X K-Rate	77	67	93

Table 23 Waseca 1989

Milk Stage R3	Dry Matter Production				Grain
0 # K-Rate only RCB	Cob	Stover	Grain	Total	Yields
Hybrid (Hybrid X N-Rate)	------------T/A------------				Bu/A
Pioneer 3615	0.74	4.37	1.63	6.74	68.8
Pioneer 3475	0.74	4.69	1.45	6.88	61.5
LH74 X LH51	0.63	4.98	1.12	6.73	47.4
LH74 X LH82	0.61	3.79	1.70	6.11	72.2
P-Value	99	99	99	99	99
BLSD (.05)	0.05	0.30	0.12	0.51	5.1
N-Rate					
0	0.58	4.28	1.28	6.15	54.2
80	0.75	4.65	1.63	7.04	69.0
160	0.70	4.44	1.52	6.67	64.4
P-Value	99	96	99	99	99
BLSD (.05)	0.04	0.30	0.10	0.40	4.5
Hybrid X N-Rate	98	98	98	99	98
100 # K-Rate only RCB					
Hybrids					
Pioneer 3615	0.66	4.52	1.29	6.48	54.7
Pioneer 3475	0.66	4.81	1.19	6.67	50.7
LH74 X LH51	0.59	5.37	0.93	6.90	39.3
LH74 X LH82	0.60	4.17	1.51	6.29	64.1
P-Value	99	99	99	97	99
BLSD (.05)	0.05	0.25	0.10	0.45	4.0
N-Rate					
0	0.52	4.61	0.96	6.10	41.6
80	0.67	4.66	1.37	6.71	58.9
160	0.69	4.89	1.36	6.95	57.6
P-Value	99	94	99	99	99
BLSD (.05)	0.04		0.09	0.33	
Hybrid X N-Rate	28	68	46	63	46
Split Plot without the 0 # N-Rate					
K-Rate					
0	0.72	4.57	1.57	6.87	66.4
100	0.68	4.85	1.37	6.91	58.0
P-Value	73	77	94	12	94
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.74	4.47	1.50	6.71	63.5
Pioneer 3475	0.74	4.78	1.42	6.95	60.3
LH74 X LH51	0.65	5.30	1.13	7.09	48.0
LH74 X LH82	0.68	4.29	1.82	6.80	76.9
P-Value	99	99	99	99	99
BLSD(.05)	0.03	0.18	0.06	0.32	2.8
N-Rate					
80	0.70	4.70	1.48	6.90	62.8
160	0.70	4.72	1.45	6.88	61.6
P-Value	6	19	70	10	70
Inhibitor					
None	0.70	4.66	1.47	6.84	62.2
N-Serve	0.70	1.47	1.47	6.94	62.1
P-Value	12	84	7	66	7
Hybrid X N-Rate	74	77	25	70	25
Hybrid X Inhibitor	98	99	99	99	99
N-Rate X Inhibitor	78	11	72	41	72
Hybrid X N-Rate X Inhibitor	37	78	96	97	96
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	99	93	83	94	83
N-Rate X K-Rate	94	99	98	99	98
Hybrid X N-Rate X K-Rate	43	72	12	54	12
Inhibitor X K-Rate	60	52	32	51	32
Hybrid X Inhibitor X K-Rate	35	18	23	15	23
N-Rate X Inhibitor X K-Rate	80	21	34	19	34
Hybrid X N-Rate X Inh. X K-Rate	54	68	86	73	86

Table 24. Waseca 1989	N-Concentration			N-Removal			
0 # K-Rate only RCB (Hybrid X N-Rate)	Cob	Stover	Grain	Cob	Stover	Grain	Total
Hybrids Milk Stage R3	------------%----------			------------#/A------------			
Pioneer 3615	0.77	1.00	1.70	55.4	88.2	55.4	155.1
Pioneer 3475	0.80	0.98	1.58	11.9	93.7	46.1	151.8
LH74 X LH51	0.73	1.14	1.86	9.2	114.4	41.7	165.4
LH74 X LH82	0.67	1.06	1.56	8.3	81.2	53.9	143.4
P-Value	99	97	99	99	99	99	97
BLSD (.05)	0.03	0.12	0.07	0.7	12.0	3.8	16.2
N-Rate							
0	0.70	0.81	1.56	8.2	70.6	39.6	118.4
80	0.74	1.17	1.70	11.1	109.9	54.9	176.3
160	0.79	1.16	1.77	11.2	102.8	53.3	167.4
P-Value	99	99	99	99	99	99	99
BLSD (.05)	0.03	0.09	0.06	0.6	10.0	3.3	11.4
Hybrid X N-Rate	72	75	99	99	98	99	99
100 # K-Rate only RCB							
Hybrid							
Pioneer 3615	0.83	1.03	1.76	10.9	93.7	45.9	150.7
Pioneer 3475	0.86	1.08	1.61	11.4	105.2	38.5	155.3
LH74 X LH51	0.77	0.99	1.92	9.2	107.1	36.2	152.5
LH74 X LH82	0.72	1.00	1.58	8.6	84.8	48.5	142.0
P-Value	99	93	99	99	99	99	81
BLSD (.05)	0.05	0.08	0.07	0.9	9.1	3.9	
N-Rate							
0	0.78	0.69	1.62	8.1	64.1	31.0	103.3
80	0.79	1.13	1.76	10.6	105.8	47.8	164.4
160	0.81	1.25	1.78	11.2	123.2	48.0	182.7
P-Value	67	99	99	99	99	99	99
BLSD (.05)		0.05	0.06	0.7	7.4	3.2	9.8
Hybrid X N-Rate	69	86	99	67	67	52	45
Split Plot without the 0 # N-Rate							
K-Rate							
0	0.76	1.15	1.72	11.7	105.0	53.4	169.6
100	0.81	1.16	1.79	11.2	113.1	48.7	173.1
P-Value	99	93	89	25	85	92	41
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3615	0.80	1.14	1.77	11.9	102.4	53.1	167.5
Pioneer 3475	0.87	1.14	1.63	12.8	109.2	46.5	168.6
LH74 X LH51	0.77	1.18	1.94	10.1	125.5	44.0	179.7
LH74 X LH82	0.72	1.15	1.66	9.8	99.2	60.5	169.5
P-Value	99	75	99	99	99	99	99
BLSD(.05)	0.02		0.04	0.5	5.6	2.3	8.2
N-Rate							
80	0.78	1.11	1.73	11.0	104.9	51.0	167.1
160	0.80	1.19	1.77	11.4	113.2	51.0	175.6
P-Value	97	99	94	90	99	4	99
Inhibitor							
None	0.78	1.18	1.75	11.1	110.4	51.0	172.6
N-Serve	0.80	1.12	1.75	11.3	107.7	51.0	170.1
P-Value	87	99	7	60	78	3	63
Hybrid X N-Rate	92	87	69	98	85	67	80
Hybrid X Inhibitor	26	76	99	71	99	99	99
N-Rate X Inhibitor	85	93	50	21	83	53	81
Hybrid X N-Rate X Inhibitor	62	98	42	29	99	97	99
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	25	99	20	99	90	37	53
N-Rate X K-Rate	23	99	13	79	99	93	99
Hybrid X N-Rate X K-Rate	17	57	82	54	66	3	48
Inhibitor X K-Rate	69	63	97	72	4	90	55
Hybrid X Inhibitor X K-Rate	31	99	87	71	95	3	83
N-Rate X Inhibitor X K-Rate	57	77	80	39	76	64	48
Hybrid X N-Rate X Inhibitor X K-Rate	28	95	49	46	98	70	98

Table 25 Waseca 1989

Dent Stage R3	Dry Matter Production				Grain
0 # K-Rate only RCB	Cob	Stover	Grain	Total	Yields
Hybrid	-------------T/A-----------				Bu/A
Pioneer 3615	0.69	3.53	3.40	7.62	143.8
Pioneer 3475	0.67	3.87	3.22	7.77	136.1
LH74 X LH51	0.59	4.19	2.97	7.76	125.5
LH74 X LH82	0.60	3.22	3.03	6.85	128.1
P-Value	99	99	97	98	97
BLSD (.05)	0.06	0.29	0.35	0.71	14.9
N-Rate					
0	0.57	3.56	2.76	6.91	116.9
80	0.69	3.84	3.41	7.94	144.1
160	0.64	3.71	3.29	7.65	139.2
P-Value	99	86	99	99	99
BLSD (.05)	0.05		0.25	0.56	10.9
Hybrid X N-Rate	92	91	62	83	62
100 # K-Rate only RCB					
Hybrid					
Pioneer 3615	0.67	3.60	3.03	7.30	128.1
Pioneer 3475	0.60	3.85	2.78	7.24	117.6
LH74 X LH51	0.58	4.47	2.64	7.70	111.8
LH74 X LH82	0.61	3.75	3.01	7.39	127.5
P-Value	99	99	99	69	99
BLSD (.05)	0.05	0.27	0.25		10.9
N-Rate					
0	0.53	3.83	2.40	6.77	101.7
80	0.65	4.01	3.09	7.77	130.9
160	0.67	3.91	3.10	7.69	131.1
P-Value	99	66	99	99	99
BLSD (.05)	0.04		0.19	0.43	8.3
Hybrid X N-Rate	50	97	76	93	76
Split Plot without the 0 # N-Rate					
K-Rate					
0	0.67	3.72	3.33	7.73	141.0
100	0.66	3.98	3.13	7.79	132.5
P-Value	13	87	95	92	95
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.73	3.63	3.39	7.75	143.3
Pioneer 3475	0.67	3.86	3.27	7.81	138.3
LH74 X LH51	0.61	4.34	2.93	7.89	124.1
LH74 X LH82	0.65	3.57	3.34	7.57	141.4
P-Value	99	99	99	61	99
BLSD(.05)	0.03	0.19	0.14		6.2
N-Rate					
80	0.67	3.88	3.24	7.80	137.2
160	0.66	3.82	3.22	7.72	136.3
P-Value	20	56	28	45	28
Inhibitor					
None	0.66	3.87	3.22	7.76	136.3
N-Serve	0.67	3.83	3.24	7.75	137.2
P-Value	37	33	28	4	28
Hybrid X N-Rate	69	53	32	47	32
Hybrid X Inhibitor	32	73	5	28	5
N-Rate X Inhibitor	55	55	47	55	47
Hybrid X N-Rate X Inhibitor	14	62	34	52	34
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	98	66	82	82	82
N-Rate X K-Rate	99	98	98	99	98
Hybrid X N-Rate X K-Rate	63	72	10	42	10
Inhibitor X K-Rate	10	71	62	68	62
Hybrid X Inhibitor X K-Rate	89	92	83	91	83
N-Rate X Inhibitor X K-Rate	20	97	27	92	27
Hybrid X N-Rate X Inh. X K-Rate	40	68	42	57	42

Table 26. Waseca 1989	N-Concentration			N-Removal			
0 # K-Rate only RCB (Hybrid X N-Rate)	Cob	Stover	Grain	Cob	Stover	Grain	Total
Hybrids Dent Stage R3	%			#/A			
Pioneer 3615	0.56	0.91	1.41	7.7	64.9	96.3	168.9
Pioneer 3475	0.60	0.85	1.34	8.0	67.0	87.4	162.5
LH74 X LH51	0.50	1.01	1.42	5.9	85.6	85.4	177.0
LH74 X LH82	0.60	0.83	1.39	7.3	54.3	85.6	147.2
P-Value	99	99	92	99	99	89	99
BLSD (.05)	0.04	0.08	0.07	0.7	8.5		18.7
N-Rate							
0	0.55	0.68	1.21	6.3	49.4	67.5	123.3
80	0.55	1.01	1.48	7.7	78.2	101.1	187.0
160	0.59	1.01	1.47	7.7	76.2	97.4	181.4
P-Value	84	99	99	99	99	99	99
BLSD (.05)		0.06	0.05	0.6	7.2	7.9	13.9
Hybrid X N-Rate	16	78	96	96	92	85	91
100 # K-Rate only RCB							
Hybrid							
Pioneer 3615	0.58	0.83	1.39	7.7	60.5	85.1	153.5
Pioneer 3475	0.62	0.83	1.32	7.5	64.8	74.3	146.7
LH74 X LH51	0.53	0.82	1.35	6.3	73.1	72.2	151.7
LH74 X LH82	0.61	0.85	1.35	7.5	65.1	83.0	155.6
P-Value	99	11	87	99	96	99	35
BLSD (.05)	0.05			0.7	9.7	6.9	
N-Rate							
0	0.58	0.59	1.17	6.1	45.4	56.6	108.2
80	0.59	0.92	1.40	7.7	74.5	86.9	169.2
160	0.59	0.99	1.49	7.9	77.6	92.5	178.1
P-Value	12	99	99	99	99	99	99
BLSD (.05)		0.05	0.04	0.6	6.8	5.4	11.4
Hybrid X N-Rate	92	99	93	18	94	58	77
Split Plot without the 0 # N-Rate							
K-Rate							
0	0.57	0.99	1.47	7.6	74.5	98.4	180.6
100	0.59	0.96	1.45	7.8	77.4	90.9	176.2
P-Value	49	82	77	51	66	99	68
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3615	0.57	0.94	1.48	8.3	68.2	100.6	177.3
Pioneer 3475	0.63	0.93	1.42	8.5	72.3	92.9	173.8
LH74 X LH51	0.54	1.06	1.48	6.6	93.1	86.8	186.6
LH74 X LH82	0.58	0.97	1.46	7.6	70.1	98.3	176.1
P-Value	99	99	99	99	99	99	95
BLSD(.05)	0.02	0.04	0.03	0.4	5.4	4.3	11.0
N-Rate							
80	0.57	0.95	1.44	7.6	74.8	93.7	176.2
160	0.59	1.00	1.48	7.9	77.1	95.6	180.7
P-Value	95	99	99	89	73	74	81
Inhibitor							
None	0.58	0.98	1.46	7.7	76.6	94.5	178.9
N-Serve	0.58	0.97	1.46	7.7	75.2	94.9	177.9
P-Value	35	49	10	4	49	20	23
Hybrid X N-Rate	70	87	21	90	90	27	67
Hybrid X Inhibitor	99	77	72	99	89	12	42
N-Rate X Inhibitor	39	34	6	61	60	43	60
Hybrid X N-Rate X Inhibitor	61	76	98	12	66	88	82
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	69	99	86	65	95	30	75
N-Rate X K-Rate	26	81	94	99	93	99	99
Hybrid X N-Rate X K-Rate	60	14	78	6	42	16	35
Inhibitor X K-Rate	7	90	57	21	94	78	92
Hybrid X Inhibitor X K-Rate	97	95	67	78	99	96	99
N-Rate X Inhibitor X K-Rate	97	88	91	96	50	30	52
Hybrid X N-Rate X Inhibitor X K-Rate	96	69	81	88	84	60	82

Table 27 Waseca 1989

Physiological Maturity	Dry Matter Production				Grain
0 # K-Rate only RCB	Cob	Stover	Grain	Total	Yields
Hybrid	------------T/a------------				Bu/A
Pioneer 3615	---	3.79	4.24	8.03	179.2
Pioneer 3475	---	4.03	3.98	8.02	168.5
LH74 X LH51	---	4.40	4.18	8.59	177.0
LH74 X LH82	---	3.74	3.78	7.53	159.9
P-Value		99	99	99	99
BLSD (.05)		0.20	0.29	0.41	12.3
N-Rate					
0	---	3.89	3.55	7.45	150.4
80	---	4.05	4.33	8.38	183.2
160	---	4.03	4.25	8.29	179.9
P-Value		79	99	99	99
BLSD (.05)			0.22	0.34	9.4
Hybrid X N-Rate					
100 # K-Rate only RCB					
Hybrid					
Pioneer 3615	---	3.85	3.96	7.82	167.5
Pioneer 3475	---	4.32	3.85	8.18	162.7
LH74 X LH51	---	4.50	3.94	8.45	166.8
LH74 X LH82	---	4.01	3.78	7.80	160.0
P-Value		99	51	99	51
BLSD (.05)		0.20		0.40	
N-Rate					
0	---	4.08	3.12	7.21	132.1
80	---	4.26	4.23	8.49	178.9
160	---	4.18	4.30	8.49	181.9
P-Value		81	99	99	99
BLSD (.05)			0.20	0.30	8.8
Hybrid X N-Rate		80	5	50	5
Split Plot without the 0 # N-Rate					
K-Rate					
0	---	4.07	4.27	8.34	180.4
100	---	4.21	4.19	8.41	177.4
P-Value		80	47	26	47
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	---	3.86	4.32	8.18	182.6
Pioneer 3475	---	4.21	4.27	8.48	180.4
LH74 X LH51	---	4.45	4.22	8.68	178.5
LH74 X LH82	---	4.04	4.12	8.16	174.3
P-Value		99	98	99	98
BLSD(.05)		0.10	0.14	0.20	6.1
N-Rate					
80	---	4.13	4.20	8.33	177.6
160	---	4.16	4.26	8.42	180.2
P-Value		53	81	77	81
Inhibitor					
None	---	4.13	4.28	8.41	181.0
N-Serve	---	4.15	4.18	8.34	176.9
P-Value		41	96	64	96
Hybrid X N-Rate		14	83	47	83
Hybrid X Inhibitor		66	62	77	62
N-Rate X Inhibitor		93	84	94	84
Hybrid X N-Rate X Inhibitor		57	64	54	64
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate		56	70	57	70
N-Rate X K-Rate		58	95	90	95
Hybrid X N-Rate X K-Rate		51	73	73	73
Inhibitor X K-Rate		66	65	73	65
Hybrid X Inhibitor X K-Rate		14	22	25	22
N-Rate X Inhibitor X K-Rate		87	31	73	31
Hybrid X N-Rate X Inhibitor X K-Rate		88	29	75	29

Table 28. Waseca 1989	N-Concentration		N-Removal		
0 # K-Rate only RCB (Hybrid X N-Rate)	Stover	Grain	Stover	Grain	Total
Hybrids Physiological Maturity	------%---------		---------#/A--------		
Pioneer 3615	0.45	1.33	34.2	114.1	148.2
Pioneer 3475	0.41	1.34	33.6	109.0	142.7
LH74 X LH51	0.46	1.26	41.0	106.3	147.3
LH74 X LH82	0.48	1.36	36.7	104.3	141.0
P-Value	99	94	99	72	44
BLSD (.05)	0.03	0.08	3.7		
N-Rate					
0	0.36	1.17	28.8	84.2	113.0
80	0.48	1.37	39.0	119.1	158.1
160	0.51	1.43	41.3	122.0	163.3
P-Value	99	99	99	99	99
BLSD (.05)	0.02	0.05	2.9	8.2	9.4
Hybrid X N-Rate	57	58	48	94	92
100 # K-Rate only RCB					
Hybrid					
Pioneer 3615	0.40	1.36	31.5	108.8	140.4
Pioneer 3475	0.43	1.30	37.2	101.3	138.6
LH74 X LH51	0.43	1.30	39.1	104.4	143.6
LH74 X LH82	0.45	1.35	37.0	104.0	141.0
P-Value	93	89	99	76	28
BLSD (.05)			3.9		
N-Rate					
0	0.32	1.14	26.6	71.5	98.1
80	0.45	1.36	38.7	115.7	154.5
160	0.51	1.47	43.4	126.7	170.2
P-Value	99	99	99	99	99
BLSD (.05)	0.02	0.04	3.0	5.6	6.7
Hybrid X N-Rate	74	99	89	79	94
Split Plot without the 0 # N-Rate					
K-Rate					
0	0.49	1.41	40.2	121.0	161.3
100	0.47	1.43	40.4	119.9	160.4
P-Value	52	32	7	34	14
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.45	1.42	35.5	123.1	158.7
Pioneer 3475	0.46	1.42	39.3	121.5	160.8
LH74 X LH51	0.48	1.36	43.6	115.2	158.9
LH74 X LH82	0.52	1.48	42.7	122.1	164.9
P-Value	99	99	99	99	90
BLSD(.05)	0.01	0.03	2.0	4.8	
N-Rate					
80	0.45	1.39	37.8	117.0	154.9
160	0.51	1.45	42.7	123.9	166.7
P-Value	99	99	99	99	99
Inhibitor					
None	0.49	1.41	40.6	120.9	161.5
N-Serve	0.48	1.43	40.4	120.1	160.1
P-Value	88	87	54	37	52
Hybrid X N-Rate	96	99	93	99	90
Hybrid X Inhibitor	12	17	56	63	79
N-Rate X Inhibitor	65	92	92	5	49
Hybrid X N-Rate X Inhibitor	98	76	72	88	83
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	51	30	48	79	57
N-Rate X K-Rate	99	92	99	99	99
Hybrid X N-Rate X K-Rate	60	19	74	70	86
Inhibitor X K-Rate	43	30	65	71	80
Hybrid X Inhibitor X K-Rate	96	89	72	91	88
N-Rate X Inhibitor X K-Rate	6	21	65	33	54
Hybrid X N-Rate X Inhibitor X K-Rate	99	49	99	64	97

EVALUATION OF THE EFFECT OF POTASH FERTILIZER APPLIED IN RIDGES ON THE EARLY GROWTH AND YIELD OF CORN

George Rehm, Andy Scobbie, Greg Cremers, and Gyles Randall[1]

ABSTRACT: Farmers who grow corn in ridge-till planting systems wish to place all of the phosphate and potash fertilizer in the ridge during late fall. This study was conducted to determine if practical rates of potash would have any negative impact on yield. High rates of potash applied in the center of the ridge in the preceeding fall had no negative effect on corn emergence, early growth, and yield.

Introduction:

Many farmers who have switched to ridge-till planting systems have complained about problems associated with using starter fertilizers and they seek alternatives. There is equipment available which allows for placement of either liquid or dry fertilizer in a band in existing ridges. This equipment can be used to apply needed phosphate and potash in the ridge in the late fall. There is reason to believe that the use of this practice could substitute for the use of a starter fertilizer at planting.

Objective:

This study was planned and conducted to evaluate the effect of rate of potash fertilizer applied in a band in the center of an existing ridge on the early growth and yield of corn.

Experimental Procedures:

This study was conducted at the Southern Experiment Station at Waseca. The soil pH was 6.1. The phosphorus level was high (28 ppm) and the soil test value for potassium was in the medium range (117 ppm).

The experimental area was planted to soybeans in 1988 and ridges were established at that time. Four rates of K_2O, (20, 40, 80, 160 lb./acre) were knifed into the center of the ridges in late October of 1988. The potash bands were at a depth of 3 to 3.5 inches. Adequate N as 82-0-0 was also applied in the fall. Corn was planted in early May of 1989. Recommended practices to assure good corn yields were used throughout the growing season.

Whole plant samples were collected from each plot at approximately 4 weeks after emergence. These plants were dried, weighed, ground, and analyzed for K. Stand counts were also taken at this time. Grain yields were measured in mid-October and corrected to 15.5% moisture.

Results and Discussion:

The data that were collected in this study are summarized in Table 1.

Table 1. The effect of rate of potash fertilizer applied in the center of existing ridges on the growth and yield of corn. Waseca, 1989.

	K_2O Applied (lb./acre)				
Variable	0	20	40	80	160
Stand (plants/20ft.)	34	34	34	35	34
Weight of 6 Young Plants (gm)	26.5	31.0	29.8	29.3	30.0
K Concentration Young Plants (%)	2.69	3.10	3.14	2.92	3.12
K Uptake by 6 Young Plants (mg)	736	961	934	851	936
Grain Yield lb./acre	160.1	166.9	161.8	161.6	162.3

Statistical analysis shows that the rate of potash applied had no significant effect on any of the variables that were measured. There was no negative effect on corn emergence and early growth. The K concentration in young plants, K uptake by young plants, and grain yield were not affected. With soil test values for K in the medium to high range, these results could be anticipated.

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BANDED APPLICATION OF POTASH FERTILIZER FOR CORN IN A RIDGE-TILL PRODUCTION SYSTEM

George Rehm, Greg Cremers, Andy Scobbie[1]

ABSTRACT: In recent years, potassium deficiency symptoms have appeared in corn planted in a ridge-till system even though soil test values for potassium are in the high range. In this trial, the application of K_2O in a band in the center of the ridge increased corn grain yield. Uptake of potassium was also enhanced by the banded application of K_2O. This study will be continued to monitor effects on yield and growth of soybeans.

Introduction:

In recent years, there have been numerous reports of corn which exhibits potassium (K) deficiency symptoms when grown in ridge-till production systems. These symptoms occurred even though soil test K values were considered to be in the high or very high range. The severity of the symptoms were thought to be related to hybrid. The problem was not confined to specific soils or specific environments. Reports of the problem have come from a diversity of corn producing regions in Minnesota.

Banded application of essential plant nutrients has proven to be an effective practice for supplying nutrients in a fertilizer program for corn. With equipment which is currently available, it is possible to place fertilizer bands at various positions in relation to the seed. this is especially true for ridge-till planting systems.

The problem described above had not been addressed in previous research programs. Therefore, the study described in the sections that follow was designed to develop an answer to this widespread problem.

Objectives:

Recognizing the needs just cited, this study was conducted to:

1. Measure the effect of K_2O applied in a band on corn yield in a ridge-till planting system where soil test levels for K are high.
2. Determine if the response, if any, to applied potash is related to variety.
3. Measure the effect of rate of applied potash on K uptake by corn in these planting systems.

Experimental Procedure:

This study was initiated in a farmer's field in Murray County in the fall of 1988. Soybeans were grown on ridges in 1988. After soybean harvest, various rates of K_2O (0, 40, 80, 160 lb./acre), supplied as 0-0-60 were knifed into the center of the existing ridges. With the equipment available, the K_2O was placed at a depth of 3 to 3 1/2 inches below the soil surface.

The existing ridges were intensively sampled in the fall of 1988 to monitor the variability of pH, P, and K. To complete this sampling, cores were taken from the center of the ridge then at 3, 6, 9, 12 and 15 inches from the center. Each core was then sectioned into depths of 0-3, 3-6, 6-9, and 9-12 inches. This intensive sampling was conducted at 16 locations in the plot area and the soil composited for analysis. Results of these analyses are summarized in Tables 1, 2, and 3.

Corn was planted on April 24 at a population of 28,112 plants per acre. Three hybrids (Pioneer 3902, Pioneer 3732, Pioneer 3737) were combined with the applied rates of K_2O in a complete factorial design arranged in a randomized complete block design with 4 replications in the field. Weed control was achieved by banding Lasso over the row at planting.

Plant samples were collected from all plots at 3 times during the growing season. These samples were dried, weighed, ground, and analyzed for K. The first sample consisted of 10 plants/plot and was taken on June 7. Six plants were taken from each plot on June 21 for the 2nd sampling. Ear leaf samples were collected at silking.

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[1] Extension Soil Scientist, Assistant Scientist, and Junior Scientist, Soil Science Dept., respectively.

Whole plants from selected treatments were excavated on June 20 in order to measure the effect of both hybrid and applied K_2O on early root growth. To do this, a steel box (6 in. x 15 in. x 18 in.) was pushed into the soil so that the box surrounded on plant and its root system. The box was pushed into the soil to a depth of about 12 inches. The box was then pulled from the soil and soaked in water over night. Soil was carefully washed away from the root system with a fine spray of water. The resulting root samples were dried, weighed, ground, and analyzed for K. Uptake of K by the young root systems was also computed. For the root investigation, plants of each variety were taken from plots which received no K_2O as well as the plots which had been fertilized with 80 lb. K_2O/acre. Only 2 replications were sampled because of a shortage of equipment.

Grain yields were measured in late September and corrected to 15.5% moisture. Selected treatments were applied in the fall of 1989 and soybeans will be planted in the experimental area in 1990.

Results and Discussion

Soil Test Values

In general, the pH values increased with depth regardless of the position from the center of the ridge (Table 1). Values were neutral to slightly acid.

Table 1. Soil pH in a ridge-till planting system. Fall 1988

	Distance From the Row (in.)					
Depth	0	3	6	9	12	15
in.	pH					
0-3	6.2	6.3	6.2	6.2	6.1	6.1
3-6	6.3	6.2	6.2	6.3	6.2	6.5
6-9	6.4	6.4	6.5	6.7	6.8	6.9
9-12	6.8	6.8	6.8	7.0	7.1	7.1

Soil test values for P were very high close to the soil surface (0-3 in.). The soil test P values also decreased with depth and distance from the row.

Table 2. Soil test values for P in a ridge-till planting system. Fall 1988.

	Distance From the Row (in.)					
Depth	0	3	6	9	12	15
in.	ppm P*					
0-3	44	43	49	55	50	48
3-6	36	41	42	43	26	22
6-9	30	31	27	20	12	17
9-12	15	12	13	9	7	7

* Soil test P measured by the Bray and Kurtz #1 procedure.

Soil test values for K are listed in Table 3. As was the case with P, soil test values were high close to the soil surface and decreased with depth and distance from the row. The average for the 0-9 inch depth to a distance of 15 inches from the row was 145 ppm. This is considered to be a high soil test value by current standards.

Table 3. Soil test values for K in a ridge-till planting system. Fall, 1988.

	Distance From the Row (in.)					
Depth	0	3	6	9	12	15
in.	- - - - - - - - - - - - - ppm K[*] - - - - - - - - - - - -					
0-3	173	157	166	187	194	179
3-6	141	138	146	139	125	118
6-9	138	132	126	113	101	128
9-12	111	107	105	103	105	107

[*] Soil test K measured by the ammonium acetate procedure

Early Growth and Yield

Rate of K_2O applied had a significant effect on the early growth of corn and grain yield. Early growth measured at the first sampling and yield were also significantly affected by hybrid. Plant growth measured at the second sampling was not affected by hybrid. There was no significant interaction between rate of applied K_2O and hybrid for any of the growth measurements. Therefore, the effects of K_2O rate and hybrid are summarized in Tables 4 and 5, respectively.

Table 4. Effect of rate of K_2O applied on early growth and grain yield.

K_2O Applied	Early Growth 1st Sample	Early Growth 2nd Sample	Grain Yield
lb./acre	wt. of 10 plants,g	wt. of 6 plants,g	bu./acre
0	6.8 c[*]	28.9 c	150.9 b
40	9.4 b	41.6 b	164.2 a
80	10.2 a b	43.6 a b	163.1 a
160	10.9 a	45.9 a	162.9 a

[*] Treatment means in any column followed by the same letter are not significantly different at the .05 confidence level.

Table 5. The effect of corn hybrid on early growth and grain yield.

Hybrid	Early Growth 1st Sample	Early Growth 2nd Sample	Grain Yield
	wt. of 10 plants,g	wt. of 6 plants,g	bu./acre
Pioneer 3902	8.2 b[*]	40.5 a	150.3 c
Pioneer 3732	9.8 a	38.8 a	158.1 b
Pioneer 3737	10.0 a	40.7 a	172.5 a

[*] Treatment means in any column followed by the same letter are not significantly different at the .05 confidence level.

When averaged over the 3 hybrids used, early growth increased curvilinearly with rate of K_2O applied. The response was similar for both the first and second sampling. Grain yield did not show the curvilinear response. The use of 40 lb. K_2O per acre was adequate for optimum yield. Although the early growth may have been affected by the ability of corn to take up K early in the season, root development was apparently adequate to absorb some K supplied by the soil. Consequently, the use of 40 lb. K_2O per acre was adequate for optimum yield of all hybrids. Even though the soil test value for K was high, there was still a response to K_2O. As yet, there is no explanation for this.

When averaged over the rate of K_2O applied, hybrid had as significant effect on the growth measured at the first sampling and yield (Table 5). The early growth of Pioneer 3902 was significantly less than growth of Pioneer 3732 and Pioneer 3737 which were not significantly different from each other. This is probably due to the fact that the Pioneer 3902 is a short-season hybrid.

The Pioneer 3902 also produced the lowest yield. The Pioneer 3737 produced the highest yield with the yield of Pioneer 3732 being intermediate.

Potassium Concentration and Uptake

Both rate of applied K_2O and hybrid had a significant effect on the K concentration in plant tissue and subsequent uptake. When averaged over the 3 hybrids used, the K concentration in both the young plants and ear leaf tissue increased with rate of K_2O applied (Table 6). The uptake of K computed from K concentration and plant weight data also increased with each rate of applied K_2O. The concept of luxury consumption of K has been well documented and is illustrated in this study by the K uptake data.

Table 6. The effect of rate of applied K_2O on K concentration in corn tissue and K uptake by young plants.

K_2O Applied	1st Sampling K Conc.	1st Sampling K Uptake	2nd Sampling K Conc.	2nd Sampling K Uptake	Ear Leaf K Conc.
lb./acre	%	mg in 10 plants	%	mg in 6 plants	%
0	.91 d[*]	63 d	1.08 d	321 d	.95 d
40	2.18 c	204 c	1.49 c	621 c	1.21 c
80	2.57 b	258 b	1.75 b	763 b	1.37 b
160	3.06 a	335 a	2.08 a	950 a	1.46 a

[*] Treatment means in any column followed by the same letter are not significantly different at the .05 confidence level.

When averaged over rates of applied K_2O, the hybrid had a significant effect on concentration of K in plant tissue and K uptake (Table 7). The K concentration in the tissue of each hybrid was significantly different from the K concentration of the other two. The ranking was the sampling was the same for all stages. The concentration was lowest in Pioneer 3732 and highest in Pioneer 3737. This could be due to a fixed trait or the result of a more poorly developed root system. The data collected do not provide for an explanation of this observation.

Potassium uptake by young plants was lowest for the Pioneer 3732 hybrid. This is the result of reduced weight and a lower concentration of K in the plant tissue.

Table 7. The effect of corn hybrid on K concentration in corn tissue and K uptake by young plants.

Hybrid	1st Sampling K Conc.	1st Sampling K Uptake	2nd Sampling K Conc.	2nd Sampling K Uptake	Ear Leaf
	%	mg in 10 plants	%	mg in 6 plants	%
Pioneer 3902	2.23 b[*]	193 b	1.71 b	715 a	1.23 b
Pioneer 3732	1.92 c	200 b	1.28 c	524 b	1.15 c
Pioneer 3737	2.40 c	252 a	1.80 a	753 a	1.36 a

[*] Treatment means in same column followed by the same letters are not significantly different at the .05 confidence level.

Root Growth and K Uptake

Because of a limited amount of equipment, root samples were only taken from each variety where the K_2O rates were 0 and 80 lb./acre. Two of the four replications were sampled. Therefore, there was no statistical analysis of the data. The data collected are summarized in Table 8.

Table 8. The effect of K_2O applied and corn hybrid on root growth, K concentration in the root tissue, and K uptake by the roots of a young corn plant.

Hybrid	K_2O Applied	Root Weight	K Conc.	K Uptake
	lb./acre	gm	%	mg
Pioneer 3902	0	4.5	.189	8.5
	80	5.5	.197	10.8
Pioneer 3732	0	3.0	.239	7.2
	80	5.0	.215	10.8
Pioneer 3737	0	4.5	.213	9.6
	80	5.0	.187	9.4

The root weight of all hybrids appeared to be increased by the application of K_2O. The concentration of K in the root tissue was variable. The lowest concentrations were associated with the highest weights which is a result of plant dilution. The concentration of K in the root system was not as high as in the plant tissue. Uptake of K seemed to be higher for the 80 lb./acre K_2O rate. This is a reflection of K_2O on early plant growth. Much more research is needed to study the effect of potash fertilizer and corn hybrid on the growth of roots of young corn plants.

Summary

The application of potash fertilizer to the center of the existing ridge certainly had a positive effect on corn production. A substantial yield increase for three hybrids was measured even though the soil test value for K was in the high range.

The data collected in this study do not provide evidence for the cause of the problem. Much more research is needed before the cause can be identified and corrected.

FIELD EVALUATION TO DETERMINE BEST FLUID STARTER RATIOS FOR CORN

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

ABSTRACT: Starter fertilizers have been important to corn growers in Minnesota for many years. This study was conducted to evaluate the effect of rate of N applied in a starter and the N:P_2O_5 ratio of a starter on early growth and yield of corn. The N:P_2O_5 ratios used had no effect on early growth, nutrient uptake by young plants and grain yield. Grain yield increased with rate of applied P_2O_5 at 1 of 2 sites. The rate of N applied in a starter had no effect on emergence, early growth, and grain yield.

Background:

Use of a starter fertilizer is a key management tool for corn production in Minnesota. Although it is possible to formulate liquid starters having several grades, a few grades have become very popular for use in corn production. They have been effective. However, with the emphasis on efficiency of nutrient use, several questions revolving around the analysis of liquid starters have been raised.

Recent research from Alabama has questioned the agronomic value of the conventional 1:3 N:P_2O_5 ratio for starter fertilizers used for corn production. There is also some question about the importance of various nutrients that can be supplied in a starter fertilizer. There is some argument that a starter containing N, P, K, S, and Zn may be superior to a starter which contains only N and P. This contention must be tested with field research trials.

Growers are also concerned about the rate of N and P_2O_5 that can be applied in a starter fertilizer. There is a small possibility that high rates of N applied in this way could cause problems. These concerns also need to be addressed in field research trials.

Objective:

Recognizing the research needs just cited, this study was planned and initiated to:

1. Measure the impact of the N:P_2O_5 ratio in a liquid starter fertilizer on corn production.
2. Determine the effect of the nutrients which may be supplied in a starter fertilizer on corn production.
3. Evaluate the rate of N and/or P_2O_5 applied in a starter fertilizer on corn growth and yield.

Experimental Procedure:

This study was conducted at two locations in Minnesota in 1989. The relative soil test level for P was used as a major deciding factor in site selection. Soil samples were collected from each site prior to treatment application for the purpose of site characterization. By current Minnesota standards, the P level at the Renville County site was considered to be medium to high (Table 1) while the P level at the McLeod County site was in the low range (Table 2).

Table 1. Relevant soil properties at the Renville County site

	Depth (in.)					
Measurement	0-6	6-12	12-24	24-36	36-48	48-60
pH	7.8	7.8	7.8	7.7	7.8	7.8
P (Bray #1), ppm	13.5	11.5	5.5	7.5	9.5	8.5
P (Olsen), ppm	9.5	5.5	1.5	2.5	4.0	4.5
K, ppm	115	-	-	-	-	-
O.M., %	6.4	-	-	-	-	-
Zn, ppm	.9	-	-	-	-	-
NO_3-N, lb./acre	34	32	17	13	12	32
soil texture:	silty clay loam					

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[1] Extension Soil Scientist, Assistant Scientist, and Junior Scientist, Soil Science Department, respectively.

The soil test values for P decrease with depth. This is typical of soils in western Minnesota. The Zn test is in the medium range.

Table 2. Relevant soil properties at the McLeod County site

	Depth (in.)					
Measurement	0-6	6-12	12-24	24-36	36-48	48-60
pH	7.8	7.7	7.9	8.0	8.0	8.0
P (Bray #1), ppm	5.3	3.5	2.4	1.8	1.8	1.7
P (Olsen), ppm	7.4	2.8	1.4	.9	1.2	1.2
K, ppm	115	-	-	-	-	-
O.M., %	6.4	-	-	-	-	-
Zn, ppm	.8	-	-	-	-	-
NO_3-N, lb./acre	38	57	82	33	22	27
soil texture:	silty clay loam					

Soil test values for P are in the low range and, in agreement with the Renville County site, decrease with depth. The Zn test is also in the medium range.

Although the amount of N applied in a starter fertilizer varied with treatment, the total amount applied to all treatments was constant at 180 lb./acre for both sites. This N (supplied as 46-0-0) was broadcast and incorporated before planting.

The management practices used at each site are outlined below:

	Renville County	McLeod County
previous crop:	soybeans	soybeans
primary tillage:	fall chisel	fall chisel
planting date:	5/10/89	5/3/89
variety:	Pioneer 3737	Pioneer 3737
planted population:	27,000	27,000
herbicide:	Lasso (incorporated) 2, 4-D (post emergence)	Lasso (incorporated) 2, 4-D (post emergence)

Fluid fertilizers formulated by Nutra-Flo Chemical, Sioux City, Iowa were used to supply the needed nutrients. This assistance is gratefully acknowledged.

Stand counts were taken from all plots at about 4 weeks after emergence. Six whole plants were also taken from each plot at this time. These plants were dried, weighed, ground, and analyzed for N, P, K, S, and Zn. Uptake of these nutrients was computed from plant weight and nutrient concentration data.

Grain yields were measured in mid-October and corrected to 15.5% moisture.

At each site, treatments were placed in the field in a randomized complete block design with 4 replications. Several statistical procedures were used in the analysis of the data. These procedures will be briefly described in the Results and Discussion section.

Results and Discussion:

The 18 treatments that were applied in the field were used to complete several small studies. Each of these studies will be discussed separately in the sections that follow.

N:P_2O_5 Ratio

Three ratios were evaluated at 2 rates of P_2O_5 (20, 40 lb./acre). Yield, early growth, and stand count data are summarized in Table 3. The impact of these ratios on the nutrient concentration in young corn plants is summarized in Table 4, and uptake values are provided in Table 5.

Table 3. The effect of $N:P_2O_5$ ratio on corn grain yield, early growth and emerged stand measured at 4 weeks after emergence.

$N:P_2O_5$ Ratio	County and P_2O_5 Rate (lb./acre)			
	Renville		McLeod	
	20	40	20	40
Grain Yield: (bu./acre)				
.4 : 1.0	164 a*	157 a	153 a	176 a
1.0 : 1.0	161 a	161 a	147 a	174 a
2.0 : 1.0	162 a	162 a	147 a	177 a
Early Growth : (weight of 6 plants, gm)				
.4 : 1.0	14.3 a	13.0 a	14.8 a	18.5 a
1.0 : 1.0	13.5 a	13.0 a	12.8 b	15.0 b
2.0 : 1.0	13.5 a	13.5 a	10.0 c	11.5 c
Emerged Stand: (plants/20 ft.)				
.4 : 1.0	28 a	25 a	29 a	30 a
1.0 : 1.0	27 a	27 a	28 a	29 a
2.0 : 1.0	26 a	26 a	30 a	29 a

*Treatment means in any column at each site are not significantly different at the .05 confidence level.

At the Renville County site, the $N:P_2O_5$ ratio had no significant effect on any of these variables measured. This was true for both rates of applied phosphate indicating no response to the rate of P_2O_5 used. Considering the medium to high soil test for P, this would be expected.

The $N:P_2O_5$ ratio had no significant effect on grain yield at the McLeod County site. Yields, however, did increase as the phosphate rate increased from 20 to 40 lb./acre. With the low soil test values for P, this yield increase would be expected.

The weight of the young corn plants decreased as the $N:P_2O_5$ ratio increased at the McLeod County site. This observation was consistent for both rates of applied phosphate. This decrease was not expected and cannot be readily explained by the data collected in this study. This decreased early growth, however, was not reflected in yield and the importance of this observation is, therefore, questioned.

Table 4. The effect of $N:P_2O_5$ ratio on the nutrient concentration in young corn plants.

County	P_2O_5 Rate	$N:P_2O_5$ Ratio	Nutrient N	P	K	S	Zn
	lb./acre		- - - - - -	- - %	- -	- - - - -	ppm
Renville	20	.4:1.0	4.16	.420	3.22	.260	28.6
	20	1.0:1.0	4.22	.407	3.35	.263	28.7
	20	2.0:1.0	4.18	.392	3.03	.257	27.9
Renville	40	.4:1.0	4.18	.396	3.17	.257	28.7
	40	1.0:1.0	4.23	.407	2.90	.257	29.7
	40	2.0:1.0	4.20	.390	3.11	.256	28.6
McLeod	20	.4:1.0	3.96	.318	2.69	.279	27.0
	20	1.0:1.0	4.08	.326	2.65	.283	29.1
	20	2.0:1.0	3.88	.289	2.39	.274	29.2
McLeod	40	.4:1.0	4.09	.332	2.04	.288	28.1
	40	1.0:1.0	4.05	.341	2.11	.288	29.9
	40	2.0:1.0	3.97	.317	2.28	.277	29.2

Except for the P concentration at the Renville County site when the applied phosphate was 20 lb./acre, the $N;P_2O_5$ ratio had no significant effect on the concentration of N, P, K, S, and Zn in the whole plant tissue. The P concentration decreased linearly with an increase in the $N:P_2O_5$ ratio at the Renville County site. There, as yet, is no apparent explanation for this observation. There was also no significant increase in P concentration as the rate of applied phosphate was increased from 20 to 40 lb./acre. The 20 lb./acre rate was apparently adequate for growth of the young plants.

Table 5. The effect of N:P_2O_5 ratio on the nutrient uptake by young corn plants.

County	P_2O_5 Rate	N:P_2O_5 Ratio	N	P	Nutrient K	S	Zn
	lb./acre		- - - - - -	mg in 6 plants	- - - - - -		
Renville	20	.4:1.0	594	60	476	37	.4
	20	1.0:1.0	572	55	450	35	.4
	20	2.0:1.0	564	53	409	35	.4
Renville	40	.4:1.0	545	52	417	33	.4
	40	1.0:1.0	551	53	383	33	.4
	40	2.0:1.0	567	53	426	34	.4
McLeod	20	.4:1.0	584	47	393	41	.4
	20	1.0:1.0	521	42	330	36	.4
	20	2.0:1.0	388	29	245	28	.3
McLeod	40	.4:1.0	758	62	373	53	.5
	40	1.0:1.0	612	53	307	44	.5
	40	2.0:1.0	457	37	259	32	.3

Nutrient uptake by the young plants was not affected by the N:P_2O_5 ratio at the Renville County site. For both rates of applied phosphate, uptake at the McLeod County site decreased as the N;P_2O_5 ratio increased. This is mainly due to the decrease in plant growth (Table 3).

N Rate in a Starter

No phosphate was used in the starter fertilizer for this study. This would allow for a true measurement of the effect of N rate. The rates of K_2O, S, and Zn were held constant at 5, 4, and .8 lb./acre respectively. The N was applied at rates of 8, 16, 20, 40, and 80 lb./acre.

Grain yields, whole plant weights and stand counts are summarized in Table 6. The plant weight listed is the total weight of 6 corn plants. Regression analysis was used to determine the effect of the rate of N applied in the starter fertilizer band.

Table 6. The effect of N rate in a starter fertilizer on grain yield, weights of young corn plants, and stand counts at about 4 weeks after emergence.

	County					
	Renville			McLeod		
N Rate	Grain Yield	Weight of 6 Plants	Corn Plants	Grain Yield	Weight of 6 Plants	Corn Plants
lb./acre	bu/acre	gm	#/20 ft.	bu/acre	gm	#/20 ft.
0	159	13.5	26	134	11.0	31
8	148	12.8	26	149	11.0	29
16	152	12.8	27	144	12.0	27
20	156	11.8	27	141	12.0	28
40	149	11.8	26	159	11.5	27
80	160	12.8	27	140	12.5	27
CV, %	9.9	18.6	5.1	20.1	25.0	6.0

The rate of fertilizer N in the starter band had no significant effect on grain yield, early growth of young plants as measured by plant weight and corn emergence at both sites. There are substantial differences in treatment averages for yield at the McLeod County site. Because of variability in the data (CV = 20.1%), these differences are not statistically significant.

Table 7. The effect of N rate in a starter fertilizer on the concentration of nutrients in young corn plants.

N			Nutrient		
Rate	N	P	K	S	Zn
lb./acre	- - - - - - - - - - -	%	- - - - - - - - - - -		ppm
Renville Co.:					
0	4.13	.395	3.48	.252	28.1
8	4.11	.386	3.31	.262	28.9
16	4.22	.395	2.97	.259	28.8
20	4.29	.400	3.04	.261	28.3
40	4.25	.400	3.13	.268	28.2
80	4.13	.394	3.33	.254	27.4
CV: %	2.80	5.83	21.20	4.37	16.00
McLeod Co.:					
0	3.82	.294	2.54	.270	28.4
8	3.91	.299	2.53	.274	29.6
16	4.01	.301	2.71	.281	28.1
20	3.93	.311	2.82	.276	29.5
40	3.95	.297	2.19	.273	29.2
80	3.86	.290	2.64	.269	29.9
CV: %	5.36	13.47	17.07	4.50	7.73

The effect of rate of N applied in a starter band on the nutrient concentration in young corn plants is summarized in Table 7. At the Renville County site, the concentration of both N and S increased curvilinearly with rate of applied N. The concentrations of P, K, and Zn were not affected. Since increases in concentrations were not reflected in yield, the practical significance of these increases in concentration are not well defined at this time.

In contrast to the Renville County site, rate of N in the starter band had no significant effect on the nutrient concentration in young corn plants at the McLeod County site.

Nutrient uptake was computed by multiplying plant weight by concentration. These values are summarized in Table 8.

Table 8. The effect of rate of N in a starter fertilizer on uptake of selected nutrients in young corn plants.

N			Nutrient		
Rate	N	P	K	S	Zn
lb./acre	- - - - - - - - - - -	mg in 6 plants	- - - - - - - - - - -		
Renville Co.:					
0	558	53.5	476	33.9	.4
8	526	49.1	427	33.3	.4
16	539	50.2	382	32.9	.4
20	503	47.1	365	30.6	.3
40	500	47.4	383	31.2	.3
80	529	50.4	438	32.4	.3
CV: %	19.8	20.7	34.80	18.0	10.3
McLeod Co.:					
0	426	34.2	264	29.7	.3
8	429	33.0	274	30.1	.3
16	486	37.0	319	33.8	.3
20	472	37.4	340	33.0	.4
40	463	35.8	251	31.9	.3
80	487	37.1	328	33.9	.4
CV: %	5.36	13.47	17.07	4.50	7.73

Uptake of N, P, K, S, and Zn was not affected by rate of N applied in a starter band at both sites. All plots received ample N that was broadcast and incorporated before planting. So, all plants had access to ample amounts of N and major effects resulting from the rate of N applied in a starter should not be anticipated.

Impact of K, S, and Zn

The objective of this study was to measure the effect of each nutrient, applied in a starter band, on grain yield, early growth of corn, and the emerged stand. The results of this study are summarized in Table 9. Except for the control, the rate of N and P_2O_5 was held constant at 20 lb./acre. The Duncan's Multiple Range Test was used for mean separation.

Table 9. The effect of K, S, and Zn applied in a starter fertilizer band on grain yield, early growth, and emergence.

Nutrient Applied						Grain	Weight of	Emerged
N	P_2O_5	K_2O	S	Zn		Yield	6 plants	Stand
- - - - lb./acre - - - -						bu./acre	gm	plants/20 ft.
Renville Co:								
0	0	0	0	0		159 a*	13.5 a	26 a
20	20	5	4	0		161 a	12.0 a	26 a
20	20	5	0	.8		167 a	14.3 a	27 a
20	20	0	4	.8		165 a	13.0 a	26 a
20	20	0	0	0		162 a	15.0 a	27 a
20	20	5	4	.8		161 a	13.5 a	27 a
20	0	5	4	.8		156 a	11.8 a	27 a
					CV:	3.7	14.3	9.4
McLeod Co:								
0	0	0	0	0		117 a	12.3 a	28 a b
20	20	5	4	0		170 c	15.5 a	30 a
20	20	5	0	.8		163 b c	16.0 a	27 b
20	20	0	4	.8		152 b c	12.3 a	29 a b
20	20	0	0	0		146 b	12.3 a	28 a b
20	20	5	4	.8		147 b	12.8 a	28 a b
20	0	5	4	.8		140 a b	12.0 a	28 a b
					CV:	13.7	22.0 a	5.9

* Treatment means in any one column at each site which are followed by the same letter are not significantly different at the .05 confidence level.

Corn yield and early growth at the Renville County site were not affected by any nutrient applied in the starter band. There was no yield increase when the starter was used. The soil test level for both P and Zn was in the medium to high range and a response to the use of a starter fertilizer could be expected in some years. Spring soil conditions were warm and moist. This reduces the possibility that a starter fertilizer might increase yield at these soil test levels.

The starter usage had no damaging effect on the emerged stand. This would be expected for this soil type.

In contrast to Renville County, use of a starter fertilizer produced a substantial improvement in yield at the McLeod County site. There was a substantial amount of variability in yields and this may have masked other treatment effects. The use of the starter fertilizer had no significant effect on the weight of young plants (weight of 6 plants, gm). With a low soil test for P, a response to applied phosphate would be expected. The soil test level for Zn was marginal and there was no significant yield increase when Zn was added to the starter.

Summary and Conclusions

It's not possible to make broad and sweeping conclusions after one year of study at only two sites. Yet, there were some effects that were observed. These are summarized below.

- The N:P_2O_5 ratio in the starter fertilizer did not affect grain yield. This was true for both rates of applied phosphate at each site.
- Grain yield increased as the rate of applied phosphate was increased from 20 to 40 lb./acre at the McLeod County site where the soil test for P was low.
- The early plant growth was inversely related to the N:P_2O_5 ratio at the McLeod County site.
- Emerged stand was not affected by the N:P_2O_5 ratio.
- In general, nutrient uptake by young plants was not affected by the N:P_2O_5 ratio. Nutrient uptake paralleled the effects on early growth.
- The rate of N applied in a starter fertilizer had no significant effect on grain yield, early growth, and emergence.
- Use of the starter fertilizer increased grain yield at one of the two sites. At the responsive site, soil test P was low. The yield increase was attributed to the N and P_2O_5 in the starter. There was no benefit from the addition of K, S, and Zn.

Acknowledgement

The assistance of Nutra Flo Chemical of Sioux City, Iowa was vital for the success of this study. Their cooperation in the preparation of the various materials saved considerable amounts of time and eliminated the potential for many frustrations.

PRECISION PLACEMENT FOR IMPROVED EFFICIENCY OF PHOSPHATE USE WHEN GROWING CORN WITH A RIDGE-TILL PLANTING SYSTEM

George Rehm, Greg Cremers, Andy Scobbie, Sam Evans, and Wally Nelson[1]

ABSTRACT: Use of a starter fertilizer is a good management practice for corn production in a ridge-till planting system. Yet, this can be a problem in years when it is wet at planting time. This study was conducted to evaluate the effect of banded phosphate fertilizer on the growth and yield of corn. Use of 69 lb. P_2O_5 per acre produced optimum yield. Placement had no significant effect on yield. The application of phosphate in a band in the center of the ridge in the previous fall appears to be a promising alternative to a starter fertilizer in a ridge-till planting system.

Introduction:

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

Past research has shown that rates of fertilizer P needed for maximum economic production can be reduced substantially if banded rather than broadcast applications of phosphate fertilizer are used. The lower rates needed to achieve the same yield translate into reduced costs which, in turn, improves the potential for increased farm profitability. In addition to providing for increased efficiency of P use, placement of phosphate fertilizer in a band can reduce concerns for environmental quality which center on the movement of broadcast phosphate attached to soil particles which might reach surface waters via erosion.

The effect of distance between the corn seed and the rate of band applied P needed for optimum production has not been addressed. The root growth model of Dr. Barber focuses more on the volume of soil that needs to be fertilized to produce maximum efficiency of fertilizer use. Since root surface area and concentration of P and/or K near the root are important components of this model, one can speculate that the rate of phosphate fertilizer needed for most efficient production could vary with the distance between the seed and the fertilizer. This speculation needs to be verified in field trials.

Objectives:

In an attempt to improve the efficiency of P use by corn planted in a ridge-till planting system, this study is being conducted to:

1. Measure the effect of distance between seed and phosphate fertilizer on the early growth of corn and subsequent grain yield.
2. Determine if repeated application of banded P in a localized area will improve the efficiency of P use by corn.
3. Monitor uptake of P by corn during the growing season as influenced by distance between the seed and phosphate fertilizer applied at several rates.
4. Determine the effect of initial soil test level for P and environmental conditions on the efficiency of use of fertilizer P applied in bands.

Experimental Procedure:

In 1989, this study was conducted at the West-Central Experiment Station at Morris and the Southwest Experiment Station at Lamberton. At Morris, treatments were reapplied to the treatments established for the 1988 growing season. Two sites were used at Lamberton. At one site, treatments were reapplied to the treatments established for the 1988 growing season. The same treatments were applied to a second site which had not received P fertilizers for a number of years.

At each site, 0-46-0 was used to supply 23, 46, and 69 lb P_2O_5 per acre. Four methods of phosphate placement were compared at each experimental site. These were:

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[1] Extension Soil Scientist, Assistant Scientist, Junior Scientist, Soil Science Department, Soil Scientists, West-Central Experiment Station and Southwest Experiment Station, respectively.

1. Broadcast

2. Starter (a band below and to the side of the seed at planting)

3. Subsurface band at a depth of 3.5 to 5.0 inches placed in the center of the existing ridge. This application of phosphate was made in the fall. This is identified as the ridge center treatment.

4. Subsurface band at a depth of 3 to 4 inches at a distance of 10-12 inches from the row. This band was placed to one side of the existing ridge. This application of phosphate was also completed each fall. This is identified as the ridge shoulder treatment.

The treatments used were arranged in a complete factorial design placed in the field in a randomized complete block arrangement with 4 replications. A control (non-fertilized) treatment was included, but was not part of the complete factorial design for purposes of statistical analysis. In addition to the treatments in the factorial design, various combinations of phosphate placement were compared. For these combinations, the phosphate rate was held constant at 46 lb. P_2O_5 per acre with 23 lb. P_2O_5 per acre applied in each portion of the combination.

Soil samples from the added site at Lamberton were collected in 1-foot intervals to a depth of 5 feet prior to fertilizer application. The results of the analysis of soil samples from all sites are summarized in Table 1.

The ridges constructed in the fall of 1987 , for the 1988 and 1989 growing seasons, were maintained. Corn was planted in late April or early May at all sites. Management practices, such as plant population, hybrid, and nitrogen rate, were selected to provide for high yields. Nitrogen rate was 120 lb./acre at all sites and a uniform application was made to all plots.

Whole plant samples were collected from each plot at approximately 4 weeks after emergence. Six plants were taken from the center rows. The plot size was 10 ft. x 55 ft. These samples were dried, weighed, ground, and analyzed for P. Uptake of P by the young corn plants was computed from these measurements. Ear leaf samples were collected at silking, dried, ground, and analyzed for P. Grain yields were measured in mid-October and corrected to the 15.5% moisture base.

Table 1. Relevant soil properties for the experimental sites.

Soil			Site*	
Property	Depth	Morris	Lamberton(88)	Lamberton(89)
pH	0-6	8.1	6.4	6.5
	6-12	8.1	6.5	6.4
	12-24	8.2	7.3	7.2
	24-36	8.2	7.8	8.0
	36-48	8.4	8.1	8.1
	48-60	8.3	8.2	8.1
P**, ppm	0-6	5.5	5.1	2.7
	6-12	6.9	4.1	1.3
	12-24	3.8	2.8	.8
	24-36	.6	3.1	1.8
	36-48	.5	3.5	2.8
	48-60	.5	3.4	3.0
K, ppm	0-6	111	188	137
	6-12	155	147	117
	12-24	118	103	93
	24-36	72	92	67
	36-48	67	90	80
	48-60	93	98	97
Zn, ppm	0-6	2.2	1.0	.6
O.M., %	0-6	4.7	4.3	4.0

* Lamberton (88) = site established for 1988; treatments repeated for 1989
Lamberton (89) = site established for 1989

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

Results and Discussion:

Yield

In 1989, grain yield was increased by rate of P applied at all sites (Table 2). Placement had no significant effect on yield and there was no significant rate x placement interaction. When averaged over placement, grain yields were not increased by the application of either 23 or 46 lb. P_2O_5 per acre at the sites where trials were initiated in 1988 and treatments repeated for 1989 (Morris, Lamberton-88). The application of 69 lb. P_2O_5 per acre did, however, increase yields at these two sites. Compared to the control, all rates of applied phosphate increased yields at the second Lamberton site where the study was initiated in 1989. Yields were equal when the phosphate rate was 23 and 46 lb. per acre. Yields increased when the rate was increased to 69 lb. P_2O_5 per acre.

Table 2. Effect of rate and placement of phosphate fertilizer on corn yield.

	P_2O_5		Site	
Placement	Applied	Morris	Lamberton (88)	Lamberton (89)
	lb./acre	- - - - - - - - - - - bu./acre - - - - - - - - - -		
None	0	145.9	114.3	98.7
Broadcast	23	147.9	110.2	117.4
	46	145.5	119.8	110.8
	69	155.9	117.0	120.2
Starter	23	148.3	113.4	112.8
	46	148.2	117.0	114.0
	69	153.7	115.8	123.4
Ridge Center	23	150.5	114.5	108.1
	46	150.6	115.6	111.7
	69	156.8	121.1	121.9
Ridge Shoulder	23	154.1	116.5	116.8
	46	137.0	119.1	121.2
	69	153.4	124.0	126.9
CV, %	-	6.1	6.8	8.4
Main Effects:				
Rate	0	145.9	114.3	98.7
	23	150.2	113.7	113.7
	46	145.4	117.9	114.4
	69	155.0	119.5	123.1
Placement				
	Broadcast	149.8	115.7	116.1
	Starter	150.1	115.4	116.7
	Ridge Center	152.6	117.1	113.9
	Ridge Shoulder	148.2	119.9	121.6

The various combinations of phosphate placement that were used had a significant effect on yield at the Morris location only (Table 3). Dry weather limited yields at the Lamberton location. Some differences among yields may have been observed if yields had been higher.

Table 3. The effect of phosphate placement combination on corn yield. Total rate of applied phosphate was 46 lb./acre for each combination.

		Site	
Combination	Morris	Lamberton (88)	Lamberton (89)
	- - - - - - - - - - - - - - bu./acre - - - - - - - - - - -		
None	145.8 b	114.3 a	98.7 b
Ridge Center + Broadcast	160.7 a	115.4 a	121.9 a
Ridge Center + Ridge Shoulder	154.5 a b	121.0 a	122.7 a
Starter + Broadcast	150.3 b	114.9 a	113.0 a b
Starter + Ridge Shoulder	150.5 b	118.6 a	121.4 a

At Morris, the highest yields were measured when some of the phosphate was applied in the band in the center of the ridge. Yields were not significantly different from the control when the starter + broadcast and starter + ridge shoulder placements were used.

Except for the starter + broadcast combination, all placement combinations increased yields when compared to the control at the Lamberton (89) site. The combination used had no effect on yield at the Lamberton (88) site. This lack of a significant yield increase is attributed to variability caused, in part, by the dry weather.

Soil test values for P were low at all sites (Table 1) and a response to applied phosphate would be expected. The absence of a larger response to applied P at sites where treatments were repeated is somewhat surprising but cannot be explained at this time.

Weight of Young Plants

The effects of rate and placement on the weight of young corn plants sampled approximately 4 weeks after planting were quite varied and inconsistent (Table 4).

Lower weights were recorded at the Morris site because plants were sampled at an earlier growth stage. Both rate and placement of phosphate affected early growth at this site. The use of 46 and 69 lb. P_2O_5 per acre increased growth when compared to the check and the 23 lb. P_2O_5 per acre treatments. Considering placement, the best growth was measured when the P_2O_5 was placed in the center of the ridge. The lowest early growth occurred when the phosphate was applied on the shoulder of the ridge. The effects of broadcast and starter placements were intermediate.

Neither rate of applied phosphate nor placement had a significant effect on early growth at the Lamberton (88) site. The extremely dry weather early in the season caused a great deal of variability and this variability may have masked treatment effects.

Phosphate placement, but not rate, affected early growth at the Lamberton (89) site. Lowest plant weights were associated with the broadcast and starter placements. The best early growth was produced by the ridge center and ridge shoulder placements.

The effects of combinations of phosphate placement were also quite varied (Table 5). Using the Duncan's Multiple Range Test for mean separation, placement combination had no significant effect on early growth at Morris. At both Lamberton sites, the best early growth occurred where some of the phosphate was applied in the center of the ridge.

Table 4. Effect of rate and placement of phosphate fertilizer on the weight of young corn plants.

Placement	P_2O_5 Applied	Site Morris	 Lamberton(88)	 Lamberton(89)
	lb./acre	- - - - - - - weight of 6 plants, gm - - - - - - -		
None	0	9	65	56
Broadcast	23	8	92	55
	46	10	71	59
	69	12	72	48
Starter	23	9	76	53
	46	13	82	59
	69	10	84	58
Ridge Center	23	11	68	61
	46	12	91	63
	69	12	91	68
Ridge Shoulder	23	9	72	62
	46	9	78	61
	69	9	97	63
CV, %	-	14.2	15.5	12.9
Main Effects:				
Rate	0	9	65	56
	23	9	77	58
	46	11	81	61
	69	11	86	59
Placement				
Broadcast		10	78	54
Starter		11	81	57
Ridge Center		12	83	64
Ridge Shoulder		9	82	62

Table 5. The effect of phosphate placement combination on the weight of young corn plants. The rate of applied phosphate was 46 lb./acre for each combination.

		Site	
Combination	Morris	Lamberton (88)	Lamberton (89)
	- - - - - - - -	weight of 6 plants, gm	- - - - - - - -
None	9 a	65 b	56 b
Ridge Center + Broadcast	12 a	85 a	69 a b
Ridge Center + Ridge Shoulder	11 a	79 a b	77 a
Starter + Broadcast	9 a	84 a	58 b
Starter + Ridge Shoulder	9 a	72 a b	63 b

P Concentration in Young Plants

The effect of rate and placement of phosphate fertilizer is summarized in Table 6. Concentrations at Morris are higher because plants were sampled at a younger growth stage. At Morris, P concentration was affected by both rate and placement. Compared to the check, all P_2O_5 applications increased the P concentration in young plants. There were, however, no differences among rates. Considering placement, the highest concentration was produced by the starter placement. All other placements had an equal effect.

Rate and placement of phosphate also affected the P concentration at the Lamberton (88) site. Increases in concentration as affected by rate were small. The 23 lb./acre rate did not produce a significant increase. The 46 and 69 lb./acre rates produced equal increases. Lowest P concentrations were associated with the starter and broadcast placements. The band on the ridge shoulder produced the highest concentration with the ridge center band being intermediate. These data show that the roots of young corn plants are able to reach the phosphate band placed on the shoulder of the ridge. It's notable, also, that this occurred with extremely dry soil conditions.

Table 6. The influence of rate and placement of phosphate fertilizer on the phosphorus concentration in young corn plants.

	P_2O_5		Site	
Placement	Applied	Morris	Lamberton (88)	Lamberton (89)
	lb./acre	- - - - - - - -	%	- - - - - - - -
None	0	.391	.291	.231
Broadcast	23	.419	.265	.237
	46	.420	.299	.266
	69	.425	.304	.264
Starter	23	.432	.282	.276
	46	.438	.269	.263
	69	.470	.294	.297
Ridge Center	23	.421	.301	.261
	46	.422	.313	.273
	69	.433	.300	.301
Ridge Shoulder	23	.426	.307	.310
	46	.401	.340	.314
	69	.411	.331	.299
CV, %	-	5.5	8.0	11.0
Main Effects:				
Rate	0	.391	.291	.231
	23	.425	.289	.271
	46	.420	.305	.279
	69	.435	.307	.290
Placement				
	Broadcast	.421	.289	.256
	Starter	.447	.282	.279
	Ridge Center	.425	.305	.278
	Ridge Shoulder	.413	.326	.308

At the Lamberton (89) site, all rates of applied phosphate increased the P concentration when compared to the check. Concentration, however, did not increase as rate increased. Consistent with data from the

Lamberton (88) site, highest p concentrations were associated with the band on the shoulder of the ridge. When averaged over rate, all other placements had an equal effect.

The influence of placement combinations on P concentration is summarized in Table 7. Except for the improvement over the check treatment, no distinct effects emerged from this measurement. Plant dilution could account for much of the variability.

Table 7. The effect of phosphate placement combinations on the P concentration in young corn plants. The rate of applied phosphate was 46 lbs/acre for each combination.

		Site	
Combination	Morris	Lamberton (88)	Lamberton (89)
	% P		
None	.391 b	.291 b	.231 c
Ridge Center + Broadcast	.427 a	.305 a b	.255 b c
Ridge Center + Ridge Shoulder	.425 a	.312 a	.287 a
Starter + Broadcast	.431 a	.301 b	.243 c
Starter + Ridge Shoulder	.423 a	.318 a	.276 a b

Phosphorus Uptake by Young Plants

Phosphorus uptake by young corn plants is probably the best measure of the effect of placement on the early growth of the crop. Calculated from plant weight and concentration measurements, this measure overcomes problems caused by plant dilution.

At Morris, uptake at this stage of growth was affected by both rate and placement and the rate x placement interaction was significant. When averaged over all placements, P uptake increased curvilinearly with rate with maximum uptake occurring with the application of 46 lb. P_2O_5 per acre. Considering placement, P uptake was lower when the phosphate fertilizer was either broadcast or placed in a band on the ridge shoulder.

Table 8. The influence of rate and placement of phosphate on phosphorus uptake by young corn plants.

	P_2O_5		Site	
Placement	Applied	Morris	Lamberton (~~88~~ A)	Lamberton (~~89~~ B)
	lb./acre	mg P/6 plants		
None	0	35.3	185	130
Broadcast	23	34.5	235	130
	46	43.3	200	159
	69	49.5	211	127
Starter	23	40.5	212	147
	46	58.0	210	154
	69	46.7	243	170
Ridge Center	23	44.5	194	159
	46	49.7	279	170
	69	52.5	265	206
Ridge Shoulder	23	39.5	213	188
	46	35.8	268	189
	69	37.3	315	186
CV, %	-	15.5	15.6	15.0
Main Effects:				
Rate	0	35.3	185	130
	23	39.8	214	156
	46	46.7	239	168
	69	46.5	259	172
Placement				
Broadcast		42.4	215	139
Starter		48.4	222	157
Ridge Center		48.9	246	178
Ridge Shoulder		37.5	265	188

Both rate and placement had a significant effect on P uptake at both Lamberton sites. Uptake continued to increase with rate at Lamberton (88) site. At the Lamberton (89) site, this increase was not measured. Compared to the control, however, all rates of applied P_2O_5 increased P uptake.

The application of phosphate in a band in either the center of the ridge or on the shoulder of the ridge produced the highest uptake at the Lamberton (88) site. Both broadcast and starter placement produced lower uptake by the young plants. This same observation holds true for the Lamberton (89) site.

The combinations of placements also affected P uptake (Table 9). In general, uptake was higher at all locations when the phosphate fertilizer or a portion of the total amount applied was placed in a band either in the center of the ridge or on the shoulder of the ridge. These results are consistent with those obtained from the other phase of the study.

Table 9. The effect of phosphate placement combinations on the P uptake by young corn plants. The rate of applied phosphate was 46 lb./acre for each combination.

		Site	
Combination	Morris	Lamberton (88)	Lamberton (89)
	- - - - - - - - - - -	mg P/6 plants	- - - - - - - - - -
None	35.3 b	185 b	130 c
Ridge Center + Broadcast	51.5 a	254 a	178 b
Ridge Center + Ridge Shoulder	47.8 a b	245 a	222 a
Starter + Broadcast	38.0 a b	248 a	142 b c
Starter + Ridge Shoulder	47.3 a b	228 a b	175 b

Phosphorus Concentration in Ear Leaf Tissue

Ear leaf samples collected at silking were analyzed for P in an attempt to monitor the effects of rate and placement at a later point in the growing season. At all sites, P concentration increased with rate of applied phosphate, but placement had no significant effect on this value (Table 10). The response to rate was linear at all sites. Root development later in the growing season is apparently extensive enough to take up the P regardless of placement.

Table 10. The effect of rate and placement of phosphate fertilizer on the P concentration in ear leaf tissue of corn.

	P_2O_5		Site	
Placement	Applied	Morris	Lamberton (88)	Lamberton (89)
	lb./acre	- - - - - - - - - - - -	% P	- - - - - - - - - - -
None	0	.256	.255	.193
Broadcast	23	.254	.273	.220
	46	.265	.266	.244
	69	.274	.296	.250
Starter	23	.246	.243	.239
	46	.254	.269	.248
	69	.290	.279	.263
Ridge Center	23	.272	.261	.217
	46	.268	.279	.231
	69	.275	.286	.267
Ridge Shoulder	23	.264	.263	.241
	46	.254	.274	.259
	69	.255	.289	.253
CV, %	-	7.0	5.9	7.4
Main Effects:				
Rate	0	.256	.255	.193
	23	.259	.260	.229
	46	.260	.272	.246
	69	.274	.288	.258
Placement				
Broadcast		.264	.278	.238
Starter		.263	.264	.250
Ridge Center		.272	.275	.238
Ridge Shoulder		.258	.275	.251

The P concentration in the ear leaf tissue was also not affected by combinations of phosphate placement (Table 11). The P concentration was increased by P application, regardless of placement combination.

Table 11. The effect of phosphate placement combinations on the P concentration in the ear leaf collected at silking. The rate of applied phosphate was 46 lb./acre for each combination.

Combination	Morris	Site Lamberton (88)	Lamberton (89)
	- - - - - - - - - -	% P	- - - - - - - - - -
None	.256 b	.255 b	.193 b
Ridge Center + Broadcast	.266 a	.278 a	.250 a
Ridge Center + Ridge Shoulder	.270 a	.279 a	.252 a
Starter + Broadcast	.273 a	.278 a	.223 a
Starter + Ridge Shoulder	.272 a	.275 a	.246 a

Summary

After evaluating the data collected from three experimental sites in 1989, there are some limited statements that can be made. These are listed below.

- With low soil test values for P at all sites, the use of phosphate fertilizer increased grain yield at all sites. The rate of 69 lb. P_2O_5 per acre was necessary for maximum yield. This response was noted even though dry weather limited yields at the Lamberton sites.
- Placement of phosphate had no significant effect on grain yield.
- In general, uptake of phosphorus by young corn plants was higher when phosphate fertilizer was applied in a band in the center of the ridge in the previous fall.
- As would be expected, phosphorus uptake by young plants increased with the rate of phosphate applied.
- The application of phosphate in a band in the center of the ridge appears to be a promising alternative to placement in a starter fertilizer band.

EVALUATION OF THE BRAY AND OLSEN SOIL TEST PROCEDURES FOR PREDICTING PHOSPHATE FERTILIZER NEEDS FOR CORN

George Rehm, Greg Cremers, Andy Scobbie, and Bob Munter[1]

ABSTRACT: Traditionally, the Bray and Kurtz #1 procedure has been used to predict phosphate requirements when the soil pH is 7.3 or less. The Olsen procedure is recognized for use when the soil pH is 7.4 or higher. This study was conducted to evaluate these procedures for situations where P extracted by the Bray procedure exceeds P values when the Olsen procedure is used if the soil pH is high.

Introduction:

There is general agreement that the Bray and Kurtz #1 procedure should be used to predict phosphate fertilizer needs for corn when the soil pH is 7.3 or less. Likewise, the Olsen procedure is widely used to predict these needs when the soil pH is 7.4 or higher. The concentration of P measured by the Bray procedure is usually too low to accurately reflect the P status of soils when the soil pH is 7.4 or higher.

Recently, there have been numerous situations in highly calcareous soils where the P extracted by the Bray and Kurtz #1 procedure is higher than the amount of P extracted by the Olsen procedure. There is no apparent explanation for these observations. Therefore, there was a need to determine which procedure was accurately describing the P status of soils in these situations.

Objective:

This study was conducted to determine which P extraction procedure would accurately predict the P status of highly calcareous soils that would be planted to corn.

Experimental Procedure:

This study was conducted at two locations in Renville County (Moritz, Hillman). Soil samples were collected to 5 feet prior to treatment application. The soil properties at the Moritz site are summarized in Table 1, while those from the Hillman site are listed in Table 2.

Both sites were calcareous. For the Moritz location, the P measured by the Bray and Kurtz #1 procedure (0-6 inches) was higher than the procedure measured by the Olsen procedure. The reverse was true at the Hillman site. There was also interest in measuring P by a universal extractant. Therefore, the Soltanpour procedure was also used to measure P in these soils.

Six rates of P_2O_5 (20, 40, 60, 80, 100, 300 lb./acre) supplied as 0-46-0, were broadcast and incorporated before corn was planted. The appropriate control was used. Management practices appropriate for high yields of corn were used at both sites.

Phosphorus uptake was monitored by collecting leaf samples from opposite and below the primary ear at silking. At physiological maturity, whole plant samples were taken from each plot. These samples were dried, weighed, ground, and analyzed for P. Phosphorus uptake was computed by combining P concentration, plant weight, and plant population data.

Grain yields were measured in October and corrected to 15.5% moisture. Following harvest, soil samples (0-6 inches) were collected from all plots to measure changes in soil test P. Both Bray and Kurtz #1 and Olsen procedures were used for these samples.

Results and Discussion:

At the Moritz location, soil test P as measured by the Bray and Kurtz #1 procedure in the initial sample (0-6 inches) was considered to be high. Using the Olsen procedure, the soil test P is considered to be in the medium range. There was a significant curvilinear increase in yield with rate of applied P_2O_5 (Table 3). The rate of 60 lb. P_2O_5 per acre was adequate for optimum yield. This type of yield response to broadcast phosphate would not be expected if soil test P values were in the high range. Apparently, the Olsen procedure, showing soil test P to be in the low to medium range, was more accurate at this site.

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As would be expected, soil test P, as measured by both the Bray and Kurtz #1 procedure and the Olsen procedure, increased with rate of applied phosphate. The increase was linear for both measurements.

The grain yield at the Hillman location also increased with the rate of applied phosphate. The relationship was curvilinear with the broadcast application of 100 lb. P_2O_5 per acre producing optimum yields (Table 4). The effect of applied phosphate on dry matter yield was also significant. The relationship was curvilinear with the rate of 100 lb. P_2O_5 per acre producing maximum dry matter. The soil test P level at this site is considered to be low by both measurements and a response to applied phosphate would be expected.

The soil test value for P also increased linearly with rate of applied phosphate at this site. Again, this relationship was observed for both methods used.

The problem that is addressed by this study cannot be solved by collecting data from only 2 sites. This study must be conducted at numerous sites in the years ahead before an answer can be found.

Table 1. Soil test values for the Moritz experimental site.

	Depth (in)					
Property	0-6	6-12	12-24	24-36	36-48	48-60
pH	7.7	7.7	7.9	8.1	8.1	8.0
organic matter, %	6.8	-	-	-	-	-
K (1N $NH_4C_2H_3O_2$), ppm	167	-	-	-	-	-
Zn, ppm	.6	-	-	-	-	-
NO_3-N, lb./acre	42.5	33.4	30.0	18.0	17.2	24.8
Bray P, ppm	16.2	2.8	1.4	1.7	1.5	1.5
Olsen P, ppm (organic)	7.8	5.2	2.3	1.0	.3	.2
Olsen P, ppm (inorganic)	12.3	2.8	1.5	1.5	.8	1.0
Soltanpour P, ppm	10.2	3.5	1.7	.9	.5	.7

Table 2. Soil test values for the Hillman experimental site.

	Depth (in)					
Property	0-6	6-12	12-24	24-36	36-48	48-60
pH	7.7	7.7	7.9	8.1	8.1	8.1
organic matter, %	6.3	-	-	-	-	-
K (1N $NH_4C_2H_3O_2$), ppm	100	-	-	-	-	-
Zn, ppm	.6	-	-	-	-	-
NO_3-N, lb./acre	37.8	52.6	77.3	30.8	16.0	20.4
Bray P, ppm	5.8	2.7	1.8	1.3	1.2	1.5
Olsen P, ppm (organic)	9.2	7.5	2.6	.9	.3	.3
Olsen P, ppm (inorganic)	5.8	2.8	1.0	.5	.5	.5
Soltanpour P, ppm	7.0	4.0	1.9	.8	.4	.5

Table 3. Effect of rate of P_2O_5 on corn yield, P uptake, and soil test P at the end of the growing season at the Moritz site.

	P_2O_5 Applied (lb./acre)						
Measurement	0	20	40	60	80	100	300
Grain Yield, bu./acre	157.3	159.7	159.3	164.4	161.7	164.6	154.5
D.M. Yield, ton/acre	7.4	7.5	7.4	7.3	7.4	7.7	7.5
% P, Mature Plants	.208	.212	.233	.258	.240	.207	2.41
Total P Uptake, lb./acre	30.8	32.1	34.2	30.6	35.5	31.6	36.3
% P, Ear Leaf	.266	.273	.261	.258	.266	.255	.278
Bray P, ppm	16.5	19.1	22.0	19.1	22.3	31.6	41.3
Olsen P, ppm	10.4	13.9	15.3	12.5	14.5	24.8	36.0

Table 4. Effect of rate of P_2O_5 on corn yield, P uptake and soil test P at the end of the growing season at the Hillman site.

	P_2O_5 Applied (lb./acre)						
Measurement	0	20	40	60	80	100	300
Grain Yield, bu./acre	105.5	124.2	123.4	133.2	140.4	152.5	149.1
D.M. Yield, ton/acre	4.6	5.2	4.9	5.5	5.6	5.8	5.4
% p, Mature Plants	.100	.125	.126	.162	.175	.134	.164
Total P Uptake, lb./acre	9.4	13.4	12.6	17.9	20.6	15.5	17.9
% P, Ear Leaf	.145	.187	.178	.209	.231	.225	.282
Bray P, ppm	5.0	6.0	6.8	12.1	26.3	19.8	50.0
Olsen P, ppm	4.3	5.7	8.7	8.9	10.8	10.3	27.0

EVALUATION OF FERTILIZER RECOMMENDATIONS FROM TWO SOIL TESTING LABORATORIES IN WATONWAN COUNTY

Gary Wyatt and George Rehm[1]

ABSTRACT: Questions about fertilizer recommendations from various soil testing laboratories still persist. This study was conducted in farmer fields in Watonwan County to compare fertilizer recommendations for corn from two laboratories (MVTL, A & L). Recommendations from the A & L Laboratory produced fertilizer costs that were $20 to $30 per acre higher than the recommendations from MVTL. The fertilizer recommendations associated with the highest costs did not increase grain yield.

Introduction:

In recent years, there have been intensive efforts to develop more uniform fertilizer recommendations that are provided by several soil testing laboratories. Yet, there are still some differences in recommendations that produce substantial differences in fertilizer costs. Therefore, there is still a need to evaluate various fertilizer recommendations. It is especially important that these evaluations take place in farmers fields.

Objective:

This project was conducted to evaluate the effect of fertilizer recommendations from two soil testing laboratories on corn yield and return to fertilizer use in south-central Minnesota.

Experimental Procedure:

For this project, there was considerable cooperation among the Watonwan County Corn Growers, the Watonwan County Extension Office, and the Watonwan Farm Service. Soil samples were collected from fields of cooperating farmers by personnel of the Watonwan Farm Service in the fall of 1988. Samples were split and sent to two soil testing laboratories (A & L, MVTL). Recommended rates of phosphate, potash, sulfur, and zinc were broadcast by the Watonwan Farm Service, in April, in the fields of cooperating farmers. These nutrients were incorporated by the secondary tillage operations.

Nitrogen fertilizer recommendations from each laboratory were nearly equal. Therefore, the same N rate was used for the corn fertilized with recommendations from each soil testing laboratory. There was also a treatment where N was applied without the use of phosphate, potash, sulfur, and zinc.

Grain yields were measured in October, 1989, and were corrected to a base of 15.5% moisture. Fertilizer costs were computed and cost per acre calculated from these values. Costs were $.21, $.14, $.45, and $.70 per pound for P_2O_5, K_2O, S, and Zn, respectively.

Cooperating farmers prepared the seedbed, planted and cultivated the corn. Recommended hybrids, plant populations, herbicides, and insecticides were used throughout the project.

Results and Discussion:

Results of the analysis of soil samples, which were sent to the two laboratories, are summarized in Table 1. The analytical results from each site were rather uniform if the major nutrients are considered. There was less agreement in analytical results if the micronutrients are considered.

Fertilizer recommendations, fertilizer costs, and grain yields are summarized in Table 2. There were differences in the rates of nutrients recommended as well as the nutrients that were suggested for a fertilizer program. Consequently, there were substantial differences in cost for the nutrients applied. Statistical analysis showed that there was no significant difference in yields that were the end result of the fertilizer recommendations. When N only was applied, the yield was 154 bu./acre at the Winkelman location and 181 bu./acre at the Samuelson location.

When compared to the use of N only, the broadcast use of P_2O_5, K_2O, and Zn produced a significant yield increase at the Winkelman location. Sulfur had no effect on yield. No S was suggested by MVTL and yields were not reduced. Considering the soil test values for P and Zn, the yield increase at this location can probably be attributed to the use of phosphate and zinc.

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[1] County Extension Agent, Watonwan County and Extension Soil Scientist, respectively.

The yield from the MVTL recommendations at the Samuelson location was significantly higher than the yield from the N only treatment. The yields from the A & L recommendation was not significantly different than the yield from the N only treatment.

Although there was no difference in yield at two locations, the recommendations from A & L Laboratories increased fertilizer costs by about $20 to $30 per acre. The results from this project are in agreement with results of similar comparisons conducted at the Southern and West-Central Experiment Stations in past years.

Table 1. Results of the analysis of soil samples taken from two farms which were analyzed by two soil testing laboratories.

	Farmer and Laboratory			
	Winkelman		Samuelson	
Analysis	A & L	MVTL	A & L	MVTL
pH	6.9	6.5	6.4	6.3
P_1 (Bray #1) ppm	13.0	10.0	15.5	20.0
P_2 (Bray) ppm	19.0	NA	55	NA
P (Olsen) ppm	NA	8.5	NA	16.5
K, ppm	107	125	126	145
organic matter, %	3.5	3.4	4.4	3.9
ENR (estimate nitrogen release), lb./acre	83	NA	93	NA
magnesium, ppm	742	715	586	550
calcium, ppm	2419	3150	2352	2900
sulfur, ppm	14.0	21.0	15.0	24.0
zinc, ppm	.9	.7	1.2	1.0
iron, ppm	62.0	25.6	53.0	25.7
copper, ppm	1.2	.9	1.0	.9
manganese, ppm	12.0	5.5	25.0	12.7
boron, ppm	1.1	2.0	1.3	2.3
Cation Exchange Capacity, meq/100 gm	18.6	22.0	18.6	19.4

NA = not analyzed

Table 2. Fertilizer recommendations, cost of fertilizer applied, and grain yields for corn production in Watonwan County in 1989.

		Recommendations					
Farmer	Soil Testing Laboratory	P_2O_5	K_2O	S	Zn	Fertilizer Cost	Grain Yield
		- - - - - - - -	lb./acre	- - - - - - - -		$/acre	bu./acre
Winkelman	A & L	95	215	10	4.0	57.35	162 a*
	MVTL	80	45	0	8	28.70	162 a
Samuelson	A & L	35	165	9	4.5	37.65	186 a
	MVTL	45	15	0	8	17.15	192 a

* Treatment means from each location followed by the same letter are not significantly different at the .05 confidence level.

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 in terms of the experimental error term each design would give for a given trial. Trials were located at 4 experiment stations and 8 farmer fields. The RCB design provided the lowest experimental error term in all cases while the strip with "tester" design resulted in the highest experimental error term for the trials. Based on these results and the 1988 results the practice of replication and combining results across locations is recommended.

INTRODUCTION

As the trend develops to place increasing emphasis on on-farm trials, the validity of these trial results must be emphasized. 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. The objectives of this project are to compare the precision of three experimental designs used in on-farm research.

MATERIALS AND METHODS

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 (strip with "tester"), in which the number of plots equals the number of treatments times 2 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.

The experimental design used in the field trials (Figure 1) incorporated each of the three experimental designs investigated in this study. Eight of the locations in Minnesota were on farmers' fields, with the plot's width between 10-30 feet and length's from 300 to 1447 feet. Four sites were at University of Minnesota experiment stations, with width's of 10-15 feet and the length between 30 and 426 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 3733. Pioneer brand 3737 was used as the "tester" in the strip with "tester" design. Grain yields were measured after physiological maturity using a combine (except at one experiment station). Grain yields were adjusted to 15.5% moisture.

The error variance for the plot area using a strip design having as many treatments as there are strips was approximated by calculating the residual mean square from a completely random design (CRD) analysis 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.

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. 1. 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.

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Equation 1:

$$Y_A = [Y_U - \frac{(T_L + T_R)}{2}] + T_{Ave.}$$

Y_A = Adjusted Treatment Yield
Y_U = Unadjusted Treatment Yield
T_L = Tester Yield on Left Side of Treatment Plot
T_R = Tester Yield on Right Side of Treatment Plot
$T_{Ave.}$ = Tester Yield Average for Entire Trial

The estimated experimental error for a RCB design used on the plot area is calculated by using a randomized complete block analysis. This partitions both replicate and treatment effects from the experimental error term.

1989 RESULTS

The overall error variance of the trial area using an unreplicated strip design was almost one-half the magnitude of the strip with "tester" design's error variance (Table 1). The frequency of the "tester" is not as beneficial in reducing the error variance of the area as some would expect. The best design, in terms of achieving the lowest error variance for the trial area, is the randomized complete block. As well as having the lowest error variance, the range of these values was also the smallest.

The effect of plot size was noted in 1989. The data (Table 1) indicates that the smaller plots tended to have higher experimental error terms than did the larger plots. The confounding factor of this observation is that the smaller plots all had border rows between plots that were not harvested, whereas the larger plots did not have border rows. Therefore, it cannot be fully explained as to whether the border rows do provide a more diverse group of treatment means that truly do have more variance or if the larger plots are less effected by soil variability and do provide a smaller experimental error.

Table 1. The effect of experimental design and plot size on estimating error variances (S^2) of corn hybrid trials, 1989.

Expt'l. Design	Plot Size[1]	# Sites	S^2	Range of S^2
Strip	Small	4	128.1	12.3 - 275.5
	Large	8	22.2	5.3 - 57.1
	Overall	12	57.5	5.3 - 275.5
Strip w/"Tester"	Small	4	239.4	30.5 - 500.2
	Large	8	47.9	12.3 - 129.2
	Overall	12	111.7	12.3 - 500.2
R.C.B.	Small	4	76.3	9.5 - 144.2
	Large	8	16.8	1.7 - 54.0
	Overall	12	36.6	1.7 - 144.2

[1] The "large" plots averaged 0.3012 A per plot and the "small" plots averaged 0.0504 A per plot.

2-YEAR SUMMARY

The overall mean of the strip and RCB design's error variance were not substantially different from 1988 and 1989 (Schmitt and Openshaw, 1989). While there was a large difference in the strip with "tester" design's error variance between the years, this difference should be attributed to the change made in the frequency of the "tester" made in 1989 (see materials and methods).

The RCB design with three replicates provided the lowest error variance of the three designs evaluated. The reduction in error variance was about 40-50% when compared to the unreplicated strip design. However, when using the error term for differentiating treatment means, the RCB error variance will be divided by the number of replicates to arrive at the variance of a treatment mean. The large reduction in error variance provided by the RCB is logistically offset by the fewer number of treatments that can be evaluated--still assuming that the plot size and number are fixed at a site.

To increase the precision and differentiation of treatments in agronomic trials, the practice of replication must be endorsed. Along with this, interpretability can also be improved if the trials are statistically combined from several locations. This will, in effect, increase the number of replications. While the use of the "tester" hybrid may provide an estimate as to the variability within one trial site, the results of this project show that it does not increase (and can decrease) the experimental error precision when adjusting treatment means with it.

References:

Schmitt, M.A. and S. J. Openshaw. 1988. Influence of experimental designs on on-farm trial interpretations. In A report on field research in soils, misc. publ. 2, Minn. Ag. Expt. Stn., Univ., of Minn. pp. 207-210.

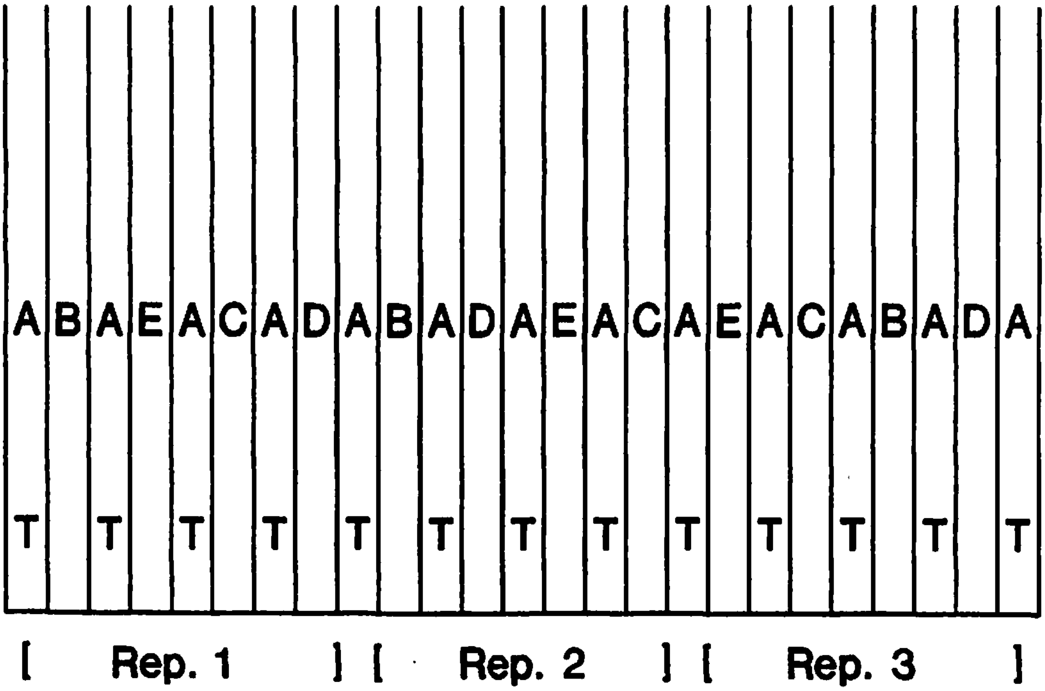

Figure 1. Experimental design used in field trials, 1989.

EVALUATION OF COMBINATIONS OF POTASSIUM FERTILIZER, VARIETY, AND FUNGICIDE USE ON PRODUCTION OF HIGH YIELDING SOYBEANS IN MINNESOTA

Ward Stienstra, George Rehm, Greg Cremers, and Andy Scobbie[1]

ABSTRACT: Phytophthora Root Rot (PRR) continues to be a problem for soybean producers in Minnesota. This study was conducted to evaluate the effect of K fertilization, variety, and fungicide use on the incidence and severity of this disease. Potassium fertilization had no effect on severity of PRR and had no effect on yield. Variety selection was important. The use of the fungicide, Ridomil, was effective in fields where PRR was a problem.

Introduction:

Phytophthora Root Rot (PRR) is a serious and expanding problem for soybean producers in much of Minnesota. The severity of the problem is linked to several factors. Soil moisture and incidence of rainfall after planting are two of these factors. The disease is usually not a problem on well drained soils unless the soil becomes saturated in the zone 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 which are 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 on soils that require irrigation.

Researchers throughout the United States have demonstrated that soybeans respond to applications of phosphate fertilizer when soil test levels for P are low or very low. However, the response of soybeans in Minnesota to K in a fertilizer program has been conflicting. In earlier studies, 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 K values were in the medium to high range.

Objective:

There are obviously unanswered questions that revolve around soybean production in Minnesota. Therefore, the study discussed in this report 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.

Experimental Procedure:

The study was conducted at 3 sites in Mower County in southeast Minnesota in 1989. All sites had a known history of damage caused by PRR. Sites selected also had a wide range of soil test K values. Soils at the experimental sites were also representative of soils in the region.

Three factors (K rate, variety, fungicide use) were combined into a complete factorial using 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) was used for 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. Results of the analysis of these samples are summarized in Table 1.

Table 1. Relevant soil test values for the experimental sites used in the study in 1989.

Property	Depth	Site Arndorfer	Greeley	Meyer
	- in -			
pH	0-6	6.2	7.0	5.5
P, (Bray & Kurtz #1) ppm	0-6	24	30	35
Organic Matter, %	0-6	3.1	4.8	3.6
Zinc, ppm	0-6	1.2	.9	1.6
Soil Test K, ppm	0-6	82	127	142
	6-12	37	54	82
	12-24	50	55	75
	24-36	49	43	77
	36-48	59	37	64
	48-60	94	40	60

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[1] Extension Plant Pathologist, Extension Soil Scientist, Assistant Scientist, and Junior Scientist, University of Minnesota, respectively.

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

Stand densities were determined by counting the number of plants in 5 ft. of row at approximately 30 days after planting. 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 fertilizer was measured at the Arndorfer and Greeley locations. For this study, K (supplied as 0-0-60) was applied in a band to the side of and below the seed at planting to supply 0, 20, 40, and 80 lb. per acre. All plots received a uniform application of N (18 lb./acre) and P (20 lb./acre). The Corsoy 79 variety was used and Ridomil was applied to all plots. Data collection was identical to that described in the previous paragraphs.

Results and Discussion:

The soil test P values were in the high to very high range for all sites. Therefore, no phosphate fertilizer was applied. The soil test K values (0-6 in.) were in the medium range at the Arndorfer and Greeley sites and the high range at the Meyer site. The K values decreased with depth and this is to be expected.

Soybean Yield

Application of fertilizer K had no significant effect on yield at all sites. There was no significant interaction between either applied K and variety or applied K and use of Ridomil. Therefore, the effect of K rate on yield is summarized in Table 2. Because of the high soil test value, a response to K would not be expected at the Meyer site. The soil at the Arndorfer and Greeley sites was apparently able to supply adequate K for optimum soybean production in 1989.

Table 2. Influence of applied K on soybean yield.

K		Site	
Applied	Arndorfer	Greeley	Meyer
lb./acre		bu./acre	
0	39.2	41.1	38.9
40	39.7	41.4	38.9
80	40.5	40.0	38.1
160	37.6	41.5	36.5

Variety had a significant effect on yield at all locations (Table 3). Highest yields at all sites were associated with the BSR-101 variety. Yields of the Corsoy 79 variety were intermediate while the 54-254 variety produced the lowest yield at all sites.

Table 3. The effect of variety and Ridomil use on soybean yield.

	Ridomil		Site	
Variety	Use	Arndorfer	Greeley	Meyer
			bu./acre	
54-254	no	29.3	37.8	33.3
54-254	yes	37.0	36.6	35.8
BSR-101	no	43.3	44.6	42.7
BSR-101	yes	43.5	45.9	41.0
Corsoy 79	no	42.0	40.8	37.6
Corsoy 79	yes	40.5	40.3	38.0

Disease pressure from PRR was not severe in 1989. Soybean yield was increased by the use of Ridomil at the Arndorfer site only. This increase was noted with the 54-254 variety. This variety is not resistant to PRR and yield reductions from this disease would be expected if PRR races are present in a soil. The

BSR-101 is somewhat resistant to PRR and Corsoy 79 soybeans are somewhat more resistant to infection. With low levels of disease pressure, these varieties would not be expected to respond to the use of Ridomil. The application of K in a fertilizer program had no significant effect on the incidence or severity of PRR in 1989.

Plant Height

Plant height can be used as an early measure of the effect of PRR on soybean production. The application of K in the fertilizer program had no significant effect on this measurement (Table 4). This is consistent with the effect of K fertilization on yield.

The use of Ridomil increased the height of the 54-254 variety at the Arndorfer location. Otherwise, the use of this fungicide had no effect on plant height.

Soybean variety had a significant effect on plant height at all locations (Table 5). The 54-254 variety was shortest at all locations while the Corsoy 79 variety produced the tallest soybeans in 1989.

Table 4. Influence of rate of applied K on the height of soybean plants at early bloom.

K Applied	Arndorfer	Site Greeley	Meyer
lb./acre		inches	
0	46	54	61
40	47	54	62
80	50	54	60
160	47	55	59

Table 5. The effect of soybean variety on the height of soybean plants at early bloom.

Variety	Arndorfer	Site Greeley	Meyer
		inches	
54-254	43	50	56
BSR 101	46	54	59
Corsoy 79	54	59	67

Soybean Stand

In general, the number of emerged soybeans was lower than anticipated. Use of K in a fertilizer had no significant effect on emerged stand at all sites (Table 6). The measured stand, however, was affected by soybean variety at the Arndorfer and Meyer sites. (Table 7). Use of Ridomil had no significant effect on measured stand and there was no significant Ridomil x variety interaction.

Table 6. The effect of rate of applied fertilizer K on the population of soybeans after emergence.

K Applied	Arndorfer	Site Greeley	Meyer
lb./acre		plants/ft.	
0	6.0	6.7	7.1
40	6.0	6.7	7.0
80	5.8	6.6	6.9
160	5.7	6.6	7.2

Table 7. The effect of soybean variety on the population of soybeans after emergence.

Variety	Site Arndorfer	Greeley	Meyer
	plants/ft		
54-254	5.4	6.8	6.7
BSR-101	6.1	6.7	7.1
Corsoy 79	6.1	6.5	7.3

K Concentration in Leaf Tissue

Even though applied K had no effect on soybean yield, the K concentration in the most recently mature leaflet at early bloom was affected by the rate of K applied (Table 8). The highest K concentration at all locations was associated with the use of 160 lb K/acre. The K concentration in the tissue of the non-fertilized treatments was uniform for all locations.

Table 8. The effect of rate of applied K on the concentration of K in leaf tissue.

K Applied	Site Arndorfer	Greeley	Meyer
lb./acre	% K		
0	2.08	1.96	2.16
40	2.12	2.08	2.16
80	2.19	2.06	2.12
160	2.31	2.16	2.25

This is further evidence that the soils were capable of supplying adequate K for soybean growth. The higher concentrations from the use of K are considered to be the result of luxury consumption.

The variety used had a highly significant effect on the K concentration in the leaf tissue at all locations (Table 9). Concentration was lowest in the 54-254 variety. This may be a variety trait or it may reflect a lower level of root activity caused by PRR with a subsequent effect on reduced yields. There was no statistical difference in the K concentration when the BSR-101 and Corsoy 79 varieties are considered.

Table 9. The effect of variety and Ridomil use on the K concentration in leaf tissue of soybeans.

Variety	Ridomil Use	Site Arndorfer	Greeley	Meyer
		% K		
54-254	no	1.95	1.93	2.08
54-254	yes	2.07	1.95	2.08
BSR-101	no	2.27	2.15	2.25
BSR-101	yes	2.33	2.13	2.24
Corsoy 79	no	2.21	2.14	2.19
Corsoy 79	yes	2.22	2.10	2.20

The use of ridomil produced a significant increase in the K concentration of the leaf tissue of the 54-254 variety at the Arndorfer site only. This would be expected because damage from PRR was most severe at this site. Uptake of K would be restricted where root systems are damaged by PRR and the 54-254 was severely damaged by this disease at this site.

Changes in Soil Test Values

Following harvest, soil samples (0-6 in) were collected from the main plots in an attempt to measure the effect of applied K on soil test K values. These results are summarized in Table 10. There were no major changes in soil test values. There was a small increase in soil test K values at all locations as the rate of applied K increased. The largest increase was measured when the rate of applied K was increased from 80 to 160 lb./acre. Since applied K had no effect on yield, there does not appear to b any justification to apply fertilizer K in an attempt to increase K values above those measured at th beginning of this study.

Table 10. The effect of rate of applied K on the soil test values for K at the end of the growing season.

K Applied	Site Arndorfer	Greeley	Meyer
lb./acre		ppm K	
0	80	94	110
40	80	100	118
80	97	104	119
160	115	115	146

Effects of K in a Starter

The rate of K applied in a starter fertilizer had no significant effect on both soybean yield and the K concentration in the leaf tissue (Table 11). The absence of any effect of applied K on yield is consistent with the results from the companion study where fertilizer K was broadcast and incorporated. This is added evidence that the soil at all locations was capable of supplying adequate K for soybean production.

Applied K had no effect on the K concentration in the leaf tissue and this is not consistent with results from the companion study. Apparently, soybean roots did not develop near the starter band and no additional K was absorbed by the soybean plant.

Table 11. The effect of rate of applied K applied in a starter fertilizer on soybean yield and the K concentration in soybean leaf tissue.

K	Site Arndorfer		Greeley	
Applied	Yield	K Conc.	Yield	K Conc.
lb./acre	bu./acre	%	bu./acre	%
0	39.8	2.23	47.1	2.11
20	38.1	2.14	42.9	2.10
40	39.1	2.07	43.9	2.01
80	34.6	2.15	41.2	2.13

Summary And Conclusions

The results of this study conducted in both 1988 and 1989 at a total of 6 experimental sites, have been quite consistent. Based on the analysis of the data collected, it is possible to make the following conclusions.

1. Use of K in a fertilizer program had no measurable effect on the incidence or severity of PRR. The addition of this nutrient to a fertilizer program had no effect on yield where soil test values for K were considered to be in the medium or high range.

2. The incidence and severity of PRR was highly dependent on the variety used. The presence PRR reduced yields of 54-254 (a susceptible variety) in both years of the study. The yiel

of the BSR-101 (somewhat tolerant) variety was affected by PRR at only one site. The tolerant (Corsoy 79) variety was not affected by PRR at any location.

3. The use of the fungicide, Ridomil, had a positive effect on yield where PRR was present at levels that cause yield suppression. This is especially true for the 54-254 variety. This product had the most beneficial effect on yield where disease pressure was the highest.

4. Incidence and severity of PRR appears to be highly dependent on the amount of rainfall received immediately after planting. Even though the 1988 season was dry, moderate rains were received just after planting and pressure from PRR was moderate to high at all locations. There was heavy pressure from PRR at only one location (Arndorfer) in 1989. This site did receive moderate rainfall on the day that it was planted. Rainfall immediately after planting was lacking at the other 2 locations.

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IMPACT OF AG-LIME ON SOYBEAN AND POTATO PRODUCTION ON IRRIGATED SANDY SOILS

George Rehm and Carl Rosen[1]

ABSTRACT: The sandy soils of the Anoka Sand Plain typically have an acid pH. This is satisfactory for potato production, but may limit the yield of soybeans grown in the rotation. This study was conducted to evaluate the effect of ag lime on the yield of soybeans and potatoes. Soybeans were grown in 1989 and yield was not affected by the ag lime use at rates of 1, 2, and 3 ton per acre. Potatoes will be grown in 1990 to monitor the effect of lime use on potato yield.

The benefits of liming acid soils for soybean production are well documented in past research. A pH near neutral is required for optimum nodulation of the soybean plant thereby assuring that the soybean crop will have an adequate supply of nitrogen. In contrast, potatoes are normally grown on acid soils to reduce the incidence of scab.

Soybeans and potatoes are commonly grown in rotation on irrigated sandy soils in Minnesota. Growers face a dilemma when they use this rotation. Lime applied for optimum production of soybean may raise the pH to a point where it is difficult to grow high quality potatoes after soybeans.

The objective of this study, therefore, was to determine the effects of application of ag lime in a soybean/potato rotation.

Experimental Procedure:

The study was conducted at Big Lake, Minnesota on a Hubbard loamy sand soil. Based on farmer records, the soil pH was 5.3; however, after more extensive sampling, it was determined that the initial pH was 6.1 with a range of 5.9 - 6.3. The initial pH of the site was 6.2. Agricultural limestone was broadcast and incorporated before planting at the rates of 0, 1, 2, and 3 tons per acre. Each treatment was replicated 4 times in a randomized complete block design. Soil samples were collected at harvest and analyzed for pH. Trifoliate leaf samples were collected at mid season and analyzed for nutrient concentrations. Soybean yields were determined by measuring two 10′ rows from each plot.

Results:

Soil pH and soybean yield are presented in Table 1. As expected, soil pH tended to increase with increasing application of ag-lime. The increase, however, from the control plot to the 3 ton rate was only 0.2 units. We anticipate that the pH will continue to increase in the plots where lime was applied over the next year. The increase in the control plot over the growing season was probably due to the high pH water used for irrigation during this dry year. Soybean yields were not significantly affected by lime application. Part of the reason for this lack of response was due to the fact that the pH of the control plot was above 6.0. The probability of a response to lime decreases as the pH increases above this level. Concentrations of nutrients in trifoliate leaves are presented in Table 2. None of the nutrients measured were affected by lime application. Again, this lack of response was probably due to the high initial pH.

The experiment next year (1990) will concentrate on the effects of these same lime treatments on potato yield and quality.

Table 1. Effect of ag-lime on soil pH and soybean yields.

Treatment	Soil pH	Soybean Yield
Tons lime/A		bu/A
0	6.3	58.0
1	6.4	57.3
2	6.4	60.0
3	6.5	57.0
Significance	NS	NS

Table 2. Effect of ag-lime on nutrient concentrations in soybean trifoliate leaves sampled at mid season.

Treatment Tons lime/A	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%				ppm				
0	0.45	2.06	0.82	0.38	159	133	48	8	45
1	0.41	1.89	0.92	0.38	164	133	43	6	46
2	0.41	1.98	0.83	0.35	156	128	43	7	44
3	0.38	1.86	0.86	0.35	157	119	41	7	47
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS

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SOIL NITRATE MOVEMENT IN IRRIGATED POTATO/CORN ROTATIONS[1]

Carl Rosen, Louise America, Peter Bierman, and Gary Korbel[2]

ABSTRACT. Soil samples from 12 irrigated fields were collected to a depth of three feet during the 1989 growing season. Fields sampled included: 6 potato fields, 4 sweet corn fields, 1 field corn field, and 1 soybean field. Soil nitrate-N and ammonium-N were determined in KCl extracts. In addition, soil water from 5 of the 6 potato fields was collected weekly using suction tube lysimeters and analyzed for nitrate-N. Results of this study indicated that N distribution during the season in potato and corn fields differed, but that total residual N at harvest was similar. Nitrate-N and ammonium-N in the soybean field were at background levels through the season. The greatest potential for residual nitrates and nitrate-N movement occured when yields were low and when high or excessive N fertilizer applications were used. The survey shows that some growers need to improve upon production and N management practices to prevent nitrate-N losses. However, the study also shows that crops can be grown on these soils with minimal nitrate-N movement below the root zone.

The irrigated soils of Sherburne county have been identified as being susceptible to nitrate leaching. These soils are characterized as having a sandy texture over gravel with an organic matter content in the top 12" of 1 to 3 percent. Levels of nitrate-N in shallow wells have reportedly increased over the years. A level less than 10 ppm nitrate-N is considered safe for drinking. Contamination of groundwater with nitrates is a concern that has many questioning N management practices on the irrigated, sandy soils of central Minnesota. While excessive applications of N fertilizer could potentially contaminate the groundwater, few studies could be found which dealt directly with how nitrates might be moving in these soils during the growing season. The objective of this report is to obtain background information on nitrate-N levels and movement in irrigated corn and potato fields under conditions defined by growers. An irrigated soybean field was also included as a crop not receiving any fertilizer N during the season. The ultimate goal is to help improve N management practices for irrigated crops.

Experimental Procedures. Six potato fields, four sweet corn fields, one soybean field, and one field corn field, all located in Sherburne county, were selected for monitoring. The soils at all locations were classified as Hubbard loamy sands. Fertilizer source, 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. Soil samples from each field were collected to a depth of three feet at one foot increments. Samples were collected from four locations (reps) in each field and the sample from each location consisted of three cores. The first sampling date was in April/May prior to planting and fertilizer application. Fields were sampled again at the same approximate locations in July during tuber enlargement for potatoes, just prior to tasselling for the corn, and during initial pod fill for the soybean field. At this time, samples were collected both between rows and within rows. A final sampling time was in August/September within one week of harvest. Samples were again collected between and within rows.

In five of the six potato fields, recently mature leaf (leaflet plus petiole) and petiole alone samples were collected July 5. Samples were dried and ground to pass through a 30 mesh sieve. Total Kjeldahl N and water soluble nitrate-N were determined using conductimetric procedures. Other elements were determined in ashed samples dissolved in 2 N HCl using ICP procedures.

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 and ammonium-N were calculated on a dry weight basis. All results are expressed as pounds of nitrate-N or ammonium-N using the convention that ppm X 2 = lb/A for a 6" furrow slice. Bulk density of each sampling depth was not determined so the lb/A values should be considered approximate. For the July and September samples, total nitrate-N and ammonium-N in the 3 ft profile were calculated by assuming that half the field was 'within row' and the other half was 'between row'.

Suction tubes were installed in the rows of five of the six potato fields at 2.5 and 4.5 foot depths. There were two tubes at each depth in each field. Nitrates in soil water were determined in samples collected weekly during the growing season. For two of the five fields, the suction tubes were removed at harvest. For the other three fields, samples continued to be collected every other week through mid-November.

Results and Interpretations. Rainfall during the 1989 growing season was light. There were no rainfall events which totaled over 1.5 inches during any one week from mid-April to mid-August (Fig. 1). Thus, major losses of N out of the root zone at any one time during the growing season probably did not occur. Records of irrigation were not kept; however, most growers attempted to supplement rainfall to provide about 1.5" - 2" of water per week from June through mid-August.

Potato yields varied from approximately 220 cwt/A to 660 cwt/A, and N fertilizer applications ranged from 125 lb N/A to 325 lb N/A. Sweet corn yields ranged from 6.5 T/A to 9.5 T/A, and N fertilizer applications ranged from 155 lb N/A to 200 lb N/A. In both crops, highest yields were not associated with highest N applications. The field corn yield was 216 bu/A and the soybean yield was 46 bu/A.

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[1] Partial support for this project was provided by the Sherburne County Farm Bureau and the East Central Irrigators Association.

[2] Extension Soil Sci., Junior Scientist, Grad. Res. Assist., Res. Technician, Dept. Soil Science.

A summary of nitrate-N levels during the growing season over all potato fields is presented in Table 1. There was an average of 50 lb/A nitrate-N in the top 3 feet before planting and fertilizer application, with a range of 17 to 116 lb/A. There was a gradual increase in nitrate from the top foot to the bottom 2-3 foot depth. The high residual nitrate in some fields indicate that excessive amounts of N were applied the previous year. The practice of hilling and placing fertilizer N in the row affects N distribution in the field. Levels of nitrate-N in the rows were about 1.5 times greater than levels between rows. At harvest, the level of nitrate-N in the top 3 feet was similar to the level recorded before planting; however, most was still concentrated in the top of the profile rather than the bottom.

Ammonium-N levels during the growing season over all potato fields are summarized in Table 2. Levels of ammonium-N did not increase substantially over the growing season. By harvest, levels were actually lower than those found in April before planting. Most of the ammonium-N applied was either converted to nitrate-N, taken up by the plant, or immobilized in the soil organic fraction.

Nitrate-N levels in the soil water at 2.5 and 4.5 feet from 5 potato fields through the season are presented in Figures 2-6. In Field 1 (Fig. 2), nitrate-N increased through the season and particularly after harvest. The high levels of nitrate-N late in the season are due to the late applications of fertilizer (late July), relatively high rates of N applied, and relatively low yields.

In Field 2 (Fig. 3), nitrate-N increased at both depths in mid-season followed by a general decline. At the 2.5′ depth, nitrate-N levels reached a low in August (day 225) but then started to increase. The low level of nitrate-N probably corresponds to uptake by the potato crop. By day 225-250 the potato growth began to slow down followed by vine killing about day 260. Mineralization was still occurring, but there was no active crop to take up the nitrogen. The result was an increase in nitrate-N levels. This particular field had a long history of large manure applications before being used for potato production. The field was purchased for potato production about 25 years ago yet the residual from the manure may still have been affecting release of nitrate-N.

Field 3 (Fig. 4) represents an example of good N management as well as excellent potato production practices. Except for a small increase in soil nitrate-N levels in mid-season, levels remained relatively low, particularly after harvest. The main reasons for little nitrate-N movement in this field were: (1) the high yields resulted in uptake of a large portion of the applied N, (2) the timing of N application was such that N was provided when needed by the crop, and (3) the total rate of N was not excessive.

Fields 4 and 5 (Figs. 5 and 6) were only sampled through mid-August. Field 4 had relatively high levels of nitrate-N in the soil water reflecting the higher N application rate (260 lb N/A) and relatively high initial levels of soil nitrate-N (116 lb NO_3-N/A in the top three feet). In contrast, Field 5 had relatively low levels of nitrate-N in the soil water which reflects the low N application rate (124 lb N/A) and the lower initial levels of soil nitrate-N (68 lb NO_3-N/A in the top three feet).

Potato yields and elemental concentrations in the leaf tissue for five of the six potato fields are presented in Table 3. These five fields also correspond to the management practices presented in Figures 2 through 6. Fields 1 and 4 had high to excessive levels of tissue N based on established critical values for that sampling date. Fields 2 and 3 were in the adequate range and field 5 was deficient in N. Other nutrients were in the adequate range for all fields except field 2 which tended to be on the low side for K, Ca, Zn, B, and Cu. Tissue analysis for N should be an additional tool used by growers to help make N management decisions.

Soil nitrate-N and ammonium-N levels during the growing season over all corn/sweet corn fields are summarized in Tables 4 and 5. Field corn was included with the sweet corn since ranges for soil nitrate-N and ammonium-N levels were similar for both crops. Initial levels of nitrate and ammonium-N were generally lower than those found in fields to be planted in potatoes, which may in part be due to the previous crop. Further monitoring will have to be conducted to confirm the significance of previous crop. Nitrate-N and ammonium-N levels were substantially higher in corn/sweet corn compared to potatoes in July. Interestingly, most of the N was located between the rows for corn compared to within the rows for potatoes. This difference in N distribution is due to differences in fertilizer placement. In irrigated corn production most of the N fertilizer is sidedressed between the rows during the growing season. The level and distribution of residual nitrates in the corn fields at harvest were similar to that found for potatoes at harvest.

As expected, nitrate-N and ammonium-N soil levels in the soybean field were generally at background levels through the season (Table 6a and 6b). The previous crop in this field was snap beans which only received 40 lb N/A the previous year. Initial nitrate-N levels were low and even decreased by the end of the season. Soil ammonium-N levels remained constant throughout the season.

In summary, this survey has shown that N distribution during the growing season in potato and corn fields differed, but that total residual N at harvest was similar. The greatest potential for residual nitrates and nitrate-N movement occured when yields were low and when high or excessive N fertilizer applications were used. The survey shows that some growers need to improve upon production and N management practices to prevent nitrate-N losses. However, the study also shows that crops can be grown on these soils with minimal nitrate-N movement below the root zone.

Table 1. 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: 124 - 325 lb N/A
Ranges in total yield: 218 - 663 cwt/A

April 1989

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	11.6	5.8 - 19.2
1 - 2	15.7	4.2 - 42.1
2 - 3	22.3	7.1 - 59.7
Total	49.6	17.2 - 116.3

July 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/half acre[1]			
0 - 1	16.4	1.7 - 34.1	9.9	3.3 - 18.4
1 - 2	11.7	3.0 - 16.1	7.9	2.6 - 10.9
2 - 3	9.5	4.5 - 15.0	5.9	1.6 - 11.5
Total	37.6	10.8 - 58.7	23.7	8.3 - 33.7
Total lbs NO_3-N/A in field[2]			61.3	28.7 - 92.4

September 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/half acre[1]			
0 - 1	11.8	6.1 - 22.1	10.4	4.2 - 26.4
1 - 2	10.8	2.2 - 26.4	6.2	2.3 - 18.7
2 - 3	7.0	1.3 - 16.8	4.9	1.7 - 10.5
Total	29.6	10.8 - 74.2	20.7	9.4 - 54.9
Total lbs NO_3-N/A in field[2]			50.3	19.0 - 105.6

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[1] Assumes half the field was row and the other half was between row.
[2] Total lbs NO_3-N in field = total in row plus total between row.

Table 2. Summary of soil ammonium-N levels in irrigated potato fields over the growing season. Means and ranges of six commercial potato fields.

April 1989

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	13.9	3.7 - 32.4
1 - 2	12.2	2.8 - 30.6
2 - 3	4.6	3.4 - 5.6
Total	30.7	10.2 - 66.0

July 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NH_4-N/half acre[1]			
0 - 1	15.5	3.0 - 40.6	3.3	1.3 - 6.4
1 - 2	3.7	1.7 - 6.4	2.4	1.5 - 2.5
2 - 3	2.1	1.5 - 2.8	2.2	1.3 - 2.5
Total	21.3	8.0 - 46.8	7.9	4.5 - 11.2
Total lbs NH_4-N/A in field[2]			29.2	13.1 - 58.1

September 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NH_4-N/half acre[1]			
0 - 1	1.8	0.9 - 3.6	1.2	0.8 - 2.1
1 - 2	1.5	0.7 - 2.8	1.0	0.7 - 1.2
2 - 3	1.1	0.7 - 1.2	1.0	0.7 - 1.4
Total	4.4	2.3 - 7.6	3.2	2.4 - 4.3
Total lbs NH_4-N/A in field[2]			7.6	6.0 - 10.5

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[1] Assumes half the field was row and the other half was between row.

[2] Total lbs NH_4-N in field = total in row plus total between row.

Table 3. Yield, leaf and petiole nitrate-N, and leaf elemental concentrations from five potato fields. Yields were recorded at harvest. Leaf and petiole samples were collected July 5, 1989 (Means of 2 samples from each field).

		NO_3-N		Element in Leaf Tissue											
Field Number	Yield cwt/A	leaf	petiole	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Al	Na
		---- % -----		------------ % -------------					---------- ppm -----------						
1	285.7	0.42	2.04	4.87	0.30	4.70	0.90	0.50	207	302	30	8	50	147	19
2	491.9	0.25	1.52	4.25	0.41	3.80	0.49	0.49	88	395	18	5	22	28	23
3	661.4	0.26	1.21	4.34	0.28	4.45	1.25	0.65	82	156	22	13	30	19	17
4	449.4	0.56	2.50	5.06	0.25	4.55	0.98	0.64	173	863	69	8	31	43	16
5	398.9	0.09	0.34	3.72	0.26	5.09	0.66	0.54	104	480	28	9	30	40	20

Table 4. Summary of soil nitrate-N levels in irrigated corn/sweet corn fields over the growing season. Means and ranges of five commercial corn/sweet corn fields.

Ranges in total N fertilizer applied:		155 - 203 lb N/A
Ranges in total yield	(sweet corn):	6.5 - 9.5 T/A
	(field corn):	213 bu/A

April 1989

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	13.1	3.4 - 28.7
1 - 2	16.2	2.9 - 64.2
2 - 3	14.9	4.7 - 42.0
Total	40.3	9.6 - 134.7

July 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/half acre[1]			
0 - 1	10.3	4.1 - 28.1	53.8	15.2 - 128.1
1 - 2	9.6	4.1 - 19.3	16.6	9.6 - 31.3
2 - 3	6.2	3.3 - 11.9	9.0	5.7 - 16.7
Total	26.1	16.2 - 37.7	79.4	30.6 - 151.6
Total lbs NO_3-N/A in field[2]			105.5	68.4 - 187.4

September 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/half acre[1]			
0 - 1	8.5	3.5 - 19.5	16.1	8.6 - 24.9
1 - 2	4.1	1.4 - 10.9	11.4	6.7 - 16.5
2 - 3	2.8	1.4 - 6.7	7.5	5.4 - 11.4
Total	15.9	6.6 - 36.7	35.0	22.7 - 46.1
Total lbs NO_3-N/A in field[2]			50.4	30.1 - 72.1

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[1] Assumes half the field was row and the other half was between row.

[2] Total lbs NO_3-N in field = total in row plus total between row.

Table 5. Summary of soil ammonium-N levels in irrigated corn/sweet corn fields over the growing season. Means and ranges of five commercial corn/sweet corn fields.

Ranges in total N fertilizer applied:	155 - 203 lb N/A
Ranges in total yield (sweet corn):	6.5 - 9.5 T/A
(field corn):	213 bu/A

April 1989

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	4.3	1.8 - 10.2
1 - 2	3.7	1.8 - 7.2
2 - 3	3.7	1.5 - 7.4
Total	11.7	5.1 - 24.9

July 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NH_4-N/half acre[1]			
0 - 1	6.6	0.7 - 24.4	95.9	7.7 - 195.1
1 - 2	1.9	0.4 - 4.0	17.6	5.3 - 34.9
2 - 3	1.7	0.6 - 2.6	9.0	2.8 - 20.3
Total	10.2	1.7 - 31.0	122.5	15.7 - 247.9
Total lbs NH_4-N/A in field[2]			132.7	46.7 - 253.1

September 1989

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NH_4-N/half acre[1]			
0 - 1	1.5	0.8 - 2.2	3.8	1.6 - 7.5
1 - 2	1.2	1.0 - 1.6	2.4	1.1 - 6.7
2 - 3	1.2	0.9 - 1.5	1.8	1.0 - 4.4
Total	3.9	2.9 - 5.3	8.0	3.8 - 14.5
Total lbs NH_4-N/A in field[2]			11.9	6.8 - 17.4

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[1] Assumes half the field was row and the other half was between row.

[2] Total lbs NH_4-N in field = total in row plus total between row.

Table 6a. Summary of nitrate-N levels in sandy soils used for soybean production. Means and ranges of one soybean field (4 samples per field).

N Fertilizer Management: 0 N applied
Estimated Soybean Yield: 50 bu/A

	Sampling Date				
	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	lb NO_3-N/half acre[1]			
0-1	8.9 ± 3.0	2.7 ± 0.4	3.8 ± 1.8	4.4 ± 1.6	3.8 ± 0.8
1-2	7.8 ± 1.0	4.8 ± 2.1	4.7 ± 2.2	2.6 ± 1.2	1.9 ± 0.4
2-3	6.7 ± 2.4	3.7 ± 1.1	5.0 ± 1.5	1.8 ± 0.5	1.3 ± 0.4
Total	23.4 ± 4.4	11.2 ± 2.9	13.5 ± 4.8	8.7 ± 2.4	7.0 ± 0.9
Total lbs NO_3-N/A in field[2]		24.7 ± 7.3		15.7 ± 3.0	

Table 6b. Ammonium-N levels in sandy soils used for soybean production (means of 4 samples per field).

	Sampling Date				
	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	lb NH_4-N/half acre[1]			
0-1	2.4 ± 0.5	1.0 ± 0.7	0.4 ± 0.1	1.0 ± 0.2	1.0 ± 0.2
1-2	2.6 ± 0.4	0.6 ± 0.5	1.1 ± 0.7	1.6 ± 1.2	1.1 ± 0.3
2-3	2.6 ± 0.4	1.1 ± 0.6	1.3 ± 1.0	1.6 ± 0.8	1.0 ± 0.1
Total	7.6 ± 0.9	2.7 ± 1.0	2.8 ± 1.7	4.2 ± 1.2	3.1 ± 0.5
Total lbs NH_4-N/A in field[2]		5.4 ± 2.0		7.3 ± 1.4	

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[1] Assumes half the field was row and the other half was between row.

[2] Total lbs NH_4-N in field ≈ total in row plus total between row.

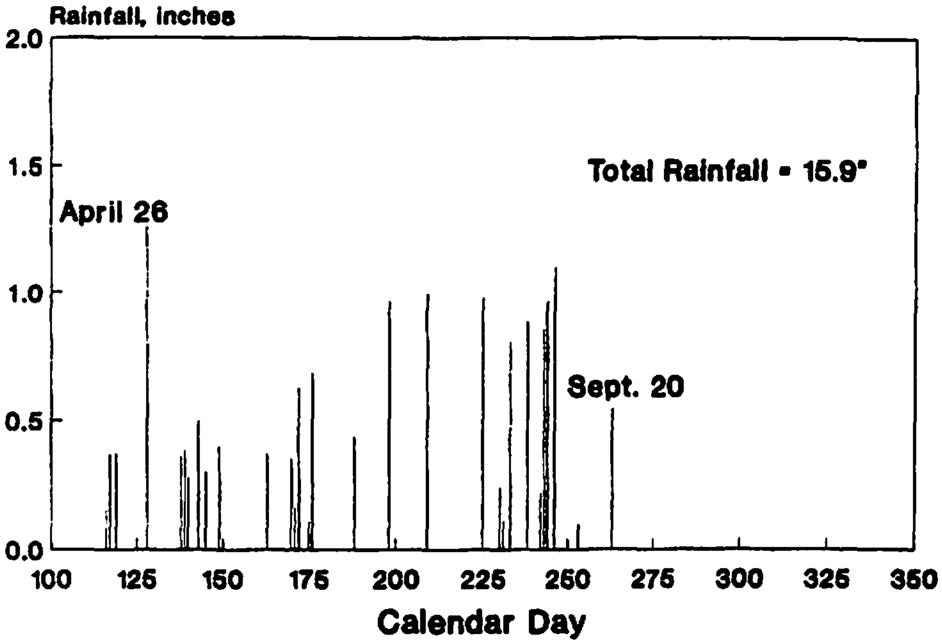
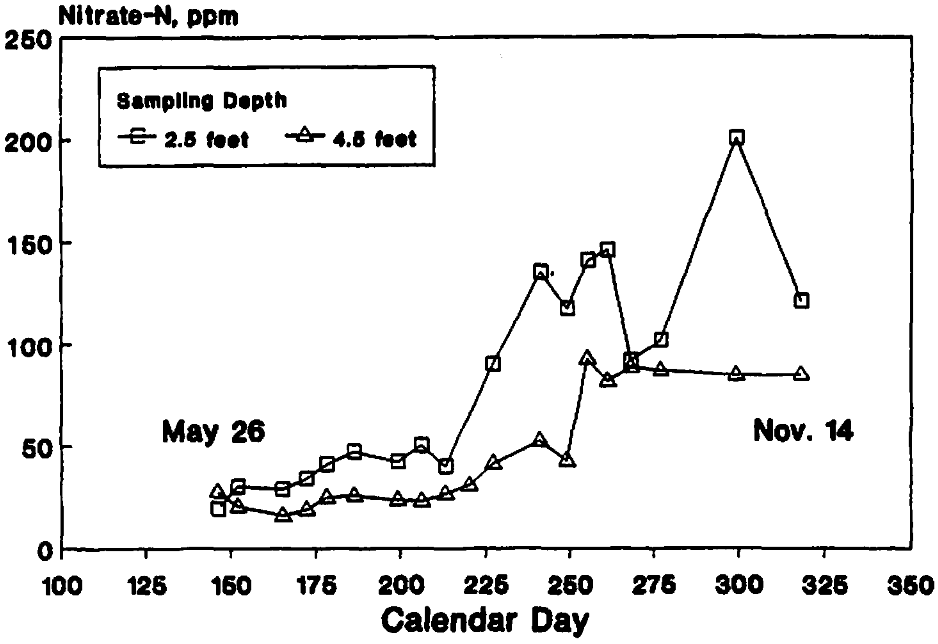


Figure 1. Rainfall distribution during the growing season at Big Lake, MN. This location was within a 15 mile radius of all fields sampled. April 26 indicates begining of rainfall measurments, Sept. 20 indicates final rainfall measurement.

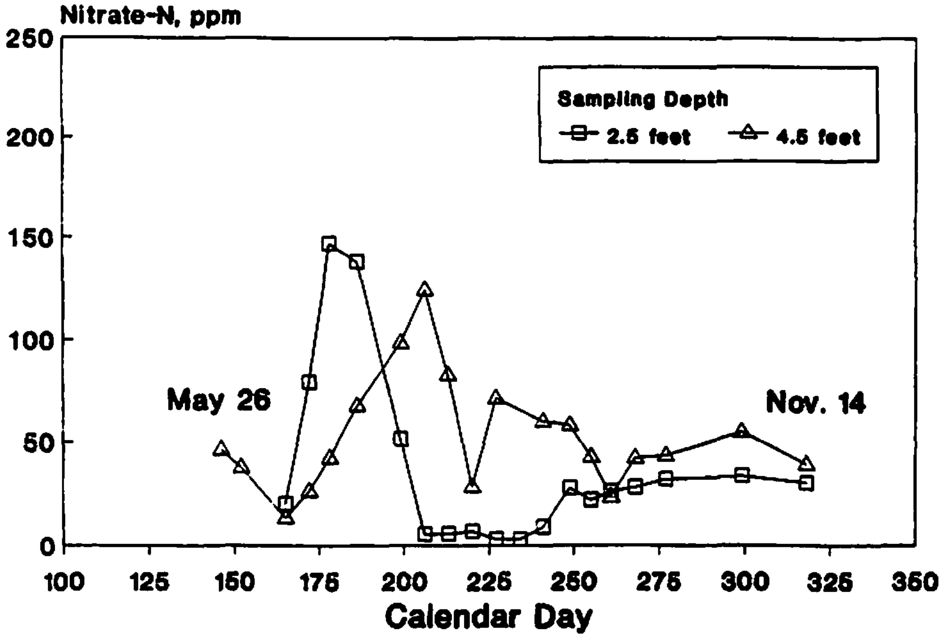


Cultivar - Norkota
Planting Date - May 12
Harvest Date - Sept. 20

N rate and mgmt. -
80 lb N/A starter
90 lb N/A hilling
90 lb N/A irrigation (late July)
Total 260 lb N/A

Total Yield - 280 cwt/A

Figure 2. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 1. May 26 indicates the first sampling date and Nov. 14 indicates the last sampling date.

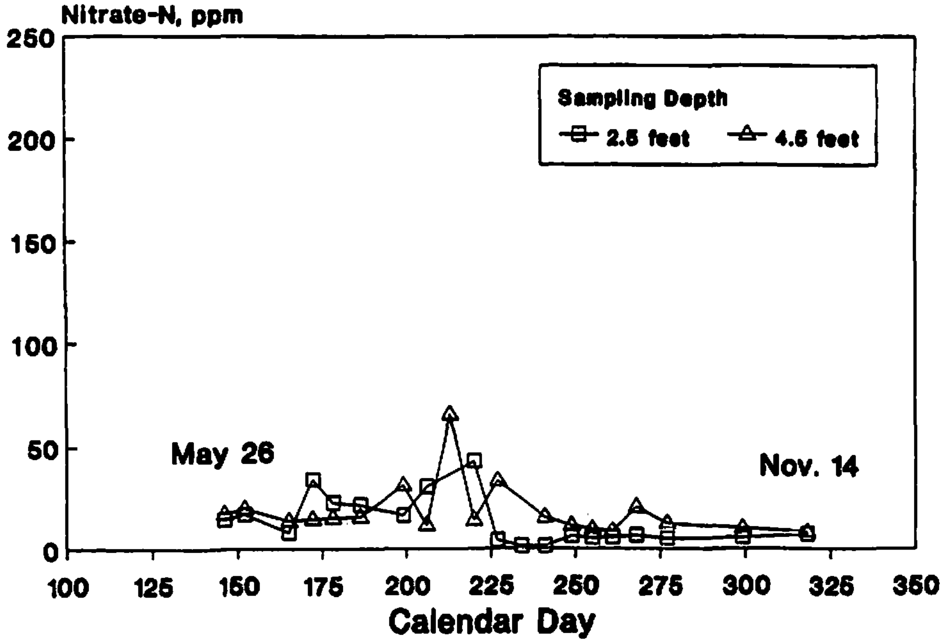


Cultivar - Russet Burbank
Planting Date - April 18
Harvest Date - Sept. 20

N rate and mgmt. -
70 lb N/A starter
180 lb N/A emergence (82-0-0)
75 lb N/A hilling
Total 325 lb N/A

Total Yield - 490 cwt/A

Figure 3. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 2. May 26 indicates the first sampling date and Nov. 14 indicates the last sampling date.

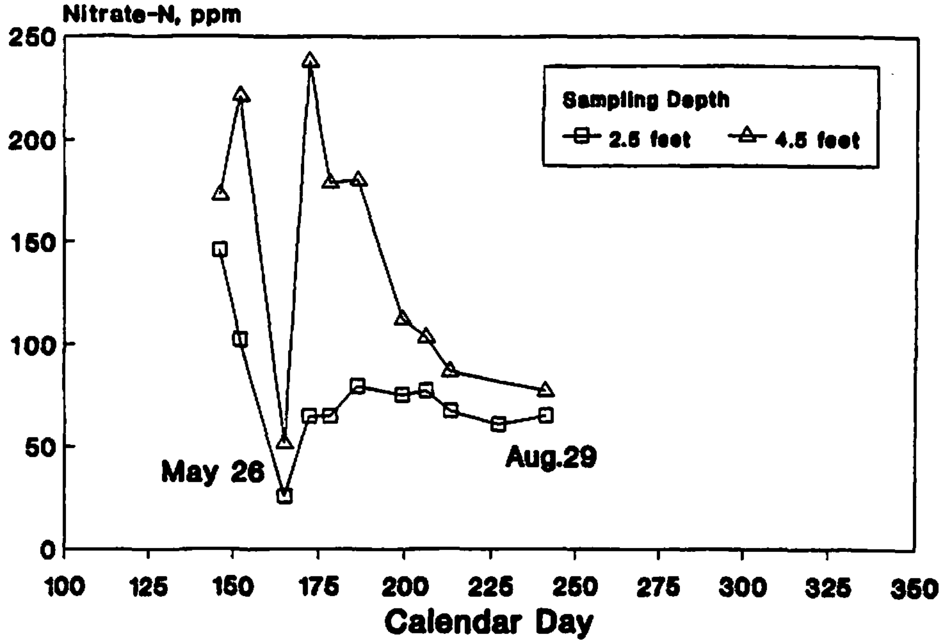


Cultivar - Russet Burbank
Planting Date - April 20
Harvest Date - Sept. 25

N rate and mgmt. -
60 lb N/A starter
80 lb N/A hilling
60 lb N/A irrigation (mid-July)
Total 200 lb N/A

Total Yield - 660 cwt/A

Figure 4. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 3. May 26 indicates the first sampling date and Nov. 14 indicates the last sampling date.

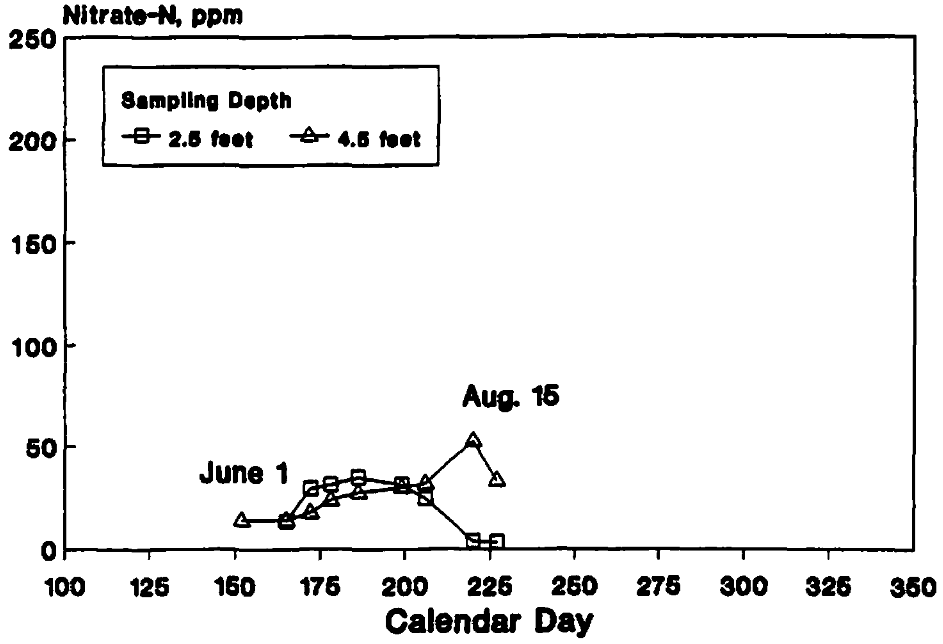


Cultivar - Norkota
Planting Date - April 20
Harvest Date - August 29

N rate and mgmt. -
60 lb N/A starter
100 lb N/A emergence
110 lb N/A hilling
Total 270 lb N/A

Total Yield - 450 cwt/A

Figure 5. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 4. May 26 indicates the first sampling date and Aug. 29 indicates the last sampling date.



Cultivar - Norchip
Planting Date - April 25
Harvest Date - August 29

N rate and mgmt. -
90 lb N/A starter
35 lb N/A emergence
Total 125 lb N/A

Total Yield - 400 cwt/A

Figure 6. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 5. June 1 indicates the first sampling date and Aug. 15 indicates the last sampling date.

EVALUATION OF N-HIB AS A NITROGEN AND CALCIUM SOURCE FOR POTATOES[1]

Carl Rosen, Duane Preston, and John Lamb[2]

ABSTRACT: Two field experiments were conducted to evaluate the effects of N-hib as a Ca and N source for potato production. One experiment was conducted at Becker, MN under irrigated conditions using the cultivar 'Reddale'. The other experiment was conducted at Grand Forks, ND under nonirrigated conditions using the cultivar 'Norchip'. Under the conditions of these studies, N-hib did not improve yields or tuber quality over conventional sources of Ca and N. Adding Ca as gypsum or N-hib had no effect on potato yield or tuber quality indicating that the amount of Ca added from these amendments was low in relation to that supplied by the soil.

N-hib is a recently introduced product that has been promoted to improve potato yield and quality. The product has an analysis of 12% calcium and is registered as calcium monocarbamide monohydrogen chloride. N-hib is intended to be mixed with urea or urea containing solutions, reduce nitrification, and supply calcium. Little research has been conducted to evaluate the effects of N-hib on potato production. The objectives of these experiments, therefore, were to determine the effects of N-hib on potato yield and tuber quality and to compare these effects to those obtained with conventional N and Ca sources.

EXPERIMENTAL PROCEDURES:

Field experiments were conducted at two locations: the Sand Plains Research Farm in Becker, MN under irrigation and the Potato Research Farm in Grand Forks, ND. Procedures varied with each location and therefore each location will be discussed separately.

Sand Plains Research Farm, Becker, MN: the soil at this location is classified as a Hubbard loamy sand and had the following soil test values: pH - 6.3; Organic matter - 2.5%; Bray P1 - 95 lb/A; NH_4OAc K, Mg, Ca - 282 lb/A, 409 lb/A, 1473 lb/A respectively; Hot Water B - 0.2 ppm; 2 N KCl nitrate-N (0-2 ft)- 14 lb/A. The cultivar 'Reddale' was planted April 20, 1989. This cultivar was selected because it usually has low levels of tuber Ca which may be the cause of the high incidence of internal browning under irrigated conditions. All plots received the fertilizer pretreatment which was 875 lbs 8-10-30 banded at planting and 100 lbs 34-0-0 at emergence. The N-hib was mixed with liquid urea to give a final analysis of 18-0-0-7Ca. There were six treatments:

1. 70 lbs N/A as urea at hilling
2. 70 lbs N/A as urea at hilling, 80 lbs Ca/A as gypsum at emergence
3. 70 lbs N/A as urea at hilling, 80 lbs Ca/A as gypsum at emergence, 2 lbs B/A at hilling
4. 70 lbs N/A as urea plus 30 lbs Ca/A as N-Hib at hilling
5. 70 lbs N/A as urea plus 30 lbs Ca/A as N-Hib at hilling, 2 lbs B/A at hilling
6. 70 lbs N/A as urea plus 30 lbs Ca/A as N-Hib at hilling, 2 lbs B/A (foliar) split at hilling and three weeks after hilling

All plots were hilled June 9. The experimental design was a randomized complete block with 4 replications. Irrigation was used to supplement rainfall to provide approximately 1.5 - 2" of water per week. Vines were killed August 1 and tubers were harvested August 28. Leaf (petiole plus leaflets) samples were collected July 13 and a subsample of tubers was collected at harvest for elemental analysis. A subsample of 25 tubers from each size category was cut to determine the incidence of brown center and/or hollow heart.

Potato Research Farm, Grand Forks, ND: The soil at this location is classified as a Nutley/Aberdeen silty clay loam and had the following soil test results: pH - 7.8; Organic matter - 5.3%; Olsen P - 30 lb/A; NH_4OAc K, Mg, Ca - 445 lb/A, 795 lb/A, 5000 lb/A respectively; Hot Water B - 1.3 ppm; 2 N KCl nitrate-N (0-2 ft)- 46 lb/A. The cultivar 'Norchip' was planted June 1, 1989. There were five treatments:

1. Control, no fertilizer applied
2. Conventional: 50 lbs N/A as urea broadcast and incorporated before planting
3. Conventional plus 70 lbs N/A as 28% prior to emergence banded near the row
4. Conventional plus 70 lbs N/A plus 30 lbs Ca/A as N-Hib before emergence banded near the row
5. Conventional plus 70 lbs N/A plus 30 lbs Ca/A as N-Hib before emergence banded near the row plus 2 lbs B/A (foliar) split in 2 applications (at hilling and 3 weeks after hilling)

All plots except the controls received 20 lb P_2O_5/A as a broadcast application before planting. All plots were hilled July 20. The experimental design was a randomized complete block with 6 replications. Leaf samples were collected on July 31 and subsamples of tubers were collected at harvest for elemental analysis. Tubers were harvested September 28, 1989.

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[1] Partial support for this project was provided by Stoller Chemical Co.

[2] Assoc. Prof., Dept. Soil Science; Area Exten. Agent-Potato; Assist. Prof., North West Expt. Sta.

RESULTS:

Becker, MN: Yields of Reddale potatoes were significantly lower with N-hib plus foliar B compared to the other treatments (Table 1). Yields with N-hib and N-hib plus soil applied B were similar to yields with urea and urea plus gypsum. Surprisingly, the highest yields were obtained when urea was applied with gypsum and soil B. Further experimentation is needed to confirm this apparent response to soil applied B. None of the treatments significantly affected the internal browning disorder, which was generally high in all treatments (Table 2). Boron applications increased boron levels of leaves (Table 3). Nitrogen concentrations in tubers and leaves were not significantly affected by treatment, but levels tended to be higher in the N-hib treatments. Calcium levels in leaf tissue were not affected by treatment. Zinc levels in leaves tended to be low in all treatments and may indicate the need for supplemental zinc. Calcium levels in tubers were not affected by treatment, but tended to be highest when Ca was applied either in the form of gypsum or N-hib (Table 4). Boron levels in tubers tended to be higher when boron was applied, although the overall effect was slight and nonsignificant.

Grand Forks, ND: This experiment was conducted without irrigation which simulates conditions for over 90% of the growers in the Red River Valley. Unfortunately, the summer of 1989 was extremely dry which caused severe crop stress, low yields, and high experimental variability. Yields were not affected by any of the treatments, although the no fertilizer control tended to be lower than the other treatments (Table 5). Chip color and specific gravity of the tubers were not affected by treatment (Table 6). Magnesium concentrations in leaf tissue were highest in the control plot and boron concentrations were highest when boron was applied (Table 7). Other nutrient levels in the leaves were not affected by treatment. Nutrient concentrations in tubers were not affected by treatment (Table 8). In general, these results indicate the drought was severe enough to override any treatment effects.

SUMMARY:

Under the conditions of these studies, N-hib did not improve yields or tuber quality over conventional sources of Ca and N. Adding Ca as gypsum or N-hib had no effect on potato yield or tuber quality, indicating that the amount of Ca added from these amendments was low in relation to that supplied by the soil.

Table 1. Comparative effects of N-hib, urea, and supplemental calcium and boron on Reddale potato yields (Becker, 1989).

Treatment	Tuber Size				
	<1"	1-2"	2-3.5"	>3.5"	Total
	cwt/A				
urea	11.5	105.8	291.9	59.0	468.2
urea+gyp	11.1	110.9	296.9	51.6	470.5
urea+gyp+B	12.0	114.2	333.6	54.8	514.6
N-Hib	14.7	110.6	290.9	55.8	472.0
N-Hib+B (soil)	14.8	104.6	283.4	68.8	471.7
N-Hib+B (foliar)	11.4	109.1	258.9	59.8	439.1
Significance	NS	NS	*	NS	**
LSD (0.05)	--	--	42.9	--	27.3

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

Table 2. Comparative effects of N-hib, urea, and supplemental calcium and boron on internal browning of Reddale tubers (Becker, 1989).

Treatment	Tuber Size		
	1-2"	2-3.5"	>3.5"
	% infected		
urea	6.0	25.3	73.0
urea+gyp	2.0	17.5	70.0
urea+gyp+B	2.0	21.0	76.0
N-Hib	1.0	15.0	72.0
N-Hib+B (soil)	3.0	11.5	76.3
N-Hib+B (foliar)	7.0	21.5	78.3
Significance	NS	NS	NS

NS = Nonsignficant.

Table 3. Comparative effects of N-hib , urea, and supplemental calcium and boron on nutrient concentrations in Reddale leaf tissue sampled July 13 (Becker, 1989).

Treatment	Nutrient										
	NO3-N	Total-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	ppm	%					ppm				
Urea	1971	4.50	0.30	4.35	1.28	0.55	80	99	15	24	39
Urea+gypsum	2025	4.52	0.32	4.70	1.25	0.52	79	86	16	27	37
Urea+gypsum+Boron	1687	4.31	0.31	4.76	1.32	0.55	79	92	14	22	97
N-hib	2453	4.56	0.30	4.37	1.19	0.50	81	93	17	21	36
N-hib+Boron (soil)	2446	4.70	0.32	4.55	1.21	0.55	82	96	19	24	82
N-hib+Boron (foliar)	2155	4.43	0.33	4.39	1.17	0.54	78	88	19	21	53
Significance	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	**
LSD	--	--	--	--	--	--	--	--	3	--	19

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

Table 4. Comparative effects of N-hib , urea, and supplemental calcium and boron on nutrient concentrations in Reddale tubers sampled at harvest August 25 (Becker, 1989).

Treatment	Nutrient									
	Total-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%			ppm						
Urea	1.48	0.29	2.33	240	1255	183	10	21	7	8.5
Urea+gypsum	1.42	0.29	2.32	279	1224	138	10	21	7	8.3
Urea+gypsum+Boron	1.50	0.30	2.45	284	1266	135	10	21	7	9.2
N-hib	1.57	0.29	2.38	276	1262	140	10	23	7	9.0
N-hib+Boron (soil)	1.61	0.30	2.40	294	1243	153	10	23	7	9.8
N-hib+Boron (foliar)	1.60	0.30	2.50	276	1261	125	10	24	7	9.6
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant.

Table 5. Effect of N-hib, supplemental nitrogen, and foliar boron on Norchip tuber yield (Grand Forks, 1989).

Treatment	Tuber Size				
	<1"	1-2"	2-3.5"	>3.5"	Total
	cwt/A				
Control	1.2	36.5	83.3	14.8	135.8
Conventional	0.8	34.3	95.9	25.8	156.8
Conventional + urea	0.7	33.2	91.2	17.3	142.4
Conventional + N-Hib	1.0	34.2	94.2	24.8	154.2
Conventional + N-Hib + B	0.6	33.8	95.0	25.2	154.6
Significance	NS	NS	NS	NS	NS

NS = Nonsignificant.

Table 6. Effect of N-hib, supplemental nitrogen, and foliar boron on Norchip tuber specific gravity and chip color.

Treatment	Specific gravity	Color
Control	1.077	46.3
Conventional	1.077	47.5
Conventional + urea	1.080	46.2
Conventional + N-Hib	1.077	45.8
Conventional + N-Hib + B	1.076	44.3
Significance	NS	NS

NS = Nonsignificant.

Table 7. Effect of N-hib, supplemental nitrogen, and foliar boron on nutrient concentration in Norchip leaf tissue sampled July 31 (Grand Forks, 1989).

Treatment	Nutrient												
	NO3-N	Total-N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	ppm	---------	-------	%	-------	-------	-------	-------	-------	ppm	-------	-------	-------
Control	1082	4.41	0.33	3.94	1.39	1.46	103	154	79	90	29	19	40
Conventional	986	4.40	0.32	3.87	1.36	1.26	105	156	61	88	30	21	38
Conventional+urea	980	4.29	0.31	4.01	1.37	1.29	105	157	90	89	29	20	44
Conventional+N-hib	1157	4.37	0.31	3.97	1.33	1.23	104	153	109	84	28	19	37
Conventional+N-hib+boron	1239	4.31	0.32	4.03	1.39	1.25	105	159	40	94	29	19	69
Significance	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	**
LSD	--	--	--	--	--	0.17	--	--	--	--	--	--	11

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

Table 8. Effect of N-hib, supplemental nitrogen, and foliar boron on nutrient concentration in Norchip tubers sampled at harvest (Grand Forks, 1989).

Treatment	Nutrient											
	Total-N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	-------	%	-------	-------	-------	-------	-------	ppm	-------	-------	-------	-------
Control	1.70	0.24	2.52	492	1286	18.3	139	37	8	28	10	6.3
Conventional	1.67	0.24	2.49	451	1282	14.6	111	31	8	27	10	6.4
Conventional+urea	1.59	0.24	2.50	487	1223	13.7	146	42	7	27	9	5.8
Conventional+N-hib	1.61	0.24	2.49	499	1221	18.7	138	39	7	27	10	6.0
Conventional+N-hib+boron	1.66	0.24	2.47	437	1241	11.7	105	42	7	27	9	5.6
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant.

NITROGEN SOURCES, RATES, AND TIME OF APPLICATION FOR HARD RED SPRING WHEAT

J.A. Lamb, S.D. Evans, and G.W. Rehm[1]

A renewed interest in foliar application of nitrogen on spring wheat occurred in 1986. This interest came from a hefty discount on protein below 14% at the elevator and increased attention by producers to intensify their management of small grains similar to what has occurred in western Europe and Eastern United States. Another factor is although the producers have superior varieties (Marshall and Wheaton) at their disposal with regard to yield and lodging, these varieties produce notoriously low protein grain. Many questions about application of liquid N materials relative to source, time of topdress application, and rate applied. To answer these questions, a study was established at the Northwest and West Central Experiment Stations with the objective to determine proper source, rate, and time of application of foliar applied N for optimum grain yield and protein content on spring wheat.

MATERIALS AND METHODS:

This study was conducted at two locations each year; Crookston and Morris in 1987 and 1988 and Mahnomen and Morris, MN in 1989. These locations represent a majority of the 3 million acres of hard red spring wheat grown in western Minnesota. The treatments involved all combinations of two sources (liquified Urea, and Urea Ammonium Nitrate solution), three times of application (tiller, boot, and heading - Zadoks 2.1, 4.3, and 5.6 respectively), and five N rates (0, 10, 20, 40, and 80 lb N A^{-1}). The plot area was soil tested and fertilized with Urea to a level of 120 lb N A^{-1}, Soil NO_3^--N 0-2' + fertilizer N). This corresponded to the Minnesota N recommendation for a 60 bu A^{-1} yield goal in 1987. The spring wheat variety 'Marshall' was used at both locations. This is a high yielding semi-dwarf variety planted on 70% of the Minnesota wheat acreage which produces a low protein grain. The seeding rate was 100 lb A^{-1}. The wheat was seeded with a double disc press wheel drill mid-April all three years. The treatments were applied with a sprayer delivering a volume of 50 gallon A^{-1} at 30 psi pressure. Leaf burn was visually evaluated one week after each application. Whole plant samples were taken at soft dough and N concentration was determined in 1987 and 1989. The grain was harvested by small plot combine in late July 1987 to 1989 and grain protein concentration was determined on the grain in 1987 and 1989.

RESULTS AND DISCUSSION:

During every year for this study, the wheat crop experienced drought stress at some point in the growing season. Most noteable was the 1988 drought which seriously reduced grain yields at both Crookston and Morris. The season started with no subsoil moisture and no spring precipitation. Only a late-May rain brought the crop through to any production at all. Both 1987 (Crookston and Morris) and 1989 (Mahnomen and Morris), had enough precipitation and soil moisture to raise reasonable crops.

Grain Yield: At all six site-years, grain yield was affected only in 1987 at Crookston (Table 1). A significant increase of 2.4 bu/A occurred with 40 lb N/A. The time of application or N source did not affect grain yield. At the other five-site-years, topdress N application did not effect grain yield. This suggests that the preplant N application supplied more than adequate N for the grain yields obtained at the five-site-years and additional N applied during the growing season was not needed.

Grain Protein and Plant N Uptake: Grain protein and plant N uptake was measured in 1987 and 1989. Because of the severe drought in 1988, grain protein and plant N uptake were not measured. In 1987, N rate increased grain protein concentration 1.0 and 0.6% at Crookston and Morris, respectively (Table 2).

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

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Table 1. Grain yield as affected by topdress N, source, and time of application at Crookston and Morris, MN, 1987-1989

	Crookston*			Morris		
N Rate	1987	1988	1989	1987	1988	1989
lb/A			bu/A			
0	49.0	25.5	48.4	58.2	8.6	56.1
10	46.9	27.4	48.6	56.6	8.2	57.0
20	50.3	27.1	47.4	59.2	8.2	55.9
40	51.4	26.1	45.8	56.1	6.9	55.6
80	49.5	25.9	45.2	55.9	8.2	54.7
Source						
UAN	49.5	26.5	46.3	56.2	8.1	55.8
Urea	49.5	26.8	47.2	57.7	7.7	55.8
Time						
Tiller	51.1	26.8	49.5	54.5	6.7	55.8
Boot	46.6	27.9	46.2	57.5	7.3	56.6
Head	50.9	25.2	44.6	58.8	9.6	55.1
Statistical Analyses						
Time	NS	NS	NS	NS	NS	NS
Source	NS	NS	NS	NS	NS	NS
Rate	.04	NS	NS	NS	NS	NS
Source*Rate	NS	NS	NS	NS	NS	NS
Time*Source	NS	.05	NS	NS	NS	NS
Time*Rate	NS	NS	NS	NS	NS	NS
Time*Source*Rate	NS	NS	NS	NS	.06	NS
C.V.	10.1	12.1	13.8	10.0	32.7	5.7

* Crookston location was actually in Mahnomen County in 1989.

Nitrogen source and application time did not affect this response. In 1989 there was a significant source by N rate interaction at both locations (Table 2). At Mahnomen the UAN increased grain protein 0.6% while Urea had no effect (Table 3). At Morris, both sources increased grain protein 0.3% but the maximum protein occurred at the 20 lb N/A rate for UAN and at 80 lb N/A for Urea (Table 3). Also in 1989 at Morris the effect of N rate on grain protein was different depending on time of application. The N applied at tiller and boot growth stages increased protein concentration up to the 80 lb N/A rate (Table 4). The N applied at heading had a maximum grain protein concentration at 20 lb N/A and actually decreased protein at the 80 lb N/A rate (Table 4).

The application of N significantly effected the N uptake at soft dough only in 1987 at Morris. This 10.8 lb/A increase was maximized at the 40 lb N/A application rate. Again time of application and N source did not effect the N uptake by the wheat.

Table 2. Grain protein and whole plant N uptake as affected by topdress N, rate, source, and time of application at Crookston and Morris, 1987 and 1989.

	Crookston*				Morris			
N Rate	Grain Protein		Plant N Uptake		Grain Protein		Plant N Uptake	
lb/A	1987	1989	1987	1989	1987	1989	1987	1989
	---- % ----		-- lb/A --		---- % ----		-- lb/A --	
0	12.2	13.0	83.2	81.4	13.4	15.3	102.9	146.9
10	12.7	13.0	82.2	82.8	13.7	15.3	99.7	147.7
20	12.8	13.2	90.5	80.7	13.7	15.5	112.6	144.9
40	13.0	13.3	92.3	85.9	13.9	15.5	113.7	146.9
80	13.2	13.4	94.1	77.7	14.0	15.4	113.7	148.9
N Source								
UAN	12.9	13.2	89.1	84.7	13.8	15.4	107.4	147.0
Urea	12.9	13.3	90.5	78.9	13.9	15.5	112.4	147.2
Time								
Tiller	12.9	13.0	91.7	91.7	14.0	15.5	104.4	146.4
Boot	12.9	13.0	83.7	68.9	13.8	15.5	116.9	146.7
Head	12.9	13.7	93.9	84.8	13.7	15.3	108.5	148.2
Statistical Analyses								
Time	NS	.10	NS	NS	NS	NS	NS	NS
Source	NS	NS	NS	NS	NS	NS	NS	NS
Rate	.0001	NS	NS	NS	.0001	NS	.08	NS
Source*Rate	NS	.10	NS	NS	NS	.09	NS	NS
Time*Source	NS	NS	NS	NS	NS	NS	NS	NS
Time*Rate	NS	NS	NS	NS	NS	.06	NS	NS
Time*Source*Rate	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	3.0	4.8	21.6	29.1	2.3	2.9	17.7	10.9

* Crookston location was actually in Mahnomen County in 1989.

SUMMARY:

At the time of this report, high protein wheat grain is being discounted so it is not economically feasible to consider the practice of N topdressing to increase grain protein concentration. The data implies that the use of topdress N in a situation where adequate preplant has been applied and not lost to denitrification or leaching will not increase grain yields under normal growing conditions (1987). Grain protein content can be increased with the use of topdress N. The N source and time of application did not consistantly effect this increase.

Table 3. The interaction of N rate and N source on grain protein concentration at Crookston and Morris, 1989.

N Rate	Crookston*		Morris	
	UAN	Urea	UAN	Urea
lb/A	-------- % -------		------- % ------	
0	13.0	13.1	15.3	15.3
10	12.8	13.2	15.3	15.4
20	13.0	13.4	15.6	15.3
40	13.3	13.2	15.5	15.5
80	13.6	13.2	15.2	15.6

* Crookston location was actually in Mahnomen County in 1989.

Table 4. The interaction of N rate and time of application on grain protein concentration in 1989 at Morris.

N Rate	Tiller	Boot	Head
lb/A	--------------- % -------------		
0	15.3	15.3	15.2
10	15.2	15.3	15.4
20	15.3	15.5	15.5
40	15.7	15.6	15.2
80	15.7	15.5	15.1

NITROGEN AND SULFUR FERTILIZATION OF HARD RED SPRING WHEAT IN GOODHUE COUNTY

Brian Schreiber, Greg Cremers, Andy Scobbie, George Rehm[1]

ABSTRACT: Studies were conducted at two locations in Goodhue County to determine the effect of N rate, method of N application, and S usage on the yield and protein content of hard red spring wheat in southeast Minnesota. Split applications were not superior to single applications of fertilizer N. A rate of 60 lb. N/acre was adequate for optimum yield. Use of S had no significant effect on either grain or straw yield as well as the protein content of the grain.

Introduction:

Hard red spring wheat is not commonly grown in eastern and southeastern Minnesota. Yet, it might be considered as an alternative to corn for the region.

Fertilizer requirements for profitable production of this crop in northwestern and west-central Minnesota have been the focus of many research trials. The environment of southeastern Minnesota, however, is much different than the environment in western Minnesota. Soils are also different. Therefore, it is reasonable to expect that fertilizer management practices might be unique for each region of the state.

Profitable production of hard red spring wheat is dependent on both yield and protein content of the grain. Therefore, a measurement of the protein percentage should be included in any evaluation of fertilizer management practices.

Sulfur, S, is a major component of plant proteins. The importance of S in a fertilizer program for spring wheat production in southeast Minnesota has also been questioned. Therefore, it's important to also fully evaluate the effect of S fertilization on spring wheat production in the region.

Objectives:

Recognizing the needs cited above, this study was conducted to:

- Determine the effect of N management practices on the yield and protein content of spring wheat grown in southeastern Minnesota.
- Measure the effect of the addition of S to a fertilizer program on grain yield and protein percentage.

Experimental Procedure:

This study was conducted at 2 locations in Goodhue County in 1989. Soils at the experimental sites were typical of soils in the area. Prior to initiation of the study, soil samples were collected from 0-6, 6-12, 12-24, and 24-36 inches. Results of the analysis of these samples are summarized in Table 1.

Nitrogen management variables consisted of 3 rates (0, 60, 120 lb. N/acre) applied in 3 timing options (single application; 1/2 of total N preplant; 1/2 at flag leaf stage; 1/2 of total N preplant; 1/4 at the tiller stage; 1/4 at the flag leaf stage. The impact of fertilizer S was evaluated by comparing the use of 60 lb. N/acre with 30 lb. S/acre applied preplant with the application of 60 lb. N/acre preplant. This comparison was also made for the 120 lb. N/acre rate. Urea (46-0-0) was used to supply the needed N for each method of application. Granular gypsum was used to supply the needed S. Each plot also received a preplant application of 100 lb./acre of 0-46-0 and 100 lb./acre of 0-0-60. All preplant fertilizers were incorporated with a disk prior to planting. The N applied (46-0-0) at tiller and boot stage was broadcast to the established stand without mechanical incorporation. All treatments were arranged to fit a randomized complete block design with 4 replications.

Cooperating farmers were responsible for seedbed preparation, planting, and herbicide usage to control major weed pests. Plots were harvested in mid-to-late July, samples were threshed with a stationary combine. Straw was collected and weighed, and grain samples were analyzed for protein N.

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[1] County Extension Agent, Goodhue County, Assistant Scientist, Junior Scientist, Extension Soil Scientist, respectively.

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

Soil Property	Depth	Site	
		Lindstrom	Davidson
	- in -		
pH	0-6	6.0	6.1
P, (Bray & Kurtz #1), ppm	0-6	21.3	33.0
K, (1M $NH_4C_2H_3O_2$), ppm	0-6	141	123
Organic Matter, %	0-6	2.5	2.6
NO_3-N, lb./acre	0-6	12.8	24.6
"	6-12	25.2	22.4
"	12-24	58.3	23.4
"	24-36	35.0	10.1
	Total	131.3	80.5

Results and Discussion:

Yield and protein data for the Lindstrom and Davidson sites are summarized in Tables 2 and 3, respectively. At the Lindstrom site, neither grain nor straw yield was affected by the method of N application for both rates of fertilizer N used (Table 2). Yields were lower than expected which can be attributed, in part, to dry conditions during the early part of the growing season.

The method of N application did have a significant effect on the protein content of the grain. Both split applications produced a higher protein percentage. Yet, there was no significant difference in the 2 methods used for the split application.

Grain yield, straw yield, and protein content of the grain were increased by the rate of N used. The rate of 60 lb. N/acre was adequate. The lack of a response to the higher N rate can be attributed, in part, to the large amount of carryover NO_3-N measured to the depth of 3 feet (131.3 lb./acre). The response to the rate of N applied was not affected by the method of application.

In agreement with the results at the Lindstrom site, the split application of N produced a significant increase in the protein percentage at the Davidson location. The use of 3 instead of 2 N applications had no effect on protein percentage.

Neither straw nor grain yield was affected by the number of N applications used at the Davidson location (Table 3). Based on the results obtained from these 2 locations, it would appear that split applications of fertilizer N are not needed for the production of hard red spring wheat in southeast Minnesota.

The protein percentage as well as the grain and straw yield was increased by the rate of N used. The use of 60 lb. N/acre was certainly adequate for top production at these sites. The previous crop at this location was soybeans and there was a considerable amount of carryover NO_3-N at the start of the growing season. Therefore, a large response to fertilizer N would not be expected.

The application of 30 lb. S/acre in combination with either 60 or 120 lb. N/acre had no significant effect on either grain or straw yield. There was also no effect on the protein content of the grain. This was true for both locations. These data show that there is no need for S in a fertilizer program for hard red spring wheat in southeast Minnesota.

Table 2. The effect of nitrogen rate, timing of nitrogen application and sulfur use on grain and straw yield and protein content of hard red spring wheat at the Lindstrom site.

N			S	Straw	Grain	Grain
Preplant	Tiller	Flag		Yield	Yield	Protein
lb./acre				ton/acre	bu./acre	%
0	0	0	0	1.52	29.4	13.6
30	15	15	0	2.03	37.7	14.7
30	0	30	0	2.00	37.0	15.1
60	0	0	0	1.94	33.0	13.4
60	0	0	30	2.06	34.4	14.4
60	30	30	0	1.85	31.2	16.1
60	0	60	0	1.91	31.3	15.5
120	0	0	0	1.68	33.2	14.9
120	0	0	30	2.07	32.7	15.6

Table 3. The effect of nitrogen rate, timing of nitrogen application and sulfur use on grain and straw yield and protein content of hard red spring wheat at the Davidson site.

N			S	Straw	Grain	Grain
Preplant	Tiller	Flag		Yield	Yield	Protein
lb./acre				ton/acre	bu./acre	%
0	0	0	0	1.42	33.1	11.8
30	15	15	0	1.69	40.3	14.0
30	0	30	0	1.67	40.3	13.6
60	0	0	0	1.62	41.5	12.9
60	0	0	30	1.77	42.6	13.1
60	30	30	0	1.74	39.0	14.4
60	0	60	0	1.74	43.7	14.2
120	0	0	0	1.66	38.7	13.0
120	0	0	30	1.74	39.7	13.8

EFFECTS OF NUTRIENT SOURCES, APPLICATION TIMING, AND RATE ON ALFALFA PRODUCTION (AND SUBSEQUENT CORN CROPS)

M.A. Schmitt, G.W. Randall, and C.C. Sheaffer[1]

ABSTRACT: The application of manure and inorganic fertilizer both increased forage yields when applied as a plowdown treatment. While the manure resulted in poor stands of alfalfa due to a compaction problem at Waseca, the response due to the fertilizer was significant. At Rosemount, the forage responded positively to the manure applications, except with the highest rate. The high levels of inorganic nitrogen measured in the soil in the summer were not present, except for the highest manure rate, in the fall.

A long-term project was started in 1989 to examine the effects of manure and alfalfa on nitrogen (N) credits for the following corn crops. An initial result of this project is the effects of various rates of manure and inorganic fertilizer on new alfalfa. Farmers often have questions regarding yields, forage quality, and nodulation when applying manure onto alfalfa ground. This paper will look specifically at first cutting forage yields and first-year soil N fluctuations due to the manure treatments. All producers handling manure need to be aware of environmental concerns of N in the groundwater.

OBJECTIVES

1. Evaluate the effects of plowdown and topdress fertilizer application, commercial and manure fertilizer sources, and rates of nutrient application on alfalfa.

2. Evaluate alfalfa nutrient uptake, forage quality, stand density, and dry matter production as a function of the various fertilizer treatments.

3. Monitor soil N forms from the manure treatments and correlate values with soil N data and corn production values in the N equivalency plots.

4. Compare and evaluate the overall economic feasibility of the fertility treatments in a 5-year rotation.

Materials and Methods

Trials were established at agricultural experiment stations at Rosemount and Waseca. At Rosemount, hog manure was used on a shallow silt loam lying on outwash gravel soil. At Waseca, dairy manure was used on a clay loam soil. Three rates of manure (3000, 6000, and 12000 gallons per acre) were broadcast and incorporated immediately. Inorganic fertilizer was also used as treatments--applied to give equivalent phosphorus and potassium rates as provided in the manure. Alfalfa was seeded directly at both sites, on April 25 in Rosemount and May 16 in Waseca.

Results

Rosemount Location. The effect of the three rates of preplant inorganic fertilizer and manure treatments on forage dry matter production at Rosemount is listed in Table 1. No visible stress was seen during the early growing season. The treatments with manure did produce taller, darker appearing alfalfa than did the inorganic fertilizer treatments. The first cutting yields increased with the manure treatments up until the highest manure rate, at which the alfalfa was noticeably lodged. Crude protein content was not affected by the treatments. The second cutting yields were not statistically different due to the treatment effects. The second half of the growing season was extremely dry and the plots also had leafhopper pressure. The weed component of the overall forage yields was positively correlated with increasing manure rates.

Since the soil tests at Rosemount were categorically "high" (Bray P at 35 ppm and K at 200 ppm) the response of the alfalfa was most likely due to factors other than just the P and K. Note, however, that yields increased with the inorganic fertilizer additions as well.

The elemental composition of the first cutting alfalfa was made using inductively coupled plasma emission spectroscopy (ICP). Nitrogen and phosphorus concentrations were unaffected by treatments (Table 2). The potassium concentrations increased with increasing manure and fertilizer rates. Other nutrient means

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with significant treatment effects included: a) a lower magnesium content with manure treatments, and b) a lower zinc content with the fertilizer treatments, both compared to the control.

Waseca Location. The increasing rates of manure resulted in lower yields of alfalfa at the Waseca site (Table 3)--which tested "low for P (8.5 ppm) and K (94 ppm). However, the forage yields increased significantly as the rate of inorganic fertilizer increased. As was true at Rosemount, the amount of weeds increased as the manure rates increased.

A major stand problem at Waseca was most likely the cause for the lower yields with the manure additions. The application equipment created a severe compaction problem, resulting in almost no stand in the wheel tracks. In addition, the alfalfa was stressed throughout the growing season by a shortage of rainfall and by leafhoppers. Due to the extremely stressed condition of the alfalfa at harvest, plant nutrient analysis was not conducted.

Soil N Status. The N status of the soil can affect alfalfa's nodulation and overall growth as well as have a direct influence on the risk of groundwater contamination. At Rosemount, the inorganic N concentrations were a function of the manure rate (Table 4). The control treatment characterizes the natural inorganic N fluctuations throughout the growing season. The manured plots' available N peaked during June and steadily decreased through late summer. At November 1, only the highest rate of manure resulted in higher inorganic N concentrations in the soil. Ammonium N dominated the inorganic N fraction early in the season whereas nitrate N was dominant later.

Summary

The application of low to medium rates of manure can result in a significant yield increase in newly established alfalfa with proper management. Inorganic fertilizer applications can result in similar increases with fewer potential management problems. The key in making this manure/alfalfa system work is applying the manure so that seedbed quality is maintained. Although the manure brings certain weed problems to the stands, these generally do not last past the first cutting. While manure adds substantial amounts of N to the soil, the treatments result in few to no soil N differences at the end of the growing season.

This is the first year of a 5-year study.

Table 1. Forage yields and composition as influenced by treatments, Rosemount, 1989.

	1st Cutting				2nd Cutting
	Total D.M.	Alfalfa D.M.	Lodging Score	Crude Protein	Total D.M.
	- - - Ton/A - -		(1-5)	- % -	- Tons/A -
Control	1.552	1.503	4.75	20.78	0.848
Manure-Low	1.792	1.680	2.00	20.76	0.645
Manure-Medium	1.963	1.818	2.00	21.73	0.978
Manure-High	1.623	1.483	2.50	21.06	0.587
Fertilizer-Low	1.600	1.580	4.00	21.19	0.820
Fertilizer-Medium	1.703	1.677	4.25	21.09	0.830
Fertilizer-High	1.760	1.610	3.00	20.17	0.742
$Pr \geq F$	0.000	0.052	0.000	0.890	0.185
LSD (0.10)	0.147	0.183	0.790	1.690	.300

Table 2. Elemental composition of the first cutting of forage as affected by treatment, Rosemount, 1989.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	% in plant					ppm in plant						
Control	3.323	0.304	2.088	1.483	0.290	95.91	112.84	477.53	26.43	18.46	6.872	27.81
Manure-Low	3.322	0.299	2.427	1.408	0.249	79.81	96.94	475.84	25.13	22.16	5.687	27.75
Manure-Medium	3.478	0.314	2.564	1.532	0.278	106.44	119.68	690.24	31.50	21.62	5.465	30.51
Manure-High	3.368	0.308	2.649	1.549	0.271	152.05	149.51	468.43	39.15	23.18	5.777	30.55
Fertilizer-Low	3.393	0.300	2.073	1.556	0.291	110.11	124.81	547.59	31.96	17.94	6.510	27.99
Fertilizer-Medium	3.375	0.306	3.199	1.554	0.292	111.19	125.53	416.16	32.26	17.22	5.825	28.48
Fertilizer-High	3.225	0.289	2.540	1.476	0.251	146.49	144.51	211.46	34.53	16.10	4.930	29.82
PR ≥ F	0.890	0.352	0.000	0.155	0.000	0.283	0 .343	0.012	0.028	0.024	0.034	>1
LSD (0.10)	0.272	0.016	0.247	0.114	0.019	76.73	51.55	175.64	6.76	3.52	0.981	3.02

Table 3. Yields of first cutting forage as infuenced by treatments, Waseca, 1989.

	Total D.M.	Alfalfa D.M.	Chlorosis Score
	Tons/A		(1-5)
Control	1.360	1.330	3.00
Manure-Low	1.445	1.375	4.00
Manure-Medium	1.163	1.063	4.00
Manure-High	1.298	0.958	4.00
Fertilizer-Low	1.482	1.380	3.00
Fertilizer-Medium	1.583	1.498	3.00
Fertilizer-High	1.583	1.498	3.00
Pr ≥ F	0.002	0.003	0.000
LSD (0.10)	0.147	0.205	0.0

Table 4. Soil nitrogen concentration as affected by manure rate and sampling date, Rosemount, 1989.

		0-12"		12-24"	
Sampling Date	Manure Rate	NO_3-N	NH_4-N	NO_3-N	NH_4-N
		ppm N			
May 1	none	7.6	19.1	6.6	11.6
	low	10.4	42.8	7.2	15.9
	medium	9.0	54.1	7.9	17.0
	high	8.9	67.9	8.9	21.0
May 31	none	8.9	9.3	8.0	6.7
	low	32.6	11.2	8.8	6.9
	medium	67.0	14.3	12.5	7.9
	high	93.2	34.5	13.0	10.2
June 22	none	9.2	16.2	8.7	13.3
	low	29.8	17.2	12.7	10.1
	medium	49.4	18.1	19.4	13.4
	high	74.0	22.9	29.3	13.6
July 11	none	2.9	8.7	1.9	4.7
	low	9.5	8.7	4.5	5.3
	medium	25.6	10.1	8.9	6.7
	high	57.2	9.9	13.6	5.0
August 3	none	2.4	6.7	0.8	5.8
	low	3.2	7.8	1.0	6.2
	medium	10.7	8.1	3.4	5.7
	high	30.2	9.1	8.2	5.7
August 28	none	2.3	3.6	2.7	0.5
	low	2.2	3.7	2.1	1.5
	medium	2.1	12.1	2.2	3.4
	high	2.8	32.8	2.0	7.1
November 1	none	1.5	6.5	0.1	3.7
	low	1.5	6.4	0.2	3.5
	medium	1.7	7.2	0.2	4.2
	high	8.3	6.5	7.1	4.1

USE OF NITRO ALFALFA IN SOUTHERN MINNESOTA

Neal P. Martin, Timothy L. Wagar, Duane A. Schriever, and George W. Rehm[1]

ABSTRACT: Trials are in progress in southeastern Minnesota to detrmine the amount of N supplied by 'Nitro' to a corn crop in rotation. The N supplied by the 'Nitro' alfalfa is compared to the amount of N supplied by perennial varieties of alfalfa and red clover. In 1989, corn following alfalfa yielded more than corn following corn and this is expected. The amount of N supplied by 'Nitro' was equal to the amount of N supplied by other varieties in the trial.

'Nitro' alfalfa is an "annual" (nondormant variety) alfalfa developed by the USDA-ARS and the University of Minnesota to provide increased amounts of nitrogen over dormant alfalfa varieties in the seeding year through symbiotic fixation of nitrogen (N). Minnesota farmers, especially dairymen, have used alfalfa in a crop rotation with corn very successfully. Alfalfa provides forage as hay or low-moisture silage which supplies high amounts of protein, energy, calcium and vitamins, while corn for silage supplies high energy feed with some protein, minerals and vitamins. The alfalfa is used in stands three-to-five years old and it boosts corn yields the first two years that corn follows alfalfa due to a rotation effect and the addition of N through symbiotic N^2 fixation. Nitro provides a new technology in crop rotations by supplying, in one year, almost as much N as a five-year old stand plus allowing 3 cuttings of forage.

Nitro was selected for higher N concentration in roots and larger root mass than available from other nondormant varieties of alfalfa. Minnesota research, Sheaffer et al, 1989, showed Nitro has 5.4, 3.6, and 3.8 percent more N in forage, N in crowns and N in roots, respectively, than other nondormant alfalfa varieties. Tests conducted at Becker, Lamberton, Rosemount and Waseca (Sheaffer et al., 1989) showed Nitro averaged 94 pounds per acre of N for plowdown in the fall of the seeding year. This was 10 and 38 pounds per acre more than nondormant and dormant alfalfa varieties, respectively. Farmers want to know how Nitro alfalfa will produce on their farms.

Objectives: A field evaluation was established at two sites (Lyle Tjosaas Farm, Byron, and Tom Pyfferoen Farm, Rochester) in southeastern Minnesota to evaluate seeding year yields of Nitro compared to dormant varieties of alfalfa available to Minnesota producers and 'Arlington' red clover. These represented a range in fall growth score (Saranac, 4.5; Ranger, 5.4; and Wrangler, 7.0). A second objective was to examine corn grain yield response following alfalfa at four rates of N (0, 50, 100 and 150 lbs/A of N).

Materials and Methods: At each site, alfalfa was direct seeded at 12 lb/A in April, harvested three times for forage, with the fall growth incorporated into the soil and corn seeded the following spring. The alfalfa varieties and red clover were planted in a randomized complete block arrangement (2 drill widths wide x 160 ft. long) and N rates were split randomly within corn plots and alfalfa plots. Each treatment was replicated 3 times.

Crop conditions at Lyle Tjosaas' Farm:

1988:
Soil Test: Soil texture- silt loam; soil pH, 6.7; Bray 1 phosphorus, 77 lb/A; potassium, 387 lb/A, and sulfur, 10 ppm.
Seeded: April 20, 1988 with 8' Brillion Seeder (16' x 160' plots), 12 lbs/A for alfalfa - 10 lbs/A for red clover
Balan @ 1 gal/A was pre-plant incorporated
Harvest dates: 6/24, 7/29, and 9/07
Fall growth determination: 10/27
Rainfall 1988 - Haverhill (Olmsted County)
April, 2.22; May, 2.22; June, 1.69; July, 1.87; August, 2.9; Sept., 5.64 and Oct., .75; inches. Total of 17.3 inches April thru October; 5.67 inches below normal.

1989: Corn @ 0, 50, 100 and 150 lb/A N over entire plot area. (Four row plots at 27,000-28,000 plants/A)

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Crop conditions at Tom Pyfferoen's Farm :

1989:
Soil Test: NA
Seeded: April 20, 1989 with Brillion seeder 200 lbs of 0-0-60/A were applied and incorporated preplant with 1-1/2 pt/A Eptam, impregnated
'Poast' was sprayed 6/17/89

Rainfall 1989 - Rochester
April, 3.56; May, 1.74; June, 2.58; July, 2.75; August, 5.62; Sept., .61 and Oct., 1.6 inches. Total April thru October 18.46 inches.
Harvest dates: 7/7, 8/9, and 9/15.
Fall growth determination: 11/06

Results and Discussion

Alfalfa yields of Nitro were below those reported at Waseca, 3.0 vs 2.4 and 2.5, T/A of DM, for 1988 and 1989, Table 1, respectively (Sheaffer et al. 1988).

Table 1. Dry matter yield by cutting in 1988 (Tjosaas and 1989 (Pyfferoen Farm).

Alfalfa variety	Dry matter yield, T/A 1	2	3	Total
	- - - - - - - - - Tjosaas Farm - - - - - - - - -			
Nitro	0.7	0.8	0.9	2.4
Saranac - IN[1]	0.7	0.5	0.8	2.0
Saranac	0.7	0.6	1.1	2.5
Ranger	0.7	0.6	0.9	2.2
Wrangler	0.7	0.7	1.0	2.4
Redclover	0.5	0.7	0.9	2.0
	- - - - - - - - - Pyfferoen Farm - - - - - - - - -			
Nitro	1.1	0.8	0.6	2.5
Saranac - IN[1]	0.8	0.5	0.5	1.8
Saranac	1.1	0.6	0.8	2.5
Ranger	1.0	0.6	0.7	2.3
Wrangler	1.1	0.6	0.6	2.3
Red Clover	0.9	1.2	1.0	3.2

[1] Line of Saranac alfalfa developed that produces nodules that are ineffective in N^2 fixation.

However, the Waseca Study was conducted under normal rainfall, an annual amount of 25 inches while our field trials in both years were below normal rainfall. In 1989, rainfall was above the 1988 drought, 18.5 vs. 17.2 inches, but severe insect damage on all alfalfa varieties on the second cutting in 1989 depressed yields by at least 25%. The insect damage resulted in red clover yields greater than alfalfa in 1989. These field trials however, do agree with the Waseca research in the comparison of Nitro to another dormant variety, Saranac AR; the summer yields were not different, 3.0 vs. 2.9, respectively, Table 1. Nitro also produced more herbage in the fall at both of our locations and at Waseca.

Corn yields at the Tjosaas' location varied most between years, 111 vs. 193 bu/A continuous corn, Table 2. Corn following alfalfa resulted in higher corn yields than corn after corn, regardless of nitrogen fertilizer level, 193 vs 206 bu/A. This finding is not new. However, the Waseca research showed corn following Nitro alfalfa cut 3 times produced an extra 30 bu/A (80 vs 50 bu/A) of corn over continuous corn at no N fertilization or an extra 37 bushels at 100 pounds of actual N (137 vs 100 bu/A). Although corn following Nitro at Tjosaas' resulted in an extra 11 bushels (204 vs. 193 bu/A, Table 2; this agrees with Sheaffer et al, 1989), our trial did not show Nitro different from other alfalfa varieties in subsequent corn yields. We did not measure N produced by Nitro, thus, we hypothesize the lack of response was due to two different problems. First, Nitro may not have produced as much extra N as reported by Sheaffer et al., 1989 (Nitro produced 32 more lb/A of N than Saranac AR) or second, the N available in the soil was excessive. N production during the fall could have been prevented from drought; eliminating Nitro's advantage. We expect N was excessive because corn grown after Saranac-IN (the ineffective variety of alfalfa which does not fix N) produced similar corn yield as other alfalfa varieties 202 vs 204, 205, 203, and 209 bushels per acre, respectively, Table 2. Tjosaas regularly uses dairy manure on his fields and his soil has a higher organic matter content. Therefore, we are not surprised with this response.

Table 2. Corn yields at Tjosaas Farm in 1988 and 1989 at three levels of N in continuous corn and corn-on-corn on following alfalfa or red clover.

			Corn grain yield, bu/A					
N level	Continuous		Following legume - 1989					
lb/A	1988	1989	Nitro	Sar-IN	Saranac	Ranger	Wrangler	R. Clover
0	110	193	204	202	205	203	209	196
50	115	192	201	207	206	202	204	202
100	109	194	212	209	210	211	208	212
150	111	191	198	216	213	204	207	206
Avg	111	193	204	209	208	205	207	204

Economics of Nitro

We made a cost-and-return comparison using yields and quality data collected at Waseca (Recommended column - Table 3): 3.0 ton/acre DM; 29.4% ADF; 37.8% NDF; and 162 RFV index. Hay price was calculated using quality-tested hay auction data collected 1985-89 (Y = -69.453 + 1.2464X where Y = $/T and X = RFV index). Yield and quality values were deducted for harvest losses. The demonstration yield was 2.45 tons per acre of dry matter; quality was estimated.

Table 3. Cost of returns of Nitro from research and demonstration plots.

Item	Inputs	Recommended	Demonstration
		$/T	
Income[1]	2.5 Ton 116.30 $/ton	290.95	208.68
Expenses			
Cash			
Lime & Fertilizer[2]	3 ton lime 30 lb P_2O_5 40 lb K_2O	50.40	---
Herbicide	(Eptam)	19.00	19.00
Harvest & Twine	3X	12.30	12.30
Seed	12 lb x $2.50	30.00	30.00
Repair & maintenance		6.24	6.24
Interest	12%	14.15	8.10
Subtotal		132.09	75.64
Overhead costs		112.50	112.50
Total		224.59	188.14
Return over cost costs		158.86	133.04
Return over total cost		46.36	20.54
Break even yield (88 $/T)			
Cash cost, T/A		1.50	.86
Total cost, T/A		2.78	2.14

[1] Yields and quality (RFV index were adjusted for harvest loss (DM x .84).
Price calculated from the statistical relationship Y = -69.453 + 1.2464X, where Y = $/T and X = RFV index.

[2] Assumed soil test of soil pH 6.3, P, 21-30 161A; and K, 151-225 lb/A. Yield goal -3 T/A.

SOURCE: Adapted from Fuller, Earl I. and Dale Nordquist. 1989.

Returns per acre were greater for the recommendation than the demonstration because the expected yield was higher (3.0 vs 2.45 T/A of DM before harvest loss) and we estimated quality of alfalfa in the demonstration to be 8% less than at Waseca. Cash cost was less on the demonstration because the soil fertility level did not require lime nor fertilizer.

Break-even yields (1.5 and 2.8 T/A, respectively) for cash and total costs were calculated using Minnesota's average hay price in 1989 (88 $/ton, Minnesota Agricultural Statistics). We have not figured the yield benefit to corn (37 extra bushels at Waseca) following alfalfa, the N fertilizer savings nor the savings in insecticide use of corn production. Profitability of Nitro alfalfa is dependent on the yield obtained, quality of hay harvested, price obtained for the hay, the fertility status of your soil and your production costs. Hay prices have been high enough the last four years to justify the use of Nitro in a corn-alfalfa rotation, unless one applies a deficiency payment to corn.

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INFLUENCE OF POTASSIUM AND SULFUR ON THE YIELD OF RED CLOVER

George Rehm, Greg Cremers, Andy Scobbie[1]

ABSTRACT: Red clover can tolerate lower soil pH values when compared to alfalfa. Therefore, less lime is required and it can be a profitable crop in North-Central Minnesota. Yet, little is known about nutrient requirements. This study evaluated the effect of the application of K and S. The use of S, but not K, increased dry matter yield. The lack of a response to K was surprising in view of the low soil test values for K. Soil test values for K increased with repeated K application.

Introduction:

The red clover crop will grow well at lower soil pH values when compared to alfalfa. Therefore, it can be an alternative legume in areas of Minnesota where low pH values and high lime costs limit the production of alfalfa. In contrast to alfalfa, few research projects have focused on determining the nutrient requirements for profitable production of this legume crop.

Objectives:

This study was designed to meet the following objectives:

- Determine the rate of fertilizer K and S needed to provide for optimum production.
- Measure the uptake of K and S by a high-yielding crop of red clover.
- Measure the effect of K application on soil test values for K.

Experimental Procedure:

This study was conducted at the Staples Irrigation Center. A good stand of red clover was established in August of 1987 in a seedbed prepared with conventional tillage techniques. Six rates of K and 3 rates of S were evaluated.

The various rates of K and S were topdressed to the established stand in early spring of 1988. Treatments were re-applied on April 20, 1989.

Two cuttings were harvested in 1989. The first harvest was on June 15 when the red clover was in the early bud growth stage. The second cutting was taken in mid-July when the red clover was in full bloom.

Whole plant samples were collected from each plot at both harvests. These samples were dried, weighed, ground and analyzed for K and S. Uptake of K and S was computed from yield and nutrient concentration data.

Soil samples (0-6 inches) were collected from each plot in early September. These samples were analyzed for extractable K in an attempt to measure the effect of 2 years of repeated K application on soil test values for K. Prior to the start of the study in 1987, results of the analysis of soil samples showed a pH of 7.0, a P level of 19.5 ppm, and a soil test value for K of 54 ppm (considered to be low to very low).

Results and Discussion:

In 1989, the yield of red clover was significantly affected by the use of fertilizer S (Table 1). Potassium use had no influence on yield (Table 2) and there was no significant interaction. Considering sulfur, the use of 25 lb. S per acre was adequate for optimum yields. This observation is consistent with the results of sulfur trials with irrigated alfalfa on sandy soils where 25 lb. S/acre was adequate for optimum yield. The largest response to S occurred with the first cutting and this was reflected in the total yield. Sulfur application had no effect on the yield of the second cutting.

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Table 1. The effect of rate of applied S on yield of irrigated red clover.

S Applied	Cutting 1	Cutting 2	Total
lb./acre	ton dry matter/acre		
0	1.40 a*	1.26 a	2.79 a
25	1.72 b	1.23 a	2.95 b
50	1.75 b	1.31 a	3.06 b

* Treatment means in any one column followed by the same letter are not significantly different at the .05 confidence level.

Table 2. The effect of rate of fertilizer K on yield of irrigated red clover.

S Applied	Cutting 1	Cutting 2	Total
lb./acre	ton dry matter/acre		
0	1.53 a	1.26 a	2.79 a
20	1.59 a	1.27 a	2.86 a
40	1.64 a	1.28 a	2.92 a
80	1.81 a	1.27 a	3.08 a
160	1.55 a	1.33 a	2.88 a
320	1.63 a	1.35 a	2.98 a

As would be expected, the concentration of K in the whole plant tissue increased with rate of applied K. This increase was linear for both cuttings (Table 3). Rate of applied S had no significant effect on the concentration of K in the red clover tissue.

Likewise, the concentration of S increased with the rate of S applied (Table 4). For the 1st cutting, the use of both 25 and 50 lb. S/acre increased the S concentration when compared to the check. There was no additional increase when the 50 lb./acre rate is compared to the 25 lb./acre treatment. For the 2nd cutting, the highest S concentration was associated with the application of 50 lb S./acre.

Table 3. The influence of rate of applied K on the K concentration in red clover.

K Applied	Cutting 1st	Cutting 2nd
lb./acre	%	
0	2.06 d*	2.00 e
20	2.48 c	2.17 d
40	2.60 c	2.43 c
80	2.70 b c	2.78 b
160	2.91 b	2.82 b
320	3.16 a	3.28 a

* Treatment means in any column followed by the same letter are not significantly different at the .05 confidence level.

Table 4. The effect of rate of applied S on the S concentration in red clover.

S Applied	Cutting 1st	2nd
lb./acre	- - - - - - - - % S - - - - - - - -	
0	.147 b*	.147 b
25	.176 a	.154 b
50	.183 a	.165 a

* Treatment means in each column followed by the same letter are not significantly different at the .05 confidence level.

Uptake of both K and S was computed by multiplying dry matter yields by concentration values. The application of both K and S had a significant effect on K uptake for each cutting (Tables 5, 6) as well as the total K uptake for the growing season (Table 7).

This would be expected because of the increased K concentration with added K. The effects of S on K uptake were erratic and closely paralleled the effect of rate of applied S on yield.

Table 5. Potassium uptake by the first cutting of red clover as affected by the rate of K and S applied.

S Rate	K Rate (lb./acre) 0	20	40	80	160	320
lb./acre	- - - - - - - - - - - - - - lb. K/acre - - - - - - - - - - - - - -					
0	53.2	69.9	81.3	79.6	74.9	87.7
25	65.9	77.7	94.5	89.7	100.0	112.5
50	65.1	87.1	80.6	125.9	96.2	110.4

Table 6. Potassium uptake by the 2nd cutting of red clover as affected by the rate of K and S applied.

S Rate	K Rate (lb./acre) 0	20	40	80	160	320
lb./acre	- - - - - - - - - - - - - - lb. K/acre - - - - - - - - - - - - - -					
0	49.8	56.6	62.4	92.1	82.5	86.4
25	50.0	50.8	61.4	55.8	69.1	91.2
50	50.2	56.4	62.4	65.7	74.1	85.6

Table 7. Total uptake for the growing season by red clover as affected by the rate of K and S applied.

S Rate	K Rate (lb./acre) 0	20	40	80	160	320
lb./acre	- - - - - - - - - - - - - - lb. K/acre - - - - - - - - - - - - - -					
0	103.1	126.6	143.7	171.6	157.4	174.1
25	115.9	128.5	156.0	145.5	168.9	203.8
50	115.3	143.5	143.0	191.6	170.2	196.0

Uptake of S was increased by the use of fertilizer S, but rate of K applied had no significant effect. For the 1st cutting, S uptake increased as the rate of applied S increased (Table 8). For the 2nd cutting, the 50 lb./acre rate produced an increase in S uptake. Total uptake for the growing season shows a linear response to applied S. It's also obvious that the uptake of S is much less than the uptake of K.

Table 8. Uptake of S as affected by the rate of S applied.

S Applied	Cutting 1st	2nd	Total
lb./acre	- - - - - - - lb. S/acre	- - - - - - -	
0	4.1 a*	3.9 a	8.0 a
25	6.1 b	3.8 a	9.9 b
50	6.5 b	4.3 b	10.8 c

* Treatment means in each column followed by the same letter are not significantly different at the .05 confidence level.

The soil samples taken at the end of the 1989 growing season were used to measure the effect of 2 years of repeated K application on the soil test level for K. These results are summarized in Table 9. The increase was linear with rate of applied K. There was very little change in the soil test value with the repeated application of 20 lb. K/acre. In general, the soil test K value increased by approximately .7 ppm for each pound of K applied.

Table 9. The effect of repeated application of K on the soil test value for K.

K Applied	Soil Test K
lb./acre	ppm
0	60.0
20	58.5
40	75.5
80	101.5
160	135.5
320	259.0

Conclusions:

Results of this study showed that yield of irrigated red clover was increased substantially by the use of fertilizer S, but K applications had no effect. The lack of a response to K is surprising when the relatively low soil test for K is considered. The yield increases would appear to be large enough to pay for the added S.

The concentration of K in plant tissue increased with rate of applied K. Likewise, the S concentration increased with the rate of S applied. These increases, however, were not associated with increases in yield.

Repeated application of fertilizer K increased the soil test value for K. In general, the soil test K value increased by about .7 ppm for each pound/acre of K applied.

NITROGEN APPLICATION FOR HIGH QUALITY SUGARBEET IN SOUTHERN MINNESOTA

John A. Lamb[1]

OBJECTIVE:

Nitrogen management is important for high quality sugarbeet production. American Crystal Sugar growers since 1983 have been paid based on the amount of sugar extracted at the factory. In December 1989, Southern Minnesota Beet Sugar Cooperative growers voted for a payment which also stressed quality and recoverable sugar at the factory. A considerable amount of N information exists for the American Crystal growers but little data exists for the high sugar varieties currently used in the southern Minnesota area. The objective of this study is to generate N application information for high sugar varieties under a quality payment system for the southern Minnesota sugarbeet growing area.

MATERIALS AND METHODS:

Two N rate experiments were conducted in southern Minnesota; one near Maynard, MN in 1988 with 5 N rates (0, 30, 60, 90, and 120 lb N/A) and one near Sacred Heart, MN in 1989 with 6 N rates (0, 30, 60, 90, 120, and 150 lb N/A). The spring two foot nitrate-N soil tests were 71 lb/A and 70 lb/A in 1988 and 1989, respectively. In both locations Urea (46-0-0) was broadcast applied and incorporated in the spring. Variety KW 1745 was overplanted and thinned to 125 plants per 100 foot of row (29,700 plant/A). Root yields were determined by machine harvest and quality run at American Crystal Sugar Company's Quality Lab at East Grand Forks, MN.

RESULTS AND DISCUSSION:

The location at Maynard in 1988 was under considerable moisture stress. The root yields, Table 1, reflect this stress. The use of N fertilizer did decrease sugar concentration from 17.0 % at 30 lb N/A to 15.9 % at 120 lb N/A. The recoverable sugar per ton of sugarbeet mimics this reduction. The reduction of sugar recovered was caused by significant increase in amino N in the sugarbeet root from the application of N fertilizer. Using American Crystal's quality payment system and expressing the gross returns as a percentage of the 0 lb N/A treatment on a per ton and per acre basis, the 0 and 30 lb N/A applications, respectively, were optimum in 1988. This would equate to 71 and 101 lb N/A as soil test 0-2 ft + fertilizer N.

The growing conditions at the Sacred Heart location in 1989 were more favorable. The root yields were greater than 1988 but there was not a significant yield increase to N application, Table 2. Neither sugar concentration or recoverable sugar per ton were effected by N application. The loss to molasses was significantly increased. This increased loss was caused by the increase in amino N concentration in the root from N fertilization. Again N application did not effect root Na or K concentrations. Gross returns per ton and per acre were maximized at 30 lb N/A or 100 lb N/A, soil test N 0-2 ft + fertilizer applied.

Particularly in 1989, the optimum soil test + fertilizer level appears to be low according to data from the Red River Valley. Root yield of the high sugar varieties being used today does not respond to N fertilization like the tonnage varieties of a decade ago. Because of the smaller amounts of N are needed for maximum root growth, the use of N must be based on what the effect will be to sugarbeet quality particularly amino N. More studies are planned to better determine optimum N fertilizer application.

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

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

Table 1. Nitrogen fertilization effects on root yield, sugar concentration, recoverable sugar, loss to molasses, impurities, and gross returns at Maynard, MN, 1989.

			Recoverable					Gross Return	
N Rate	Yield	Sugar	Sugar	LTM	Na	K	An	$/T	$/A
lb N/A	T/A	%	lb/T	%	------	ppm	------	% of	check
0	14.9	16.9	309	1.45	122	2204	382	100	100
30	15.5	17.0	309	1.55	111	2190	439	100	104
60	13.3	16.3	297	1.45	134	2044	450	93	83
90	13.9	16.2	293	1.55	125	2062	521	90	84
120	14.1	15.9	286	1.60	133	2120	504	86	82
Statistical Analyses									
N Rate	NS	**	**		NS	NS	**		
Linear	NS	**	**		NS	NS	**		
Quadratic	NS	NS	NS		NS	NS	NS		
C.V.%	18.9	3.9	4.6		31.6	7.3	11.9		

** is 0.01 significance level.

Table 2. Nitrogen fertilization effects on root yield, sugar concentration, recoverable sugar, loss to molasses, impurities, and gross returns at Sacred Heart, MN, 1989.

			Recoverable					Gross Return	
N Rate	Yield	Sugar	Sugar	LTM	Na	K	An	$/T	$/A
lb N/A	T/A	%	lb/T	%	------	ppm	------	% of	check
0	21.0	14.8	269	1.27	290	2142	289	100	100
30	26.8	15.2	278	1.23	200	2134	306	107	137
60	24.7	15.3	277	1.30	190	2262	347	106	125
90	21.7	15.0	270	1.40	240	2258	396	101	104
120	25.4	15.3	275	1.47	204	2337	436	105	127
150	20.2	15.1	267	1.55	184	2154	555	98	95
Statistical Analyses									
N Rate	NS	NS	NS	*	NS	NS	**		
Linear	NS	NS	NS	**	NS	NS	**		
Quadratic	NS	NS	NS	NS	NS	NS	NS		
C.V.%	12.4	2.4	2.9	6.7	16.6	7.9	10.6		

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

NITROGEN FERTILITY STUDIES ON GRAPES[1]

Carl Rosen, Peter Bierman, Emily Hoover, Jim Luby, and Peter Hemstad[2]

ABSTRACT: Two field experiments were conducted to determine the effects of N fertilizer application on grape nutrition, yield, and quality. Application of N fertilizer increased extractable levels of NO_3-N in the soil, but had no significant effect on yield. Differences due to cultivar were far greater than differences due to N rate. There was a slight trend for titratable acidity to increase with increasing N, although this effect was also dependent on cultivar. Tissue levels of NO_3-N varied with site and cultivar and levels generally decreased as the season progressed. Petiole NO_3-N levels tended to increase with increasing N rate at the later sampling dates. The results of this experiment indicate that N requirements for grapes grown in Minnesota appear to be low and that several years without N fertilization would be necessary before a response to N could be detected at these sites.

Interest in growing grapes for wine production and fresh consumption in Minnesota has recently increased. Little is known, however, about the fertility requirements of cold hardy grape cultivars. The objective of the present study, therefore, was to characterize the response of various grape cultivars to nitrogen fertilizer over the growing season.

MATERIALS and METHODS

Field trials were conducted at two sites: the Horticultural Research Center (HRC) in Excelsior, MN and a commercial vineyard near Hastings, MN. Both sites were nonirrigated. Experimental procedures were similar at both sites, although minor variations occurred as noted below.

Site Characterization and Experimental Design. The soil at the HRC site was a Hayden loam with medium organic matter levels. Vines were trained to a unilateral low cordon and spaced 6 ft. in the row and 9 ft. between rows. Vines were laid out in a split plot design with two cultivars, Seyval and Vignoles, arranged in subplots with four vines of each cultivar. Nitrogen fertilizer rates were the main plot treatments and there were three replications of each fertilizer x cultivar combination. The commercial vineyard was on a Hubbard loamy sand with low organic matter levels and had Marechal Foch and Millot in separate plantings. Vines were trained in the standard J system and spaced 8 ft. in the row with 9 ft. between rows. Fertilizer treatments were arranged in a randomized complete block design with three replications for each cultivar. There were four vines per fertilizer treatment in each block.

Fertilizer Treatments. A uniform N application, soon after bud break, was made at each site according to customary vineyard practices. In early May either 25 lb. (HRC) or 30 lb. (commercial vineyard) of actual N/A was broadcast and disced in between rows. Soil test levels of P and K were adequate at both sites, so no supplemental applications of these nutrients were made. Additional N was applied at both locations on May 17. Ammonium nitrate was broadcast by hand around each vine and the surface was raked to a depth of 1-2 in. At the HRC the N fertilizer treatments were 0, 37.5, and 75 lb. actual N/A. At the commercial vineyard treatments were 0, 30, and 60 lb. N/A.

Soil samples were collected on May 17, prior to fertilizer treatment applications, and also on June 6 (HRC) and June 7 (commercial vineyard). Three soil cores were taken from each fertilizer plot and samples were separated into three depths: 0-1 ft., 1-2 ft., and 2-3 ft. Moist samples from all three depths were extracted with 2M KCl (1:5 w/v) and analyzed for NH_4-N and NO_3-N by conductimetric methods. Per cent moisture was also determined, so that results could be expressed on a uniform dry weight basis. Measurements of pH (1 soil:1 H_2O, w/v) were made only on the surface layers from the May 17 soil samples.

Petiole N Determinations. Petiole samples from the most recently matured leaves of randomly chosen shoots were collected every two weeks from June 6 to Aug 31. The outer two vines in each fertilizer plot were treated as border plants, so petiole sampling consisted of 7-8 petioles from each of the inner two plants in the four vine plots at the commercial vineyard, and five petioles/vine from the inner three plants of each cultivar in the split plot design at the HRC.

Ten petioles from each sample were dried, ground, extracted with H_2O, and analyzed for NO_3-N conductimetrically. Results were expressed on a petiole dry weight basis. The remaining 4-5 petioles were used in a 'quick test' for NO_3-N in petiole sap using EM Quant Nitrate Test strips. Sap was squeezed from fresh petioles with needle-nose pliers, mixed, and the reagent pad of a strip was dipped into the sap. The time required to reach maximum, deep purple color development was measured with a stopwatch to the nearest 0.01 sec. Time measurements were converted to petiole sap concentrations using a standardized mathematical equation [nitrate (ug/ml) = $10^{(4.9-1.085 \log t)}$ where t = seconds to reach dark purple]. For samples not reaching full color development after 2 min., the NO_3-N sap concentration was estimated from the color chart provided with the strips. The results of the quick test and the conventional laboratory analysis were compared and correlated to develop a model for converting quick test, petiole sap concentrations to petiole concentrations on a dry weight basis.

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[1] Funding provided by the Minn. Agric. Expt. Sta.

[2] Assoc. Prof., Dept. Soil Science; Grad. Res. Assist., Dept. Soil Science; Assoc. Prof., Dept. Hort. Science; Assoc. Prof., Dept. Hort. Sci.; Assist. Scientist, Dept. Hort. Sci., respectively.

Yield and Fruit Quality. Harvest dates for the commercial vineyard were Sept. 9 (Foch) and Sept. 10 (Millot). Both cultivars were harvested at the HRC on Sept. 11. Fruit clusters were harvested from the middle two vines in each four vine plot, weighed, and yield was expressed on a fresh weight/vine basis. Subsamples of 40-50 berries were collected from randomly chosen clusters in each treatment group, making sure that berries were selected from different parts of each cluster. The subsamples were frozen and later analyzed for brix, pH, and titratable acidity. Results from different fertilizer treatments were compared to evaluate the effect of N fertilizer rate on the wine making quality of the fruit.

RESULTS

Soil Analysis. Nitrate-N levels in the soil to a depth of 3 ft. prior to application of differential N fertilizer treatments are presented in Tables 1 and 2. In general, highest levels were in the 0-1 ft depth at both sites. When sampled three weeks after differential N fertilizer application, levels of soil nitrate-N tended to increase with increasing N fertilizer rate (Tables 3 and 4). As on the previous sampling date, highest nitrate-N levels were in the top foot of the soil profile.

Tissue Analysis. Despite increases in soil N levels with increasing N fertilizer applications, there was little effect on N nutritional status of the petioles as measured by quick tests on fresh petioles or water extractable nitrate-N on dried petioles (Tables 5 and 6). None of the levels at flowering (June) were in a range considered to be N deficient. Toward the end of the season there was a slight trend in some cultivars for higher nitrate-N in petioles sampled from the higher N treatments. Tissue nitrate-N levels decreased over the season with initial levels in June about 10 times those of the last sampling date in August. Significant differences due to cultivar were apparent at HRC: Seyval generally had higher nitrate-N levels than Vignoles. Although a direct comparison cannot be made at the Hastings site due to experimental design, Millot tended to have greater petiole nitrate-N levels than Foch.

The correlation between the quick test and the conventional water extract on dried tissue was good ($r = 0.84$), but probably not accurate enough to be used as a quantitative measure of N status of the petiole. The best use of the quick test for grape production would be as a qualitative method for determining N status of the vines, ie. whether the N level is low, medium, or high. One note of caution is that there were some differences between different lots of strips. On two sampling dates (Aug. 3 and Aug. 17), the color development was poor and did not relate to water extractable levels. This inconsistency may limit the usefulness of this product.

Yield and Fruit Quality. Nitrogen did not significantly affect yield of the grapes in the present experiment. This lack of a response could be due to high levels of N stored within the vine which may have masked any effect of applied N. There was a slight trend for an increase in titratable acidity with increasing N rate, although this varied with cultivar. Differences due to cultivar were far greater than differences due to N rate. The results of this experiment indicate that N requirements for grapes grown in Minnesota are low and that several years without N fertilization would be necessary before a response to N could be detected at these sites.

Table 1. Initial soil NO_3-N levels at HRC. Samples were collected May 17, 1989. Mean ± Standard Deviation.

Depth (ft.)	Soil Nitrate-N ----- ppm NO_3-N -----
0-1	8.6 ± 4.6
1-2	6.7 ± 5.7
2-3	6.7 ± 6.4

Table 2. Initial soil NO_3-N levels at Hastings. Samples were collected May 16, 1989. Mean ± Standard deviation.

	Cultivar	
Depth (ft.)	Foch	Millot
0-1	5.4 ± 1.5	11.5 ± 4.0
1-2	1.1 ± 0.3	1.9 ± 0.5
2-3	0.7 ± 0.2	0.7 ± 0.2

Table 3. Soil NO_3-N levels as affected by N application at HRC. Samples were collected June 6, 1989. Mean ± Standard deviation.

Depth (ft.)	N-Rate (lb/A) 25	62.5	100
	ppm NO_3-N		
0-1	10.5±2.7	13.5±1.20	25.1±1.5
1-2	6.0±1.9	6.1±0.04	10.9±3.7
2-3	3.5±0.4	4.8±0.40	6.3±2.9

Table 4. Soil NO_3-N levels as affected by N application at Hastings. Samples were collected June 7, 1989. Mean ± Standard deviation.

	Cultivar					
	Foch			Millot		
	N-Rate (lb/A)					
Depth (ft.)	30	60	90	30	60	90
	ppm NO_3-N					
0-1	7.8±1.0	11.1±6.1	13.7±2.5	7.3±2.7	13.1±3.4	17.8±8.6
1-2	7.7±2.8	8.2±2.3	11.3±1.8	7.3±3.9	9.7±3.1	12.6±5.5
2-3	2.5±0.6	4.2±1.8	3.8±1.5	2.8±2.0	4.0±2.0	3.2±1.3

Table 5. Comparison of nitrate-N concentrations in grape petioles and petiole sap for two cultivars and 3 N rates at seven sampling dates (HRC, Excelsior 1989).

		Quick Test NO_3-N					Water Extractable NO_3-N						
		Sampling Date											
Cultivar	N Rate (lb/A)	June 6	June 22	July 6	July 20	Aug 31	June 6	June 22	July 6	July 20	Aug 3	Aug 17	Aug 31
		ug/ml NO_3-N					ug/g NO_3-N						
Seyval	25	691	412	452	261	194	1716	1767	1720	766	210	185	312
	62.5	700	603	733	386	345	2279	2448	2710	1112	727	279	306
	100	548	581	601	339	227	1795	2308	2282	1181	620	249	522
Vignoles	25	351	233	253	113	127	1061	875	1018	593	175	85	102
	62.5	279	260	300	149	158	968	1147	1383	497	261	386	356
	100	436	295	388	140	165	1520	1334	1294	363	254	219	236
Analysis of Variance													
Cultivar													
Seyval		647	532	595	329	255	1930	2174	2237	1020	519	238	380
Vignoles		355	263	314	134	150	1183	1119	1232	484	230	230	231
Significance		NS	*	**	**	NS	NS	**	**	*	**	NS	NS
N Rate													
25		521	322	353	187	160	1389	1321	1369	680	192	135	207
62.5		490	431	517	267	251	1624	1798	2047	805	494	332	331
100		492	438	495	240	196	1657	1821	1788	772	437	234	379
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Quad.		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Interaction													
CXN		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS

NS = nonsignificant; * = significant at 5%; ** = significant at 1%.

Table 6. Comparison of NO_3-N concentrations in grape petioles and petiole sap for two cultivars and 3 N rates at seven sampling dates (Hastings, 1989).

		Quick Test NO_3-N						Water Extractable NO_3-N						
		Sampling Date												
Cultivar	N Rate (lb/A)	June 7	June 23	July 6	July 20	Aug 17	Aug 31	June 7	June 23	July 6	July 20	Aug 3	Aug 17	Aug 31
		ug/ml NO_3-N						ug/g NO_3-N						
Millot	30	1394	818	814	703	278	321	3222	3885	2625	1468	966	481	364
	60	1099	804	915	717	416	429	3420	3530	2532	1747	1111	673	480
	90	1152	782	1063	622	525	321	3921	3712	2703	1349	1222	515	348
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Foch	30	785	654	649	490	339	257	2714	2407	1447	580	569	250	338
	60	1022	680	607	369	246	195	1768	1565	1261	545	577	260	203
	90	878	727	718	529	270	580	2163	1962	1219	565	709	290	352
Significance		NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
Linear		NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
Quad		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant; * = significant at 5%; ** = significant at 1%.

Table 7. Yields, brix, pH, and titratable acidity as affected by N rate. (HRC, 1989).

Cultivar	N rate (lb/A)	Yield (lb/vine)	Brix	pH	Titratable Acidity
Seyval	25	16.05	16.8	3.34	0.99
	62.5	7.50	14.7	3.18	1.33
	100	10.34	15.6	3.39	1.21
Vignoles	25	1.69	18.6	3.28	1.50
	62.5	0.49	20.1	3.17	1.08
	100	2.09	18.0	3.15	1.51
Analysis of Variance					
Cultivar					
	Seyval	11.29	15.7	3.30	1.17
	Vignoles	1.52	18.5	3.21	1.44
Significance		**	**	NS	*
N-Rate					
25		9.02	17.7	3.31	1.24
62.5		6.11	16.1	3.18	1.27
100		6.22	17.0	3.25	1.39
Significance		NS	NS	NS	NS
Linear		NS	NS	NS	NS
Quad.		NS	NS	NS	NS
Interaction					
CXN		NS	NS	NS	NS

NS = nonsignificant; * = significant at 5%; ** = significant at 1%.

Table 8. Yield, brix, pH, and titratable acidity as affected by N rate. (Hastings, 1989).

	Cultivar							
	Millot				Foch			
N Rate (lb/A)	Yield (lb/vine)	Brix	pH	Titratable Acidity	Yield (lb/vine)	Brix	pH	Titratable Acidity
30	5.97	18.5	3.46	0.78	12.10	20.0	3.27	0.92
60	5.25	17.9	3.46	0.72	13.56	19.2	3.28	0.87
90	6.72	19.4	3.42	0.83	14.02	20.1	3.39	0.89
Significance	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 = nonsignificant; * = significant at 5%; ** = significant at 1%.

EVALUATION OF THE LAND APPLICATION OF HIGH RATES OF BY-PRODUCT LIME

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ABSTRACT: Disposal of by-product-lime from water softening plants has become a major problem. One possible solution is to apply this material on agricultural land. In this study, high rates of by-product lime were applied to sandy soils. Heavy applications had no negative impact on yield of sweet corn, soybeans, and field corn. As would be expected, there were some changes in soil properties.

Introduction:

The importance of lime for optimum crop production on sandy soils has been recognized for some time. Traditionally, agricultural limestone has been used to raise the pH level of acid soils. Other sources of liming materials exist in Minnesota.

By-product lime is produced as a result of the water softening treatment process used by several municipalities. Previously, this material was disposed of in area landfills. Recent legislation has eliminated this method of disposal. Land application is one attractive alternative to disposal in a landfill. Although the benefits of the use of low rates of liming material are well known, there is very little information which pertains to the measurement of the effects of application of high rates of this by-product liming material.

Objectives:

The overall purpose of this project is to evaluate the effect of high rates of by-product lime applied to acid, sandy soils. Within this overall purpose there are specific objectives which are:

- To measure the effect of high rates of by-product lime use on crop yield.
- To monitor plant nutrient content as affected by the application of high rates of by-product lime.
- To determine the effect of the high rates of by-product lime on properties of the sandy soils.

Experimental Procedure:

This study was initiated in 1989. Seven experimental sites were selected. Three sites were established at the Sand Plains Research Farm at Becker, two were located in Isanti County, and two were established in Chisago County. One site at the Sand Plains Research Farm was seeded to alfalfa. The remaining two were planted to soybeans and sweet corn and will be part of a soybean/sweet corn rotation.

Corn was planted at both sites in Isanti County. Both corn and soybeans were planted in Chisago County. Both sites in Chisago County will be in a corn/soybean rotation. All sites selected were irrigated. Soils at the experimental sites are representative of the acid, sandy soils in East-Central Minnesota.

Soil samples were collected from each experimental site before any treatments were applied. Results of the analysis of these samples are summarized in Table 1.

Samples of the stock-piled by-product lime that was to be used for this project were analyzed for Effective Calcium Carbonate Equivalent in early April. This analysis showed that an application of 2 ton of by-product lime per acre would be equivalent to a rate of 1 ton per acre of regular ag lime. On a dry weight basis, this material was approximately 28% Ca and .5% Mg.

A practical minimum application of ag lime is 2 ton per acre. The by-product lime was applied at rates of 4, 16, 32, and 64 ton per acre at each experimental site. Two controls were also used. One was the complete control where no lime is used. The application of 2 ton of ag-lime per acre serves as the second control. An additional treatment consisted of the application of 50 lb. magnesium (Mg) per acre (supplied as epsom salts) in addition to the 32 ton of by-product lime per acre. This treatment was included to determine if added Mg would be beneficial when high rates of by-product lime were applied. Each treatment was replicated 4 times at each experimental site. All liming materials were incorporated with conventional tillage equipment prior to planting.

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Table 1. Relevant soil properties (0-6 inches) for the selected experimental sites before treatment application.

Location	Crop	pH	P	K	Mg	Zn	O.M.
			- - - - - - - - - ppm			- - - - - - - -	%
Becker	Alfalfa	5.4	20	48	55	.5	2.3
Becker	Sweet Corn	5.3	21	53	56	.5	1.8
Becker	Soybeans	5.4	21	73	69	.4	2.6
Isanti Co.	Corn (North)	5.4	80	128	33	1.5	1.4
Isanti Co.	Corn (South)	5.5	73	158	52	2.2	.7
Chisago Co.	Corn	5.5	100+	98	58	.8	1.5
Chisago Co.	Soybeans	5.3	100+	117	46	.9	1.7

Management practices conducive to high yields were used at all sites. Plant tissue samples were collected during the growing season to monitor nutrient uptake. For field corn, the leaf opposite and below the ear was taken for the sample. A similar leaf sample was collected when sweet corn was the test crop. Nutrient content of the sweet corn ear was also measured. For soybeans, the most recently matured trifoliate at early bloom was used for the sample. Water samples were collected from irrigation wells in mid summer and the results are in Table 2.

The sweet corn, soybean and field corn crops were harvested when they were mature. Following harvest, soil samples (0-6 inches) were taken from all plots. These soil samples were analyzed for pH, phosphorus (P), exchangeable calcium (Ca), exchangeable potassium (K), exchangeable magnesium (Mg), micronutrients, and heavy metals by standard analytical procedures. In addition to samples taken from 0-6 inches, soil samples were collected from 6-12, 12-24, 24-36, 36-48, and 48-60 inches from the control treatment and the 64 ton/acre BPL treatment at all locations. These samples were analyzed in the same way as samples taken from 0-6 inches.

Table 2. Nutrient content of irrigation water at the experimental sites.

Nutrient	Chisago Co.	Isanti Co.	Becker
	- - - - - - - - - -	ppm	- - - - - - - - - -
nitrogen (N)	3.9	.5	8.0
phosphorous (P)	.04	.04	.04
potassium (K)	.9	1.5	.9
sulfur (S)	8.8	4.5	11.9
calcium (Ca)	38.2	46.2	64.2
magnesium (Mg)	16.0	9.7	18.0
zinc (Zn)	.02	.03	.03
iron (Fe)	.03	.03	.03
manganese (Mn)	.19	.14	.01
copper (Cu)	.03	.03	.03
boron (B)	.03	.03	.04

Standard regression procedures and appropriate "t" tests were used to analyze the data collected.

Results and Discussion:

Yield

The alfalfa was seeded at the Becker location in late May and no yields were measured during the 1989 growing season.

The soybean yields measured at the Becker and Chisago County sites are listed in Table 3. Yields were much higher at the Becker site. This is attributed, in part, to earlier planting and less damage from grasshoppers.

Considering the rates of by-product lime at Becker, there was a linear increase in yield. The yield from the use of 2 ton of ag lime was equivalent to the application of 4 ton of by-product lime. The addition of 50 lb Mg per acre to the 32 ton of by-product lime did not increase yield.

Lime use had no significant effect on soybean yield at the Chisago County site. There was considerable variability in the data and this may have masked treatment effects.

Table 3. The effect of high rates of by-product lime on soybean yield.

Treatment	Location Becker	 Chisago Co.
ton/acre	bu./acre	
Control	53.4	30.5
2 AL[1]	54.1	33.7
4 BPL	54.1	33.3
16 BPL	54.0	33.0
32 BPL	55.7	30.3
64 BPL	55.6	32.7
32 BPL + 50 lb. Mg	53.0	33.1

[1] AL = ag lime; BPL = by- product lime

The effect of the treatment used on the yield of both sweet corn and field corn is summarized in Table 4. There was a substantial difference in yield levels at the Isanti County sites. The majority of this is attributed to soil characteristics. The soil texture at the north site was a sandy loam with an organic matter content of 1.4%. The water holding capacity of this soil was higher than the soil at the south site which was classified as a loamy sand having an organic matter content of .7%. There is a rather high probability that corn grown at the south site was stressed more during the growing season than the corn grown at the north site.

The application of high rates of by-product lime as well as 2 ton of ag lime per acre had no significant effect on grain yield at all locations in 1989. The yield of the sweet corn at the Becker location was not significantly affected by the application of either ag lime or by-product lime.

Table 4. The effect of high rates of by-product lime on the yield of both sweet corn and field corn.

Treatment	Becker[2]	Location Isanti Co. (North)	Isanti Co. (South)	Chisago Co.
ton/acre	ton/acre	bu./acre		
Control	8.6	203.7	133.4	130.7
2 AG[1]	9.4	203.4	148.3	124.7
4 BPL	7.6	190.3	162.9	131.6
16 BPL	7.9	195.4	149.4	136.2
32 BPL	8.5	196.1	130.6	133.5
64 BPL	8.8	191.6	141.8	138.8
32 BPL + 50 lb. Mg	8.2	192.2	160.7	137.2

* Sweet corn was grown at the Becker site; field corn at all other sites.

[1] Al = ag lime; BPL = by-product lime

[2] Yield of green, unhusked ears

Nutrient Content

The application of high rates of the by-product lime had a consistent effect on the concentration of potassium (K), and magnesium (Mg) in the soybean leaf tissue (Table 5). The K concentration increased slightly as the rate of lime was increased. By contrast, there was a general decrease in the concentration of Mg as lime rates increased. The concentration of Ca was quite variable.

At Becker, the concentration of copper (Cu) decreased with rate of applied lime. This was not observed at the Chisago County site. Lime application increased the P concentration in the soybean tissue at Chisago County but had no effect on the uptake of this nutrient at Becker. The uptake of iron (Fe), manganese (Mn), zinc (Zn), and boron (B) was not affected by lime application at both experimental sites.

Comparing the application of 2 ton of ag lime per acre, there was no significant difference in nutrient concentration at both locations. The use of an additional 50 lb. of Mg per acre did not increase the concentration of Mg in the soybean leaf tissue at both sites.

Table 5. Influence of lime application on the nutrient concentration of leaf tissue of soybeans at early bloom.

Treatment	Nutrient P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
tons/A	%				ppm				
Becker:									
Control	0.259	2.98	0.771	0.409	92.1	92.4	19.0	10.4	4.5
2 AG*	0.276	3.27	0.741	0.476	95.6	83.4	19.1	10.2	4.4
4 BPL**	0.271	2.99	0.804	0.442	91.9	87.1	19.9	10.5	4.5
16 BPL	0.274	3.28	0.686	0.347	88.4	107.0	21.7	9.9	4.3
32 BPL	0.262	3.21	0.735	0.394	92.3	84.1	18.8	9.6	4.3
64 BPL	0.265	2.95	0.747	0.512	93.9	79.0	17.5	10.2	4.4
32 BPL + 50 lbs. Mg	0.276	3.23	0.751	0.367	91.6	92.8	21.7	10.1	4.6
Chisago:									
Control	0.742	2.48	0.865	0.587	91.6	97.0	53.0	10.0	28.3
2 AG	0.810	2.58	0.891	0.589	86.9	80.1	54.4	9.5	29.2
4 BPL	0.759	2.46	0.902	0.581	89.3	86.5	51.8	10.1	27.6
16 BPL	0.786	2.55	0.930	0.571	88.1	69.8	50.8	9.9	27.7
32 BPL	0.789	2.56	0.881	0.591	90.4	65.9	50.2	10.4	27.4
64 BPL	0.801	2.49	0.841	0.625	87.1	70.2	50.5	10.4	28.8
32 BPL + 50 lbs. Mg	0.751	2.48	0.882	0.613	90.8	76.3	50.2	10.6	27.7

* = ag lime; ** = BPL by-product lime.

The concentration of Mg in the ear leaf of the field corn tissue increased with rate of applied lime at all locations. Nutrient concentrations from the Isanti County locations are summarized in Table 6, while concentrations for corn grown in Chisago are listed in Table 7.

The effects of the application of high rates of by-product lime on the concentration of other essential nutrients were not consistent at all locations.

The application of 2 ton of ag lime and 4 ton of by-product lime per acre had an equal effect on the concentration of all nutrients in the ear leaf tissue of corn at all locations. The addition of 50 lb. of Mg per acre to the 32 ton of by-product lime per acre did not increase the concentration of Mg in the ear leaf tissue.

For sweet corn, the Mg concentration in the ear leaf increased with rate of application of the by-product lime. The concentration of manganese (Mn) decreased as the rate of by-product lime increased. Otherwise, the application of high rates of lime had no significant effect on the concentration of nutrients in the ear leaf tissue.

The nutrient concentration in the sweet corn ear was measured at harvest and the results are summarized in Table 7. Except for a decrease in the Mn concentration, the application of high rates of by-product lime had no significant effect on the nutrient concentration in the edible sweet corn.

Table 6. Influence of lime application on the nutrient concentration of the ear leaf tissue of corn at silking in Isanti County.

Treatment	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
tons/A	%				ppm				
North Site:									
Control	0.324	2.76	0.430	0.200	229.3	102.2	46.0	9.3	4.4
2 AG *	0.319	2.77	0.440	0.203	207.7	103.7	46.2	9.1	4.4
4 BPL**	0.324	2.64	0.451	0.196	218.3	109.8	51.6	8.5	4.5
16 BPL	0.308	2.75	0.422	0.208	203.3	102.6	44.4	8.8	4.4
32 BPL	0.319	2.65	0.457	0.226	225.2	108.6	45.8	9.6	4.5
64 BPL	0.312	2.65	0.424	0.242	224.1	100.7	42.3	9.1	4.2
32 BPL + 50 lbs. Mg	0.307	2.63	0.438	0.242	215.0	113.1	46.4	8.6	4.6
South Site:									
Control	0.339	2.62	0.342	0.123	156.8	137.0	55.6	6.8	4.3
2 AG	0.315	2.63	0.364	0.141	154.4	130.3	50.1	6.9	4.1
4 BPL	0.315	2.66	0.367	0.141	147.1	119.7	52.3	7.3	4.0
16 BPL	0.313	2.62	0.369	0.179	150.0	128.8	49.7	7.2	4.2
32 BPL	0.299	2.60	0.388	0.220	141.8	119.8	42.7	6.9	4.4
64 BPL	0.313	2.69	0.379	0.233	147.9	148.8	47.1	7.3	4.5
32 BPL + 50 lbs. Mg	0.289	2.60	0.361	0.221	140.9	112.0	48.7	7.2	4.1

* = ag lime; ** = BPL by-product lime.

Table 7. Influence of lime application on the nutrient concentration of the ear leaf of corn at the Chisago County site, sweet corn at the Becker site, and the the sweet corn ear at the Becker site.

Treatment	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
tons/A	%				ppm				
Chisago Co:									
Control	0.273	2.16	0.429	0.265	89.7	66.5	26.6	9.3	4.4
2 AG *	0.276	2.19	0.429	0.268	90.1	55.0	24.3	8.6	4.4
4 BPL**	0.286	2.16	0.444	0.300	90.0	51.3	25.2	9.1	4.9
16 BPL	0.286	2.09	0.449	0.312	92.4	48.0	24.8	9.5	4.2
32 BPL	0.300	2.10	0.450	0.371	94.0	42.3	25.3	9.7	4.5
64 BPL	0.293	2.04	0.443	0.419	92.8	61.7	24.8	10.2	4.8
32 BPL + 50 lbs. Mg	0.286	2.02	0.427	0.378	87.0	51.1	23.8	9.4	4.5
Becker: (earleaf)									
Control	0.26	3.19	0.68	0.30	90	114	22	9.9	4.3
2 AG	0.27	3.21	0.74	0.36	90	94	22	10.2	4.6
4 BPL	0.27	3.06	0.78	0.36	92	98	21	10.6	4.5
16 BPL	0.27	3.10	0.78	0.44	94	83	18	10.0	4.5
32 BPL	0.27	3.15	0.77	0.46	94	78	18	9.9	4.4
64 BPL	0.29	3.35	0.70	0.49	95	85	20	10.1	4.3
32 BPL + 50 lbs. Mg	0.26	2.83	0.78	0.54	91	74	17	10.3	4.4
Becker: = (ear)									
Control	0.47	1.47	.026	0.18	36	19.6	45	6.2	6.0
2 AG	0.41	1.27	.024	0.16	35	17.1	38	6.0	5.4
4 BPL	0.46	1.41	.026	0.19	39	18.5	41	5.9	6.2
16 BPL	0.42	1.28	.025	0.17	34	16.5	38	5.7	5.5
32 BPL	0.44	1.33	.025	0.18	37	15.9	39	5.5	5.4
64 BPL	0.47	1.44	.024	0.19	32	16.6	42	5.9	5.8
32 BPL + 50 lb. Mg	0.44	1.37	.023	0.19	34	16.2	39	6.1	5.6

* = ag lime; ** BPL = by-product lime

Nutrient Content In Soil

From the measurement of yields of sweet corn, field corn, and soybeans, it was obvious that the use of very high rates of by-product lime had no negative effect on crop production. Soil samples from 0-6 inches were taken from all plots after harvest in order to determine the effect of the by-product lime on the nutrient content of soils as well as the concentration of heavy metals that might be added when the lime is applied to the land.

The results from the plots that were planted to soybeans in 1989 are summarized in Table 8. As would be expected, the soil pH increased with the rate of lime that was applied. The increase was greater at the Chisago County site. Liming had no significant effect on the K values at both sites.

The substantial increase in both exchangeable Ca and exchangeable Mg would be expected. This increase was substantial at both sites.

Considering the micronutrients, lime application reduced the level of Mn only at Becker. The decrease was curvilinear. At the Chisago County site, the application of the by-product lime reduced the amount of Fe, Mn, and Cu extracted by the DTPA procedure. At the present time, there is no apparent explanation for the differences in effect on micronutrients noted.

Table 8. Effect of lime application on soil pH and the concentration of essential nutrients in soil (0-6 inches) where soybeans were grown in 1989.

	Nutrient							
Treatment	pH	K	Ca	Mg	Fe	Mn	Zn	Cu
tons/A	ppm							
Becker:								
Control	5.3	66	636	84	75.6	27.2	1.1	.7
2 AG *	5.7	66	688	118	63.4	14.6	.8	.5
4 BPL**	5.5	74	858	106	74.3	21.9	1.0	.7
16 BPL	6.0	78	846	104	46.0	8.9	.5	.5
32 BPL	6.2	74	1248	150	53.9	9.1	.7	.6
64 BPL	6.3	82	2144	212	60.0	12.4	.8	.7
32 BPL + 50 lbs. Mg	6.2	70	1196	131	59.6	12.8	.8	.6
Chisago Co:								
Control	6.0	109	624	78	56.3	3.1	.8	.3
2 AG	6.1	121	528	125	53.3	2.3	.9	.3
4 BPL	6.4	82	726	90	47.3	1.9	.8	.3
16 BPL	6.8	105	1118	133	42.4	1.6	.7	.3
32 BPL	7.2	121	1730	190	40.1	1.7	.7	.4
64 BPL	7.6	113	3498	330	35.6	2.1	.7	.5
32 BPL + 50 lbs. Mg	7.2	98	1838	205	39.1	1.5	.7	.3

* = ag lime; ** = BPL by-product lime.

Results of the analysis of soil samples collected from the experimental sites in Isanti County are summarized in Table 9. Again, there was an increase in soil pH which is consistent with expectations. The increase was greater at the South site. The soil at this site has a lower organic matter content and, therefore, would be less resistant to changes in pH produced by liming.

In general, the effect of lime applications on soil properties was consistent at both sites. The exchangeable K content did not change. There was, however, a substantial increase in both exchangeable Ca and Mg with lime application. This observation is consistent with expectations.

The effect of liming on the amounts of micronutrients extracted by the DTPA procedure was consistent. At both sites, there was a decrease in the amount of both Fe and Mn extracted. This decrease was linear with rate of by-product lime applied.

Table 9. Effect of lime application on soil pH and the concentration of essential nutrients in soil (0-6) inches at the experimental sites in Isanti County.

				Nutrient				
Treatment	pH	K	Ca	Mg	Fe	Mn	Zn	Cu
tons/A		ppm						
North Site:								
Control	5.8	160	430	76	78.1	7.5	2.2	.5
2 AG *	6.5	179	686	146	57.1	4.8	2.0	.4
4 BPL**	6.4	129	660	94	56.3	3.4	1.5	.4
16 BPL	6.9	137	1166	138	57.2	3.3	1.7	.4
32 BPL	7.1	148	1700	188	53.8	3.8	1.5	.5
64 BPL	7.3	125	2736	269	49.3	3.5	1.9	.6
32 BPL + 50 lbs. Mg	7.0	113	1024	152	53.9	3.3	1.9	.4
South Site:								
Control	5.8	117	212	35	47.7	3.9	3.0	.3
2 AG	6.0	117	248	60	41.5	2.6	1.7	.3
4 BPL	6.3	105	416	54	38.0	2.6	1.6	.3
16 BPL	7.0	109	770	85	34.8	2.3	1.2	.3
32 BPL	7.4	90	1592	143	30.8	2.2	2.7	.4
64 BPL	7.6	98	2236	200	32.4	2.4	1.1	.5
32 BPL + 50 lbs. Mg	7.5	101	2246	191	28.6	2.4	1.5	.4

* = ag lime; ** = BPL by-product lime.

Table 10. Effect of lime application on soil pH and the concentration of essential nutrients in soil (0-6) inches) at Chisago County where corn was grown and at Becker where sweet corn was grown.

				Nutrient				
Treatment	pH	K	Ca	Mg	Fe	Mn	Zn	Cu
tons/A		ppm						
Chisago Co:								
Control	5.5	66	320	54	59.1	3.8	.9	.2
2 AG *	6.0	66	552	102	52.6	2.7	.8	.2
4 BPL**	6.1	86	502	73	48.2	2.2	.8	.3
16 BPL	6.6	74	870	112	42.6	1.8	.9	.3
32 BPL	7.2	82	2264	211	39.9	2.2	.7	.4
64 BPL	7.3	82	2586	240	41.7	2.4	.7	.4
32 BPL + 50 lbs. Mg	6.9	62	1048	144	41.3	1.9	.7	.3
Becker:								
Control	5.0	133	616	88	74.9	25.1	1.0	.7
2 AG	5.1	109	610	90	65.1	21.3	.9	.7
4 BPL	5.2	90	608	82	61.0	20.7	.8	.6
16 BPL	5.4	98	646	88	49.8	12.0	.6	.6
32 BPL	5.6	113	834	98	54.2	12.9	.8	.6
64 BPL	5.8	156	1334	152	61.3	14.8	.8	.8
32 BPL + 50 lbs. Mg	5.7	90	812	108	44.5	9.9	.6	.5

* = ag lime; ** = BPL by-product lime

The soil samples were also analyzed for lead (Pb), nickel (Ni), cadmium (Cd), and chromium (Cr). These heavy metals could be added to soils when the high rates of by-product lime are applied. At Becker, the amount of these metals extracted by the DTPA procedure did not change with lime application (Table 11). The concentration of these heavy metals decreased as rate of lime increased at the Chisago County site. It is important to note that concentrations did not increase with any rate of lime applied.

Considering the heavy metals, the amount of lead extracted decreased as rate of lime was increased at the North site (Table 12). At the South site, the amount of nickel extracted decreased as the rate of lime was increased. Otherwise, the rate of lime applied had no significant effect on the amount of 4 heavy metals extracted from the soil. Again, there was no increase in heavy metal concentrations when high rates of by-product lime were applied.

Table 11. Effect of lime application on heavy metal content of soil at sites where soybeans were grown.

Site	Heavy Metal	0	2 AG*	4 BPL	Treatment (ton/acre) 16 BPL	32 BPL	64 BPL	32 BPL+Mg
		ppm						
Becker	Lead	1.18	.91	1.11	.79	.70	1.00	.84
"	Nickel	1.61	1.11	1.36	.85	.97	1.07	1.06
"	Cadmium	.13	.09	.13	.07	.13	.15	.10
"	Chromium	.04	.05	.04	.02	.03	.03	.03
Chisago Co.	Lead	.49	.55	.48	.41	.30	.30	.34
"	Nickel	.31	.38	.25	.23	.17	.13	.15
"	Cadmium	.08	.05	.05	.05	.06	.04	.05
"	Chromium	.02	.02	.02	.02	.02	.02	.05

AG = ag lime; BPL = by-product lime

Table 12. Effect of lime application on heavy metal content of soil at the sites where corn was grown in 1989.

Site	Heavy Metal	0	2 AG*	4 BPL	Treatment (ton/acre) 16 BPL	32 BPL	64 BPL	32 BPL+Mg
		ppm						
~~Becker~~ Isanti N	Lead	.70	.36	.50	.48	.47	.31	.36
"	Nickel	.48	.45	.28	.31	.28	.21	.23
"	Cadmium	.05	.07	.04	.05	.05	.04	.03
"	Chromium	.03	.03	.02	.02	.02	.03	.02
~~Chisago Co.~~ Isanti S	Lead	.32	.35	.31	.34	.36	.34	.27
"	Nickel	.27	.19	.22	.15	.11	.09	.10
"	Cadmium	.03	.03	.02	.03	.03	.03	.03
"	Chromium	.02	.02	.02	.02	.02	.02	.02
Chisago Co.	Lead	.70	.55	.52	.40	.35	.36	.40
"	Nickel	.23	.22	.20	.17	.11	.14	.16
"	Cadmium	.05	.05	.06	.03	.03	.04	.05
"	Chromium	.02	.02	.02	.02	.02	.02	.03
Becker	Lead	1.29	1.13	1.11	.93	.97	1.01	.79
"	Nickel	1.40	1.29	1.06	.91	.96	1.02	.81
"	Cadmium	<.04	<.03	<.03	<.02	<.04	<.03	<.02
"	Chromium	<.05	<.03	<.02	<.02	<.02	<.03	<.03

* AG = ag lime; BPL = by-product lime

Soil samples were also collected to a depth of 5 feet in order to monitor any changes in soil properties below the 0-6 inch depth. To do this, the properties from the control treatment are compared to properties from plots where the rate of 64 ton per acre of by-product lime was used. This comparison was made at each site. Results are summarized in Tables 13-18.

Composite samples were prepared for each treatment and were analyzed. Therefore, there is no statistical interpretation of data presented in Tables 13-18. Except for the 6-12 inch depth, there were no major differences in the concentration of both plant nutrients and heavy metals. The increase in pH, exchangeable Ca, and exchangeable Mg at the 6-12 inch depth is probably due to the incorporation of the limestone with the tillage implements that were used for crop production.

Table 13. Effect of the application of a high rate of by-product lime on soil properties at the Chisago County site where soybeans were grown in 1989.

Crop	Lime							Soil Property						
Grown	Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	tons/A	inches						ppm						
Soybeans	0	6-12	4.9	101	296	42	58	3.1	0.6	0.3	0.59	0.18	0.03	0.05
"	0	12-24	5.7	59	402	53	33	0.6	0.1	0.2	0.43	0.19	<0.02	0.05
"	0	24-36	5.9	51	522	84	26	0.9	0.1	0.3	0.34	0.11	<0.02	0.05
"	0	36-48	6.7	35	354	66	19	1.3	0.1	0.3	0.22	0.09	<0.02	0.03
"	0	48-60	7.6	12	538	108	19	5.5	0.1	0.3	0.22	0.09	<0.02	0.03
Soybeans	64	6-12	7.4	70	1456	161	29	0.8	0.3	0.3	0.53	0.09	0.02	0.05
"	64	12-24	5.6	59	400	61	39	0.9	0.1	0.2	0.39	0.15	<0.02	0.02
"	64	24-36	6.3	62	364	53	27	0.3	0.1	0.2	0.34	0.11	<0.02	0.02
"	64	36-48	6.0	39	280	26	23	1.0	0.1	0.2	0.22	0.09	<0.02	0.02
"	64	48-60	6.9	51	276	25	-	-	-	-	-	-	-	-

Table 14. Effect of the application of a high rate of by-product lime on soil properties at the Chisago County site where corn was grown in 1989.

Crop	Lime							Soil Property						
Grown	Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	tons/A	inches						ppm						
Corn	0	6-12	5.1	74	324	52	53	2.4	0.6	0.3	0.56	0.12	<0.02	<0.02
"	0	12-24	5.9	55	382	77	32	0.4	0.1	0.2	0.34	0.09	<0.02	<0.02
"	0	24-36	6.1	47	256	34	20	0.3	0.1	0.2	0.22	0.09	<0.02	<0.02
"	0	36-48	6.3	43	502	89	23	1.4	0.1	0.2	0.25	0.11	<0.02	<0.02
"	0	48-60	6.8	39	332	74	18	0.9	0.1	0.2	0.22	0.09	<0.02	<0.02
Corn	64	6-12	6.3	66	774	110	40	0.9	0.6	0.2	0.40	0.09	<0.02	<0.02
"	64	12-24	6.0	43	376	59	29	0.3	0.1	0.2	0.31	0.09	<0.02	<0.02
"	64	24-36	5.9	31	326	43	32	0.4	0.1	0.2	0.22	0.09	0.05	<0.02
"	64	36-48	6.1	23	230	23	21	0.5	0.1	0.2	0.22	0.09	0.03	<0.02
"	64	48-60	6.6	12	238	28	18	1.2	0.1	0.3	0.34	0.09	<0.02	<0.02

Table 15. Effect of the application of a high rate of by-product lime on soil properties at the North site in Isanti County.

Crop	Lime							Soil Property						
Grown	Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	tons/A	inches						ppm						
Corn	0	6-12	4.9	82	382	49	82	8.4	0.9	0.5	1.13	0.35	<0.02	0.04
"	0	12-24	5.9	86	518	101	68	4.0	0.2	0.3	0.53	0.13	<0.02	0.03
"	0	24-36	6.0	39	314	50	42	1.1	0.1	0.2	0.64	0.09	<0.02	0.03
"	0	36-48	5.7	16	248	34	25	0.3	0.1	0.1	0.42	0.09	<0.02	<0.02
"	0	48-60	5.5	23	412	46	43	0.9	0.1	0.2	0.35	0.09	<0.02	<0.02
Corn	64	6-12	4.7	101	286	42	89	9.0	0.6	0.4	0.66	0.44	0.06	<0.02
"	64	12-24	5.3	94	336	74	74	2.0	0.1	0.2	0.22	0.12	<0.02	<0.02
"	64	24-36	5.3	12	320	46	39	0.5	0.1	0.1	0.35	0.09	<0.05	<0.02
"	64	36-48	5.6	35	282	48	51	0.7	0.1	0.1	0.22	<0.09	<0.02	<0.02
"	64	48-60	5.5	16	346	53	46	0.8	0.1	0.1	0.23	<0.09	<0.02	<0.02

Table 16. Effect of the application of a high rate of by-product lime on soil properties at the South site in Isanti County.

Crop	Lime							Soil Property						
Grown	Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	tons/A	inches						ppm						
Corn	0	6-12	4.8	47	184	20	66	7.6	0.6	0.2	<0.22	0.28	0.15	0.09
"	0	12-24	5.2	59	234	41	54	3.2	0.1	0.2	<0.22	0.11	0.02	<0.02
"	0	24-36	5.7	59	228	58	58	0.7	0.1	0.2	<0.22	<0.09	0.02	<0.02
"	0	36-48	5.7	47	288	64	48	0.6	0.1	0.1	0.45	0.11	<0.02	0.02
"	0	48-60	5.9	70	418	84	54	1.2	0.1	0.2	<0.22	<0.09	0.04	0.03
Corn	64	6-12	4.8	51	140	38	58	3.2	0.7	0.3	0.29	0.11	0.04	0.06
"	64	12-24	4.7	90	264	53	103	2.2	0.1	0.3	0.34	0.29	0.04	<0.02
"	64	24-36	5.3	90	290	74	60	0.8	0.1	0.2	<0.22	<0.09	<0.02	<0.02
"	64	36-48	6.5	74	494	94	45	1.1	0.1	0.2	<0.22	0.12	<0.02	<0.02
"	64	48-60	5.5	70	320	68	58	3.1	0.7	0.2	<0.22	<0.09	<0.02	<0.02

Table 17. Effect of the application of a high rate of by-product lime on soil properties at the Becker site where sweet corn was grown.

Crop	Lime							Soil Property						
Grown	Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	tons/A	inches						ppm						
S.Corn	0	6-12	4.9	62	632	82	53	11.7	0.6	0.6	0.93	0.77	<0.02	0.06
"	0	12-24	5.5	20	460	44	24	1.9	0.1	0.3	0.62	0.14	<0.02	0.03
"	0	24-36	5.9	12	234	18	17	4.5	0.1	0.2	0.24	<0.09	<0.02	<0.02
"	0	36-48	8.0	12	846	204	15	5.3	0.1	0.3	0.29	<0.09	<0.02	0.05
"	0	48-60	8.2	12	1858	222	14	4.5	0.1	0.3	0.42	<0.09	<0.02	<0.09
S.Corn	64	6-12	6.0	98	1114	167	41	4.0	0.5	0.6	0.53	0.46	<0.02	<0.02
"	64	12-24	5.5	31	456	52	22	1.5	0.1	0.3	0.53	0.13	<0.02	<0.02
"	64	24-36	6.1	12	208	20	14	3.0	0.1	0.2	0.51	<0.09	<0.02	<0.02
"	64	36-48	7.8	12	844	143	16	4.1	0.1	0.3	0.46	<0.09	<0.02	<0.02
"	64	48-60	8.0	12	932	160	15	3.9	0.1	0.3	0.31	<0.09	<0.02	<0.02

Table 18. Effect of the application of a high rate of by-product lime on soil properties at the Becker site where soybeans were grown.

Crop	Lime							Soil Property						
Grown	Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	tons/A	inches						ppm						
Soybeans	0	6-12	4.9	55	660	80	54	11.7	0.6	0.5	0.82	0.94	0.06	0.04
"	0	12-24	5.7	20	440	35	24	1.7	0.1	0.3	0.34	0.29	<0.02	0.03
"	0	24-36	6.0	12	268	22	17	3.6	0.1	0.3	0.39	<0.09	0.07	0.04
"	0	36-48	7.7	12	470	71	14	4.2	0.1	0.3	0.37	<0.09	<0.02	0.02
"	0	48-60	7.7	12	376	59	15	4.8	0.2	0.2	0.41	0.20	0.02	0.03
Soybeans	64	6-12	6.6	43	1692	232	42	3.5	0.4	0.6	0.32	0.63	0.02	0.03
"	64	12-24	5.6	12	510	41	26	1.7	0.1	0.5	0.57	0.27	<0.02	<0.02
"	64	24-36	7.1	12	562	59	16	3.0	0.1	0.3	0.33	<0.09	<0.02	<0.02
"	64	36-48	7.3	12	354	58	17	4.4	0.1	0.2	<0.22	<0.09	<0.02	<0.02
"	64	48-60	8.0	12	968	142	17	4.6	0.1	0.3	0.33	<0.09	<0.02	<0.02

Summary:

This study was conducted to monitor the effects of the use of high rates of by-product lime on crop yield, nutrient uptake by crops and soil properties. The data collected in 1989 lead to the following statements.

1. Use of high rates of by-product lime had no adverse effects on crop yield. Crops harvested in 1989 were sweet corn, field corn, and soybeans.
2. The high rates of by-product lime affected the uptake of some nutrients. Although changes in the concentration of some nutrients were noted, they did not affect yield.
3. Some changes in soil nutrient concentration were measured, but they had no negative effect on yield.
4. The high rates of by-product lime did not alter the concentration of heavy metals in soils.

From the data collected in 1989, it would appear that high rates of by-product lime can be applied without harm to either crop production or the environment. This study will be continued in an effort to monitor future changes.

Deep tillage and Tillage System Effects on Corn Growth and Yield on an Aquic Soil[1]

J.F. Moncrief, T.L. Wagar and J.J. Kuznia[2]

Conservation tillage and deep chiseling were evaluated on a somewhat poorly drained soil for a second year. Conservation tillage did not affect corn stand or early growth. Conservation tillage systems resulted in an average yield decline of 20 bushels per acre. Corn response to deep chiseling was an average 6 bushels per acre and not affected by tillage system.

This study is in it's third year. The purpose is to evaluate tillage system effects and deep chiseling on corn growth and yield. The soil at this site has a thin layer of loess over dense glacial till and is well tiled.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications. All main tillage plots were split with a deep chisel plowing in the fall(table 1). Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with a four row head.

Results and Discussion

Soil cover by corn residue is shown in table 2 and 3. These measurements were made after the first cultivation. Soil cover ranged from 8 to 50%. Deep chiseling reduced soil cover by about 5%. Early growth and plant stands were not affected by tillage (tables 4 and 5).

Grain yields were affected by tillage system and deep chiseling (table 6). Conservation tillage systems resulted in a 20 bu/acre reduction in yield. The deep chiseling response was not affected by tillage system. The average response to deep chiseling was 6 bushels per acre.

DODGE COUNTY

Table 1. Cultural practices at Dodge County, MN. 1989.

Tillage

Ridge Till
Fall Disc
Fall Chisel Plow
Fall Moldboard Plow
All plots split with a Mohawk chisel plow, 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.
Secondary tillage, a light discing, on May 10.
All plots were rotary hoed on May 24, cultivated once on June 17 and ridged on July 6.

Preceding Crop

1985-1988 Corn

1989 Crop

Corn-Pioneer 3737

Planting and Harvest Date

A six row John Deere 7000 with 28 inch row spacing was used.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 10, 1989	28,000 plants/A	October 18, 1989

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[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Dodge County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, SWCD, MES field staff. Without their assistance this project would have not 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. Tim L. Wagar is an area Crops and Soils Extension Agent stationed at Rochester, MN.*

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			---	lb/A	---		
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
Corn:	82-0-0	213 lbs/A	175	0	0	April 5, 1988	Injected
	7-21-7	5.5 gal/A	4	13	4	April 20, 1988	Applied with the seed

1989 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			---	lb/A	---		
Corn:	82-0-0	220 lbs/A	180	0	0	April 19, 1989	Injected
	7-21-7	6.3 gal/A	5	15	5	May 10, 1989	Applied with the seed

Soil

The soil at this site is a Skyberg silt loam (Udollic Ochraqualfs, fine-loamy, mixed mesic), with 0 to 2 percent slope and is somewhat poorly drained.

Weed Control

2.5 pt/A (2.5 lbs/A) Dual + 2 lbs/A (1.8 lbs/A) Bladex 90 DF + 1 lb/A (.9 lb/A) Atrazine 90 DF applied on May 11, 1989.

.75 pt/A (.375 lb/A) Banvel applied postemergence at 3-leaf stage.

Insecticide Control

8 lbs/A (1.2 lb/A) Broot 15G at time of planting.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue at Dodge Co. on June 20, 1989[1]

Location	Tillage Mldbd	Tillage Ridge	Tillage Disc	Tillage Chisel	Avg.
	----------	% cover		----------	
In Row	7.5c	41.7a	40.2a	27.2b	29.1
Between Row	7.7c	50.7a	31.8b	27.0b	29.3
Average	7.6d	46.2a	36.0b	27.1c	

1. The p value for residue for location, tillage and tillage by location interaction are .928 (n=96), .001 (n=48), .012 (n=24) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage, position relative to the row, and deep chiseling on soil covered by corn residue in Dodge Co. on June 20, 1989[1].

	Tillage									
	Moldboard		Ridge Till		Disk		Chisel		Average	
Location	Dp.Chisl	None	Dp.Chisl	None	Dp.Chisl	None	Dp.Chisl	None	Dp.Chisl	None
					% cover					
In Row	7.3	7.7	36.7	46.7	34.3	46.0	26.3	28.0	26.2	32.1
Between Row	5.0	10.3	46.0	55.3	30.0	33.7	27.0	27.0	27.0	31.6
Average	6.2	9.0	41.3	51.0	32.2	39.8	26.7	27.5	26.6	31.9

1. The p value for deep chisel, tillage by deep chisel, deep chisel by location, tillage by location by deep chisel interactions are .050 (n=96), .707 (n=24), .716 (n=48), and .662 (n=12) respectively.

Table 4. Effect of tillage and deep chiseling on corn population at Dodge Co. on June 20, 1989[1].

	Tillage				
	Mldbd	Ridge	Disc	Chisel	
	------ plants/Ax10^{-3} -----				Avg.
Deep Chisel	28.6	25.2	25.6	25.2	26.2
No Deep Chisel	27.7	24.5	26.3	27.3	26.4
Average	28.2a	24.9a	25.9a	26.3a	

1. The p value for deep chisel, tillage, and tillage by deep chisel interaction are .794 (n=24), .269 (n=12), .672 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage and deep chiseling on early growth of corn at Dodge Co. on June 20, 1989[1].

	Tillage				
	Mldbd	Ridge	Disc	Chisel	
	------ leaves/plant ------				Avg.
Deep Chisel	7.2	7.5	6.8	6.5	7.0
No Deep Chisel	6.7	7.0	6.3	6.7	6.7
Average	6.9a	7.3a	6.6a	6.6a	

1. The p value for deep chisel, tillage, and tillage by deep chisel interaction are .211 (n=24), .337 (n=12), .749 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage and deep chiseling on corn yield and moisture at Dodge Co. on October 18, 1989[1].

	Tillage				
	Moldboard	Ridge Till	Disc	Chisel	
	---------------- bu/A -----------				Avg.
Deep Chisel	168	155	151	146	155
No Deep Chisel	165	146	145	142	149
Average	167a	150b	148b	144b	
	----------------- % -------------				
Deep Chisel	14.2	14.0	15.0	15.3	14.6
No Deep Chisel	14.4	14.5	14.8	14.5	14.6
Average	14.1a	14.3a	14.9a	14.9a	

1. The p value for deep chisel, tillage, and tillage by deep chisel interaction for yield are .022 (n=12), .004 (n=6), .803 (n=3) respectively. The p value for deep chisel, tillage and tillage by deep, chisel interaction for moisture are .671 (n=12), .435 (n=6), .132 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Protein

Tillage System Effects on Nitrogen Availability and Small Grain Growth and Yield[1]

J.F. Moncrief, and J.J. Kuznia[2]

Conservation tillage was evaluated for wheat and barley production following soybeans on a on a well drained loam soil. Tillage did not affect wheat yields but reduced barley yields 6 bu/acre. Protein and N uptake was not affected by tillage.

This study is in it's fourth year. The purpose is to evaluate tillage system effects on growth and yield in a soybeans, barley, and wheat rotation.

Methods and Materials

The experimental design is a randomized complete block with three tillage treatments and three replications. Wheat and barley followed soybeans. Grain yields were estimated with a combine with a 22 foot head.

Results and Discussion

Grain yields were affected by tillage system for barley but not wheat (tables 2 and 3). Although wheat yields have been affected by tillage this is the first year barley yields have been affected (six site years). Test weight was not affected by tillage for either crop.

No till plots received 30 lbs/acre additional nitrogen. Tillage did not have statistically significant affects on grain nitrogen levels, protein, or N uptake of either crop (tables 4 and 5). The trend of less N available under conservation tillage systems is consistent with other sites and years however.

DOUGLAS COUNTY

Table 1. Cultural practices at Douglas County, MN. 1989

Tillage
No Till
Fall Chisel Plow-field cultivated once in spring
Fall Moldboard Plow-field cultivated once in spring

Preceding Crop
1985-Soybeans, 1986-Barley,
1987-Spring Wheat-Pioneer 2369 and
Winter Wheat-Bighorn and Roughrider
1988-Soybeans-Pioneer 1082

1989 Crop
Spring Wheat-Pioneer 2369 Barley-Robust

Planting and Harvest Date

Planter was a Haybuster with 6 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Wheat	April 26, 1989	1.5 bu/A	August 8, 1989
Barley	April 26, 1989	2.0 bu/A	July 26, 1989

Fertilization History

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/A	----	Date Applied
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.

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[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Douglas County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, and MES field staff. Without their assistance this project would have not 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.*

1989 Fertilizer

Tillage	Material Analysis	Rate	Actual N	P_2O_5	K_2O	Date Applied
			---	lbs/A	----	
No Till	46-0-0[1]	130 lbs/A	60	0	0	May 2, 1988
All Others	46-0-0[1]	100 lbs/A	46	0	0	May 2, 1988
All	18-46-0[2]	100 lbs/A	18	46	0	April 26, 1989

1. Urea was broadcast.
2. Drill applied with seed.

Soil

Complex of: Barnes-Langhei loams (Udic Haploborolls, fine-loamy, mixed)-(Typic Udorthents, fine-loamy, mixed (calcareous) ,frigid) , 2 to 6 percent slopes, well-drained eroded. The Langhei occurs on eroded knobs and Barnes on uniform slopes and valleys.

Weed Control

.5 pt/A (.25 lb/A) 2,4-D applied May 26, 1989.

Table 2. Effect of tillage on barley yields, moisture, and test weight at Douglas Co. on July 26, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	--------	bu/A	--------	
Grain Yield	58b[1]	61ab	65a	.062
	----------	%	----------	
Moisture	17.2a	12.4b	12.2b	.005
	--------	lb/bu	-------	
Test Weight	43.7a	42.7a	43.7a	.309

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Table 3. Effect of tillage on spring wheat yields, moisture, and test weight at Douglas Co. on August 8, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	---------	bu/A	--------	
Grain Yield	43a[1]	46a	43a	.663
	----------	%	----------	
Moisture	11.2a	11.0a	10.6a	.166
	--------	lb/bu	-------	
Test Weight	61.8a	62.2a	62.2a	.538

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Table 4. Effect of tillage on barley protein, percent N in grain and N uptake by grain at Douglas Co. on July 26, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	----------	%	----------	
Protein	10.6a[1]	11.5a	11.6a	.542
	----------	%	----------	
Grain N	1.7a	1.8a	1.9a	.542
	--------	lb/A	--------	
Grain N Uptake	41.2a	47.4a	50.5a	.284

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Table 5. Effect of tillage on Spring wheat protein, percent N in grain and N uptake by grain at Douglas Co. on August 8, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	----------	%	----------	
Protein	15.2a[1]	15.4a	14.9a	.637
	----------	%	----------	
Grain N	2.6a	2.7a	2.6a	.637
	--------	lb/A	--------	
Grain N Uptake	58.9a	64.9a	58.0a	.460

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Tillage System and Cultivation Effects on Corn Growth and Yield on a Well Drained Silt Loam Soil[1]

J.F. Moncrief, T.L. Wagar and J.J. Kuznia[2]

Tillage and cultivation were evaluated for a fifth year of continuous corn production on a well drained silt loam soil. Giant Foxtail and Velvet Leaf were increased by less tillage. Cultivation reduced Giant Foxtail density but not Velvet Leaf. Grain yields were reduced by conservation tillage and increased by cultivation.

This study is in it's fifth year. The purpose is to evaluate tillage system interactions with row cultivation on corn growth and yield as well as changes in weed density. The soil at this site was developed in loess and is well drained.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and three replications. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Weed measurements were made by visually estimating the amount of cover by weeds by species and assigning ratings based on a 1 to 6 range with: 1=0, 2=<15%, 3=15-25%, 4=25-50%, 5=50-75%, and 6=>75%. Grain yields were estimated with a combine with a four row head taking the center four rows 100 ft. long for yield estimates.

Results and Discussion

Soil cover by corn residue is shown in tables 2, 3, and 4. Soil cover by corn residue before cultivation in the row ranged from 4 to 51%. Soil cover residue between the row before cultivation ranged from 3 to 64%. The clearing discs on this planter did not decrease residue levels in the row. Cultivation reduced cover about 10% in all tillage treatments except the moldboard plowing system which was reduced about 3% (table 4).

Although corn stand establishment was not affected by tillage (June 5, table 7), early growth was delayed when "in row" cover was greater than 20% (table 5). Early growth of corn was delayed due to inadequate removal of crop residue in the row area. Stands later in the season (June 20, table 8) were affected differently under different tillage systems by the residual affects of cultivation from previous years. In the no till and chisel plowed plots there were higher levels of mortality of corn in the plots that were not cultivated in previous years. Residual effects from previous cultivation did not affect early growth, however (table 6).

Weed density data in table 9 suggest that the effects of previous cultivation on corn mortality between June 5th and 20th was due to foxtail populations that have developed over the lifetime of this study. The density of Giant Foxtail at harvest was reduced with cultivation but Velvet leaf was not affected (table 9). Cultivation effects on Giant Foxtail density does not appear to be consistent across tillage systems. The benefit of cultivation increased as tillage is reduced for foxtail control. Velvet leaf control was not enhanced by cultivation. Tillage system effects were greater than cultivation on velvet leaf density. Foxtail density was influenced about equally by cultivation and tillage. It should also be noted that the herbicide program at this site is fairly aggressive. The application of Banvel and Buctril in the middle of June should have pretty much taken care of any Velvet Leaf at this point in time.

Grain yields were affected by tillage system (table 10). Generally tillage reduction resulted in yield reduction. This is primarily due the ineffective row cleaning discs on the planter and increased weed densities. This has not been the case in previous years. With cultivation conservation tillage options were equal in yield to moldboard plowing.

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[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Fillmore County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by MES, SCS, and SWCD field staff. Without their assistance this project would have not 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. Tim L. Wagar is an area Crops and Soils Extension Agent stationed at Rochester, MN.*

FILLMORE COUNTY

Table 1. Cultural practices at Fillmore County, MN. 1989.

Tillage

No Till
Fall Disc
Fall Chisel Plow
Fall Moldboard Plow
Secondary tillage was done on May 7, 1989.

Cropping History

1985-1988 Corn

1989 Crop

Corn-Pioneer 3585

Cultivation

Each plot was split with cultivation on June 20, 1989.

Planting and Harvest Date

[illegible]

Fertilization History

1983-injected 5-6000 gal/A of liquid dairy manure.

Crop	Material Analysis	Rate	N	P_2O_5	K_2O	Date Applied
			Actual			
			---	lbs/A	----	
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
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.

1989 Fertilizer

Crop	Material Analysis	Rate	N	P_2O_5	K_2O	Date Applied
			Actual			
			---	lbs/A	----	
Corn:	9-23-30[1]	150 lbs/A	14	35	45	May 7, 1989
	82-0-0	183 lbs/A	150	0	0	June 5, 1989

1. Applied 2" beside and 2" below seed.

Soil

Tama silt loam (Typic Argiudolls, fine-silty, mixed, mesic) and Downs silt loam (Mollic Hapludalfs, fine-silty, mixed, mesic), eroded, 2 to 6 percent slopes and is well drained.

Weed Control

2 pt/A (2 lb/A) Dual Preemergence.
3 pt/A (1.5 lbs/A) Prowl + 2.2 lbs/A (2 lbs/A) Bladex 90 DF at spike.
.5 pt/A (.25 lb/A) Banvel + 1 pt/A (.25 lb/A) Buctril + .94 lb/A (.75 lb/A) Atrazine 80 WP at 4 leaf stage.

Insecticide

6.9 lbs/A (1 lb/A) of Counter 15G at time of planting.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue in Fillmore Co. on June 5, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
Location	% cover				Avg.
In Row	51.0a	30.7b	22.3c	4.0d	27.0
Between Row	64.3a	33.7b	19.3c	3.3d	30.2
Average	57.7a	32.2b	20.8c	3.7d	

1. The p value for residue location, tillage, and tillage by location interaction are .147 (n=48), .001 (n=24), .638 (n=12) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage and position relative to the row on soil covered by corn residue in Fillmore Co. on June 20, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
Location	% cover				Avg.
In Row	36.0a	20.3b	13.3b	3.2c	18.2
Between Row	45.8a	21.5b	16.3b	2.5c	21.5
Average	40.9a	20.9b	14.8c	2.8d	

1. The p value for residue location, tillage, and tillage by location interaction are .351 (n=96), .001 (n=48), .405 (n=24) respectively. Means within the same row with the same letter are not significantly different (α=.10). Data collected after cultivation.

Table 4. Effect of tillage, position relative to the row, and cultivation on soil covered by corn residue in Fillmore Co. on June 20, 1989[1].

	Tillage									
	NoTill		Disc		Chisel		Mldbd		Average	
	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.
Location	% cover									
In Row	35.7	36.6	15.7	25.0	9.7	17.0	1.0	5.3	15.5	20.9
Between Row	36.0	55.7	14.3	28.7	8.3	24.3	1.3	3.7	15.0	28.1
Average	35.8	46.0	15.0	26.8	9.0	20.7	1.2	4.5	15.3	24.5

1. The p value for cultivation, tillage by cultivation, cultivation by location, tillage by location by cultivation interactions are .001 (n=96), .319 (n=24), .368 (n=48), and .138 (n=12) respectively. Data collected after cultivation.

Table 5. Effect of tillage on early growth of corn at Fillmore Co.[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	leaves/plant				Sig.
6/5/89	2.5c	2.9b	3.0a	3.1a	.001
6/20/89	4.9b	5.6a	5.6a	5.6a	.031

1. Means within the same row with the same letter are not significantly different (α=.10, n=30).

Table 6. Effect of tillage and cultivation in 1988 on early growth at Fillmore Co. on June 20, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	leaves/plant				Avg.
Cultivation	5.0	5.6	5.6	5.6	5.4
No Cultivation	4.8	5.7	5.7	5.6	5.4
Average	4.9b	5.6a	5.6a	5.6a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction are .842 (n=120), .031 (n=60), .265 (n=30) respectively. Means within the same row with the same letter are not significantly different (α=.10). Data collected before cultivation.

Table 7. Effect of tillage and cultivation in 1988 on corn population at Fillmore Co. on June 5, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	plants/Ax10^{-3}				Avg.
Cultivation	27.7	27.1	26.8	29.1	27.7
No Cultivation	26.4	28.4	28.9	29.3	28.3
Average	27.1a	27.7a	27.9a	29.2a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction are .454 (n=24), .494 (n=12), .411 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10). Data collected before cultivation.

Table 8. Effect of tillage and cultivation on corn population at Fillmore Co. on June 20, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	plants/Ax10^{-3}				Avg.
Cultivation	27.8	28.7	28.9	28.3	28.4
No Cultivation	24.7	29.1	26.5	28.9	27.3
Average	26.3b	28.9a	27.7ab	28.6a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction are .065 (n=48), .014 (n=24), .061 (n=12) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 9. Effect of tillage and cultivation on weed severity[1] in corn at Fillmore Co. on October 23, 1989[2].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	Foxtail				Avg.
Cultivation	3.3	2.3	2.3	2.0	2.5
No Cultivation	4.0	2.7	3.0	2.0	2.9
Average	3.7a	2.5b	2.7b	2.0b	
	Velvetleaf				
Cultivation	4.0	2.7	1.7	1.3	2.4
No Cultivation	4.0	2.0	1.7	1.3	2.3
Average	4.0a	2.3b	1.7c	1.3c	

1. Weed severity ratings on scale 1 to 6, (percentage based on soil covered by weeds: 1 = 0%, 2 = <15%, 3 = 15-25%, 4 = 25-50%, 5 = 50-75%, and 6 = >75%).
2. The p value for cultivation, tillage, and tillage by cultivation interaction for foxtail are .020 (n=12), .061 (n=6), .613 (n=3) respectively. The p value for cultivation, tillage, and tillage by cultivation interaction for velvetleaf are .347 (n=12), .001 (n=6), .441 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 10. Effect of tillage and cultivation on corn yield and moisture at Fillmore Co. on October 23, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	bu/A				Avg.
Cultivation	145	160	164	169	160
No Cultivation	142	153	157	164	154
Average	144c	157b	161ab	167a	
	%				
Cultivation	19.2	19.4	18.7	19.1	19.1
No Cultivation	20.8	20.4	18.7	19.2	19.8
Average	20.0a	19.9a	18.7a	19.2a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction for yield are .132 (n=12), .011 (n=6), .997 (n=3) respectively. The p value for cultivation, tillage, and tillage by cultivation interaction for moisture are .411 (n=12), .547 (n=6), .871 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Tillage System Effects
on Corn Growth and Yield
in East Central Minnesota[1]

J.F. Moncrief, and J.J. Kuznia[2]

Tillage was evaluated at two sites on well drained soils in a continuous corn cropping system. Tillage had variable effects on early growth and stand establishment. Grain yields were not affected at one site and reduced under no till conditions at the other.

This study is in it's third year. The purpose is to evaluate tillage system effects on corn growth and yield on the soils and climate of East Central Minnesota. Plots were established in Pine and Isanti counties in 1987. The soil at the Pine and Isanti site is a well drained loam and somewhat poorly drained fine sandy loam respectively.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications at each site. Crop residue was measured using a line transect technique. Crop residue was characterized in and between the row. "In row" is defined as four inches centered over the row and "between row" the remainder. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with a four and six row head.

Results and Discussion

Pine County

Soil cover by corn residue is shown in table 2. Soil cover in the row area ranged from 6 to 34%. Soil cover between the row area ranged from 12 to 66%. Stand establishment was not affected by tillage at this site (table 3). Final stands were lower with the no till treatment due to higher incidence of cutworms. Early corn growth was not affected by tillage. Soil cover in the row higher than 20% usually results in delayed early growth. It was unusual at this site for the no till system (38% in row cover) not to delay early growth.

Grain yields and moisture were not affected by tillage system (table 4).

Isanti County

Soil cover levels were higher at this site due to higher yields and better corn growth in the previous two years than the Pine County site (table 6). Stands were reduced about three thousand plants per acre in the no till system (table 7). Early corn growth showed about one leaf less development under no till conditions. Other conservation tillage systems had stands and early growth equal to moldboard plowing.

Grain yields were about 23 bushels per acre lower grown with the no till system. Other systems resulted in equal yields. Grain moisture was also about 2% higher under no till conditions. This reflects the early season delay in development. Test weight was lower with no tillage. This was due to the occurrence of frost before physiological maturity with this system. Again other systems were similar in grain moisture and test weight.

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[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Soil and Water Conservation Districts of Isanti and Pine Counties. There support is greatly appreciated. Much of the data collection was aided by MES, SCS, and SWCD field staff. Without their assistance this project would have not 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.*

PINE COUNTY

Table 1. Cultural practices at Pine County, MN. 1989.

Tillage

No Till
Fall Disc-November 10, 1988
Fall Chisel Plow-November 10, 1988
Fall Moldboard Plow-November 10, 1988
On May 11, 1989 all fall tillage plots were disced with a spike tooth harrow attached.

Cropping History

1986-Corn
1987-Corn Land O'Lakes 1093
1988-Corn Land O'Lakes 1093

1989 Crop

Land O'Lakes 2093 Single cross hybrid (95 day)

Planting and Harvest Information

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
Corn	May 6, 1988	25,700 plants/A	Oct. 14, 1988
Corn	May 13, 1989	26,700 plants/A	Oct. 20, 1989

Fertilizer 1987

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	Date Applied
		---	lbs/A	---	
Corn	46-0-0[1] (250 lbs/A)	115	0	0	May 2, 1987
	10-15-35[2] (280 lbs/A)	28	42	98	May 4, 1987

1. Broadcast, incorporated with spring tillage.
2. Planter applied 2" beside and 2" below seed.

Fertilizer 1988

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	Date Applied
		---	lbs/A	---	
Corn	46-0-0[1] (200 lbs/A)	92	0	0	April 25, 1988
	9-23-30[2] (200 lbs/A)	18	46	60	May 6, 1988

1. Broadcast, incorporated with spring tillage.
1. Planter applied 2" beside and 2" below seed.

Fertilizer 1989

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Date Applied
		-----	lbs/A		-----	
Corn	8-21-27-9[1] (200 lbs/A)	16	41	54	18	May 13, 1989
	82-0-0 (165 lbs/A)	135	0	0	0	June 25, 1989

1. Planter applied 2" beside and 2" below seed.

Soil Test April 7, 1987

Nutrient	Sig. of Tillage	Tillage: No Till	Disc	Chisel	Moldboard
		-----------	lb/A		-----------
P	(.193)	124	107	61	84
K	(.711)	471	411	464	422

Soil

The soil at this site is a Cushing loam, (Glossic Eutroboralfs, fine-loamy, mixed) and is well drained.

Weed Control

No Till-1.5 qt/A (1.5 lbs/A) Atrazine on May 12, 1989.
All other plots-3 qt/A (5 lbs/A) Eradicane + 1 qt/A (1 lb/A) Bladex applied and incorporated with a Lelly Roterra on May 12, 1989.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue in Pine Co. on June 12, 1989[1].

Location	Tillage: NoTill	Disc	Chisel	Mldbd	Avg.
	----------	% cover		----------	
In Row	34.0a	10.8b	18.3ab	6.5b	17.4
Between Row	66.0a	19.0b	38.0ab	12.0b	33.8
Average	50.0a	14.9a	28.1a	9.3a	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=16), .130 (n=8), .744 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage on early growth, and population of corn in Pine Co., 1989.

	Tillage: NoTill	Disc	Chisel	Mldbd	Sig.
	--------	plants/A X 10^{-3}		-----	
June 12	30.5a[1]	30.9a	32.3a	32.3a	.774
Oct. 20	21.6b	26.5a	27.2a	28.6a	.001
	--------	leaves/plant		--------	
June 12	4.1a	4.2a	4.2a	4.2a	.321

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 4. Effect of tillage on corn yields and moisture at Pine Co. on October 20, 1989.

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	70a[1]	73a	84a	78a	.604
	%				
Moisture	31.4a	31.5a	30.2a	30.4a	.393

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

ISANTI COUNTY

Table 5. Cultural practices at Isanti County, MN. 1989.

Tillage

No Till
Spring Disc
Spring Chisel and tandem disced twice
Spring Moldboard and tandem disced twice
Spring tillage was done on May 1, 1989.

Cropping History

1986-Soybeans
1987-Corn Pioneer 3790
1988-Corn Pioneer 3772

1989 Crop

Corn Pioneer 3751 (100 day)

Planting and harvest information

A six row John Deere 7000 planter with 30 inch row spacing and equipped with 2 inch fluted coulters.

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
Corn	May 3, 1989	29,000 plants/A	Oct. 26, 1989

Fertilizer 1987

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Mg	Date Applied
		lbs/A					
Corn	12-14-26-4-3[1] (277 lbs/A)	33	39	72	11	8	May 6, 1987
	82-0-0 (146 lbs/A)	120	0	0	0	0	June 5, 1987

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1988

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Mg	Date Applied
		lbs/A					
Corn	12-14-26-4-3[1] (277 lbs/A)	33	39	72	11	8	May 3, 1988
	82-0-0 (220 lbs/A)	180	0	0	0	0	June 3, 1988

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1989

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Mg	Date Applied
		lbs/A					
Corn	12-14-26-4-3[1] (277 lbs/A)	33	39	72	11	8	May 3, 1989
	82-0-0 (146 lbs/A)	120	0	0	0	0	June 5, 1989

1. Planter applied 2" beside and 2" below seed.

1987 Soil Test

Organic Matter	pH	Bray 1 Phosphorus	Potassium	Sulfur	Zinc
		lbs/A		ppm	
Medium	7.0	115	238	15	1.1

Soil

The soil at this site is a Alstad fine sandy loam (Aquic Eutroboralfs, fine-loamy, mixed), 0 to 2 percent slope and is somewhat poorly drained.

Weed Control

1.5 pt/A (1.5 lbs/A) Dual + 1 qt/A (1 lb/A) Atrazine on May 5, 1989.

Table 6. Effect of tillage and position relative to the row on soil covered by corn residue in Isanti Co. on June 5, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
Location	% cover				Avg.
In Row	55.3a[2]	16.3b	15.0b	1.7c	22.1
Between Row	83.7a	24.3b	20.7b	6.0c	33.7
Average	69.5a	20.3b	17.8b	3.8c	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=24), .001 (n=12), .088 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage on population and early growth of corn in Isanti Co., 1989.

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
Date	plants/A X 10^{-3}				Sig.
June 5	23.7b[1]	27.6a	27.2a	26.3a	.020
	leaves/plant				
June 5	3.9b	4.9a	4.9a	5.0a	.001
June 12	6.8b	7.9a	7.9a	8.1a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=6).

Table 8. Effect of tillage on corn yield, moisture, and test weight at Isanti Co. on October 26, 1989.

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	126b[1]	149a	150a	147a	.001
	%				
Moisture	18.6a	16.2b	15.6b	16.6b	.064
	lb/bu				
Test Weight	51.8b	55.0a	54.7a	55.1a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=6).

Tillage Effects on Corn Growth and Yield on a Somewhat Poorly Drained Fine Textured Soil[1]

J.F. Moncrief, T.J. Arlt, T.L. Wagar, and J.J. Kuznia[2]

Tillage was evaluated for corn production in a corn and soybean rotation for a fourth year on a moderately well drained to somewhat poorly drained glacial till soil. Plant stands were lower with a moldboard plowing system. Conservation tillage reduced early growth slightly but did not affect grain yields.

Conservation tillage is usually more difficult to manage on poorly drained soils. Plots were established on a Le Sueur clay loam soil to evaluate tillage effects in a corn-soybean rotation. Following are the results of the third year of this study.

Methods and Materials

The experimental design is a randomized complete block with five tillage treatments and three replications. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples in each tillage plot. Grain yields were estimated with a combine with an eight row head.

Results and Discussion

Soil cover by soybean residue ranged from 6 to 18% in the row area due to tillage. Soil cover between the row ranged from 6 to 70% cover (table 2). There was a small but statistically significant reduction in early growth by the conservation tillage options (table 3). There was a reduction in stand with the moldboard and chisel plowing systems.

Grain yields and moisture were not affected by tillage.

STEELE COUNTY

Table 1. Cultural practices at Steele County, MN. 1989.

Tillage

- No Till
- Ridge Till
- Spring Disc
- Fall Chisel Plow
- Fall Moldboard Plow

Cultivated all tillage plots (except no till) and formed ridges on June 24, 1989.

Cropping History

1985-Corn, 1986-Soybeans,
1987-Corn, 1988-Soybeans

1989 Crop

Corn-Pioneer

Planting and Harvest Date

Planter used on was a six row Hiniker Econotill planter with 30 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	April 21, 1989	26,000 plants/A	October 25, 1989

Weed Control

1 qt/A (2 lbs/A) Dual + 2 qts/A (2 lbs/A) Bladex applied on April 30, 1989.

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[1] *This project is supported by the Minnesota Extension Service and the Soil Conservation Service. Much of the data collection was aided by MES, and SCS field staff. Without their assistance this project would have not 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. T.J. Arlt is the Agricultural Extension Agent in Steele County, MN. T.L. Wagar is an area crop and Soils Agent stationed at Rochester, MN.*

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.

Fertilization History

			Actual				
	Material		N	P_2O_5	K_2O		
Crop	Analysis	Rate	---	lbs/A	----	Date Applied	Method of Application
	0-0-60	250 lbs/A	0	0	150	Fall 1984	Broadcast
Corn:	7-21-7	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
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

1989 Fertilizer

			Actual				
	Material		N	P_2O_5	K_2O		
Crop	Analysis	Rate	---	lbs/A	----	Date Applied	Method of Application
Corn:	82-0-0	173 lbs/A	142	0	0	May 25, 1989	Injected-Sidedress

Table 2. Effect of tillage and position relative to the row on soil covered by soybean residue in Steele Co. on April 28, 1989[1].

	Tillage					
	Mldbd	Chisel	Ridge	NoTill	SprDsc	
Location	----------	----------	% cover	----------	----------	Avg.
In Row	6.2b	18.3a	12.8a	15.5a	17.0a	13.9
Between Row	5.7d	16.7c	59.0b	70.7a	49.3b	40.3
Average	5.9d	17.5c	35.9b	43.1a	33.2b	

1. The p value for residue for location, tillage, and tillage by location interaction are .001 (n=30), .001 (n=12), .001 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage on population and early growth in Steele Co. on June 21, 1989.

	Tillage					
	Mldbd	Chisel	Ridge	NoTill	SprDsc	
	----------	----------	plants/A X 10^{-3}	----------	----------	Sig.
Population (n=12)	19.3c[1]	22.8b	24.8ab	26.3a	24.4ab	.001
	----------	----------	leaves/plant	----------	----------	
Early Growth (n=60)	7.3a	7.1b	7.2ab	7.0bc	6.9c	.001

1. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage on weed severity[1] in corn at Steele Co. on June 21, 1989.

	Tillage					
	Mldbd	Chisel	Ridge	NoTill	SprDsc	
	----------	----------	severity	----------	----------	Sig.
Weed Count	1.0a[2]	3.0a	1.0a	1.0a	0.3a	.134

1. Weed severity rating on scale 1-10, (1=slight, 10=severe), species were foxtail, quackgrass, and Canada thistle.
2. Means within the same row with the same letter are not significantly different (α=.10, n=5).

Table 5. Effect of tillage on corn yield and moisture at Steele Co. on October 25, 1989.

	Tillage					
	Mldbd	Chisel	Ridge	NoTill	SprDsc	
	----------	----------	bu/A	----------	----------	Sig.
Grain Yield	165a[1]	161a	164a	160a	166a	.871
	----------	----------	%	----------	----------	
Moisture	12.5a	13.0a	13.0a	13.1a	12.2a	.900

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Tillage Effects on Corn and Soybean Growth and Yield on Aquic Soils[1]

J.F. Moncrief, J.J. Kuznia, M.B. Kells[2]

This is the fourth year of a tillage study in a corn and soybean rotation. Conservation tillage reduced early growth of both corn and soybeans but yields were not affected. Neither did they respond to row applied phosphorus.

This study is in it's fourth year. The purpose is to evaluate tillage system effects on the cost of inputs and grain yields. The erosion control offered by conservation tillage options allow for reduced losses of sediment and phosphorus in the Clearwater River chain of lakes.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications. All corn main tillage plots and the soybean ridge till plots were split with starter fertilizer (table 1). Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with an four row head.

Results and Discussion

Soil cover by soybean residue is shown in tables 4 and 5. Soil cover by soybean residue ranged from 2% to 13% in the row area due to tillage. Soil cover by soybean residue between the row ranged from less than 2% to 67% cover (table 4). There was a reduction in early corn growth by the ridge and no tillage systems (table 6). Chisel and moldboard plowing systems had similar early corn growth. Atypically corn grown with the ridge till system responded the least amount to row applied fertilizer (table 7).

Although final stands were not affected by tillage conservation tillage systems delayed emergence 2 days with chisel plowing to greater than a week with no tillage (table 8). Starter fertilizer did not affect emergence or final stands (table 9).

Tillage and starter fertilizer did not affect corn yields (table 10). Tillage did have a large affect on ear leaf potassium level at 50% silk emergence (table 11).

Soil cover by corn residue was much higher than soybeans with similar tillage (table 12). Soybean stands were reduced with moldboard plowing. Differences in stands would not be expected to affect yields however. Soybean growth was not correlated well with soil cover in the row by corn residue (tables 13 and 14).

Grain yields and moisture of soybeans were not affected by tillage (table 15). Starter fertilizer did not affect soybean yields grown with ridge tillage (table 16).

MEEKER COUNTY

Table 1. Cultural practices at Meeker County MN. 1989.

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 29, 1989.
  - Ridged soybean plots on July 17, 1989.

Cropping History
- Corn-soybean rotation since 1978.

1988 Crop
- Corn-Pioneer 3737
- Soybeans-BSR 101

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[1] *This project is supported by the Central Minnesota Initiative Fund, the Minnesota Pollution Control Agency, the Soil Conservation Service, the Clearwater River Watershed District, the Minnesota Extension Service, and the Wright County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, SWCD, MES field staff. Without their assistance this project would have not 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. Mary B. Kells is project coordinator of the Tri-County Conservation Project, SCS-SWCD, 3700 W. Division St. Rm, 104, St. Cloud, MN. 56301*

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 10, 1989	32,000 plants/A	October 13, 1989
Soybeans	May 22, 1989	250,000 plants/A	October 13, 1989

Fertilizer History 1985-1988

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/A	----	Date Applied
Corn:	82-0-0	183 lbs/A	150	0	0	Spring 1985
	4-15-40[1]	250 lbs/A	10	38	100	Planting 1985
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
Corn:	10-34-0[3]	19 gal/A	22	76	0	April 28, 1988
	10-34-0[1]	9 gal/A	11	36	0	May 5, 1988
	82-0-0	183 lbs/A	150	0	0	June 7, 1988
Soybeans:	10-34-0[3]	10 gal/A	12	40	0	April 28, 1988
	10-34-0[1]	5 gal/A	6	20	0	May 5, 1988
	0-46-0[2]	358 lbs/A	0	165	0	May 5, 1988

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.
3. Broadcast applied.

1989 Fertilizer

			Actual				
	Material		N	P_2O_5	K_2O		
Crop	Analysis	Rate	---	lbs/A	----	Date Applied	Method of Application
Corn:	7-21-7	15 gal/A	12	35	12	May 10, 1989	Row placement 2" x 2" on 1/2 the plots
	82-0-0	183 lbs/A	150	0	0	May 31, 1989	Anhydrous applicator
Soybeans:	7-21-7	15 gal/A	12	35	12	May 22, 1989	Row placement 2" x 2" on 1/2 the plots Ridge Till only

Soil

The soils present at this site are as follows: 29% of plot area is Delft clay loam (Cumulic Haplaquolls, fine-loamy, mixed, mesic), 43% is Koronis fine sandy loam (Mollic Haplaudalfs, fine-loamy, mixed, mesic), and the remaining 28% is Marcellon loam (Aquic Argiudolls, fine-loamy, mixed, mesic).

Weed Control

Corn

3 pt/A (1.5 lbs/A) Prowl + 2.2 lbs/A (2 lbs/A) Bladex 90 DF applied on May 19, 1989.

Soybeans

1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on June 9, 1989.

1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 3 qt/A 28% on June 23, 1989.

Soil Test

Table 2. Soil test results for corn following soybeans on April 7, 1987.

	Tillage					
	No Till	Ridge	Chisel	Moldboard		
Nutrient	----------	lbs/A	----------	----------	Avg.	Sig.
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.

	Tillage					
	No Till	Ridge	Chisel	Moldboard		
Nutrient	----------	lbs/A	----------	----------	Avg.	Sig.
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 and position relative to the row on soil covered by soybean residue in corn at Meeker Co. on May 11, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	13.3a	6.4b	5.8b	2.0c	6.8
Between Row	66.9a	47.9b	10.9c	2.4c	32.0
Average	40.1a	27.1b	8.3c	2.2c	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=128), .001 (n=64), .001 (n=32) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage on early growth of corn at Meeker Co. 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Date	leaves/plant				Sig.
6/2/89	1.45c[1]	1.71b	2.02a	2.06a	.004
6/29/89	5.00b	5.27b	5.61a	5.81a	.005

1. Means within the same row with the same letter are not significantly different (α=.10, n=160).

Table 8. Effect of tillage on corn emergence at Meeker Co. 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Date	plants/Ax10^{-3}				Sig.
5/19/89	13.1c[1]	18.2bc	22.3ab	26.2a	.053
5/22/89	23.5a	24.8a	27.4a	27.9a	.286
6/2/89	29.0a	29.2a	29.7a	29.9a	.631

1. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 10. Effect of tillage and starter on corn yield and moisture at Meeker Co. on October 13, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Avg.
Starter	111	104	111	102	107
No Starter	104	102	115	104	106
Average	108	103	113	103	
	%				
Starter	20.8	21.9	20.3	21.1	21.0
No Starter	21.3	22.1	21.0	21.2	21.4
Average	21.1	22.0	20.7	21.1	

1. The p value for tillage, starter and tillage by starter interactions for yield are .333 (n=8), .617 (n=16), .375 (n=4) respectively. The p value for tillage, starter and tillage by starter interactions for moisture are .442 (n=8), .167 (n=16), .851 (n=4) respectively.

Table 5. Effect of tillage, starter and position relative to the row on soil covered by soybean residue in corn at Meeker Co. on May 11, 1989[1].

	Tillage									
	NoTill		Ridge		Chisel		Moldboard		Average	
	Strt	None	Strt	None	Strt	None	Strt	None	Strt	None
Location	% cover									
In Row	10.8	15.8	6.0	6.8	5.5	6.0	2.0	2.0	6.1	7.6
Btwn Row	64.8	69.0	49.8	46.0	9.0	12.8	2.3	2.5	31.4	32.6
Average	37.8	42.4	27.9	26.4	7.3	9.4	2.1	2.3	18.8	20.1

1. The p value for in starter, tillage by starter, and tillage by starter by location interactions are .267 (n=128), .415 (n=32), .559 (n=16) respectively.

Table 7. Effect of tillage and starter on early growth of corn at Meeker Co. 1989[1].

	Tillage									
	NoTill		Ridge		Chisel		Moldboard		Average	
	Strt	None	Strt	None	Strt	None	Strt	None	Strt	None
Date	leaves/plant									
6/2/89	1.51	1.37	1.61	1.82	2.08	1.96	2.09	2.02	1.83	1.79
6/29/89	5.23	4.78	5.30	5.25	5.72	5.49	5.89	5.72	5.53	5.31

1. The p value for starter and tillage by starter interactions for 6/2/89 are .413 (n=320), .007 (n=80); for 6/29/89 are .001 (n=320), .079 (n=80) respectively.

Table 9. Effect of tillage and starter on corn emergence at Meeker Co. 1989[1].

	Tillage									
	NoTill		Ridge		Chisel		Moldboard		Average	
	Strt	None	Strt	None	Strt	None	Strt	None	Strt	None
Date	plants/Ax10^{-3}									
5/19/89	13.7	12.4	17.5	18.8	23.2	21.3	25.5	26.9	20.0	19.8
5/22/89	22.1	24.8	24.9	24.7	28.1	26.7	28.9	26.9	26.0	25.8
6/2/89	29.3	28.6	28.9	29.5	30.1	29.4	29.6	30.2	29.5	29.4

1. The p value for starter and tillage by starter interaction for 5/19/89 are .932 (n=64), .711 (n=16); 5/22/89 are .861 (n=64), .545 (n=16); 6/2/89 are .964 (n=64), .774 (n=16) respectively.

Table 11. Effect of tillage and starter on corn ear leaf potassium on July 27, at Meeker Co.[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	% K				Avg.
Starter	0.76	0.84	1.26	1.28	1.04
No Starter	0.89	0.80	1.07	1.87	1.16
Average	0.83c	0.82c	1.16b	1.57a	

1. The p value for tillage, starter and tillage by starter interactions for ear leaf potassium are .002 (n=8), .203 (n=16), .133 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 12. Effect of tillage and position relative to the row on soil covered by corn residue in soybeans at Meeker Co. on May 22, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	52.6a	17.5b	22.8b	4.8c	6.8
Between Row	61.6a	40.3b	25.1c	4.4d	32.0
Average	57.1a	28.9b	23.9b	4.6c	

1. The p value for residue location, tillage, and tillage by location interaction are .002 (n=112), .001 (n=64), .052 (n=32) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 13. Effect of tillage on population of soybeans at Meeker Co. 1989.

	Tillage				
	NoTill	Ridge[1]	Chisel	Mldbd	
	plants/A$\times 10^{-3}$				Sig.
7/6/89	247.7a[2]	177.6	242.6a	215.2b	.017

1. The ridge till treatment was excluded from statistical analysis because a different type of planter was used.
2. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 14. Effect of tillage on early growth of soybeans at Meeker Co. 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	nodes/plant				Sig.
7/6/89	5.44b	5.28c	5.73a	5.79a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=160).

Table 15. Effect of tillage on soybean yield and moisture, at Meeker Co. on October 13, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Sig.
Yield	30a	30a	29a	28a	.452
	%				
Moisture	8.9a	8.5a	9.0a	9.1a	.799

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 16. Effect of starter fertilizer on early growth, yield, and moisture, on of of Ridge till grown soybeans at Meeker Co.

		Ridge Till		
		Starter	No Starter	
		nodes/plant		Sig.
Growth Stage (7/7/89)	n=80	5.26	5.28	.895
		bu/A		
Yield (10/13/89)	n=4	31	30	.775
		%		
Moisture	n=4	8.5	8.5	.846

Tillage Effects on Corn and Soybean Growth and Yield on a Coarse Textured Soil[1]

J.F. Moncrief, J.J. Kuznia, M.B. Kells[2]

This is the fourth year of tillage evaluation on corn and soybean production on a coarse textured soil. Although tillage affected early growth and stands in some cases, yields were not affected.

This study is in it's fourth year. The purpose is to evaluate tillage system effects on the cost of inputs and grain yields. The erosion control offered by conservation tillage options allow for reduced losses of sediment and phosphorus in the Clearwater River chain of lakes.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications. Soybean ridge till plots were split with starter fertilizer. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with an eight row head.

Results and Discussion

Soil cover by soybean residue ranged from less than 1% to 19% in the row area due to tillage. Soil cover by soybean residue between the row ranged from less than 1% to 50% cover (table 2). Soil cover by corn residue was slightly higher with similar tillage (table 3). There was a reduction in early corn growth by the no tillage system (table 4). Other tillage systems had similar early corn growth. This is consistent with soil cover levels in the row. Chisel plowing resulted in slightly higher corn stands. Soybean growth was not correlated with soil cover in the row by corn residue (tables 3 and 5). The chisel plowing system had slightly lower soybean stands. Stand differences between corn and soybeans due to tillage would not be expected to affect yields.

Grain yields and moisture of either corn or soybeans were not affected by tillage (tables 6 and 7). Starter fertilizer did not affect soybean yields grown with ridge tillage.

WRIGHT COUNTY

Table 1. Cultural practices at Wright County, MN. 1989.

Tillage
- No Till
- Ridge Till
- Chisel Plow
- Moldboard Plow
  - Corn-Cultivated June 1, 1989, ridged June 23, 1989
  - Soybeans-Cultivated June 15, 1989, ridged July 13, 1989

Preceding Crops
Corn-soybean rotation since 1982.

1989 Crops
Corn-Pioneer 3737
Soybeans-BSR 101

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[1] *This project is supported by the Central Minnesota Initiative Fund, the Minnesota Pollution Control Agency, the Soil Conservation Service, the Clearwater River Watershed District, the Minnesota Extension Service, and the Wright County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, SWCD, MES field staff. Without their assistance this project would have not 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. Mary B. Kells is project coordinator of the Tri-County Conservation Project, SCS-SWCD, 3700 W. Division St. Rm, 104, St. Cloud, MN. 56301*

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 sweeps raised.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 11, 1989	29,900 plants/A	October 17, 1989
Soybeans	May 22, 1989	250,000 plants/A	October 17, 1989

Fertilization History

From 1983 to 1986 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. Fertilizer since 1986 is as follows:

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/a	----	Date Applied
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
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.
2. Surface banded between rows.

1989 Fertilizer

			Actual				
	Material		N	P_2O_5	K_2O	S	
Crop	Analysis	Rate	------	lbs/A	-----		Date Applied
Soybeans	4-10-47-7[1]	131 lbs/A	5	13	62	9	May 22, 1989
Corn	6-14-42-7[1]	143 lbs/A	9	20	60	10	May 11, 1989
	82-0-0	134 lbs/A	110	0	0	0	June 14, 1989

1. Planter placement 2" beside and 2" below row, soybean ridge till plots were split with starter.

Soil

Soybeans - Kanaranzi loam (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic), 2 to 6 percent slope on 95 percent of the plot area. Fairhaven loam (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic), 0 to 2 percent slope on 5 percent of the plot area. Both soils are well drained.

Corn - Kanaranzi loam (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic), 2 to 6 percent slope on 90 percent of the plot area. Salida gravelly sandy loam (Entic Hapludolls, sandy-skeletal, mixed, mesic), 3 to 6 percent slope on 10 percent of the plot area. Both soils are well drained.

Weed Control

Corn

2 qts/A (2 lbs/A) Lasso + 1.6 lbs/A (1.44 lbs/A) Bladex 90 DF on May 11, 1989 with planter.
.25 pt/A (.125 lb/A) 2,4-D amine + .5 pt/A (.188 lb/A) Roundup spot spray on May 13, 1989.

Soybeans

1 lb/A (.5 lb/A) Lorox 50 DF + 1.5 pts/A (1.5 lbs/A) Dual applied with the planter for the ridge till system on May 12, 1988.
.25 pt/A (.125 lb/A) 2,4-D amine + .5 pt/A (.188 lb/A) Roundup on May 13, 1989.
1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on June 9, 1989.
1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 3 qt/A 28% on June 23, 1989.

Table 2. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Wright Co. on May 11, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	---------- % cover ---------				Avg.
In Row	19.0a	2.3b	3.8b	0.3b	6.3
Between Row	49.5a	21.8b	9.3c	0.8d	20.3
Average	34.3a	12.0b	6.5c	0.5d	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=64), .001 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage and position relative to the row on soil covered by corn residue in soybeans at Wright Co. on May 22, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	---------- % cover ---------				Avg.
In Row	34.3a	3.8c	10.8b	3.6c	16.2
Between Row	45.5a	14.5b	9.4b	3.4c	19.4
Average	39.9a	9.1b	10.1b	3.5b	

1. The p value for residue location, tillage, and tillage by location interaction are .008 (n=112), .001 (n=64), .001 (n=32) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage on population (n=16) and early growth (n=80) of corn at Wright Co.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Population	-------- plants/A X 10^{-3} ----				Sig.
5/22/89	31.0a[1]	29.5a	31.4a	30.0a	.218
6/1/89	31.5b	29.9b	32.0a	30.2b	.066
Early Growth	-------- leaves/plant -------				
6/1/89	1.74c	2.03a	1.92b	1.97ab	.001

1. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage on population (n=32) and early growth (n=160) of soybeans at Wright Co. on July 5, 1989.

	Tillage				
	NoTill	Ridge[1]	Chisel	Mldbd	
	------- plants/A X 10^{-3} ----				Sig.
Population	264.0a[2]	159.4	207.0b	239.3a	.003
	-------- nodes/plant -------				
Early Growth	4.8a	4.5b	4.5b	4.8a	.001

1. The ridge till treatment was excluded from statistical analysis of population because a different type of planter was used.
2. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage on corn yields and moisture at Wright Co. on October 17, 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	---------- bu/A ----------				Sig.
Grain Yield	79a[1]	104a	75a	85a	.203
	------------ % ------------				
Moisture	24.9a	23.6a	23.9a	25.0a	.653

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 7. Effect of tillage on soybean yields and moisture at Wright Co. on October 17, 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	---------- bu/A ----------				Sig.
Grain Yield	28.2a[1]	25.9a	25.5a	26.3a	.455
	------------ % ------------				
Moisture	7.7a	7.5a	7.8a	7.6a	.899

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 8. Effect of starter fertilizer on yields and moisture of ridge till grown soybeans at Wright Co. on October 17, 1989.

	Ridge till		
	Starter[1]	No Starter	Sig.
	----- bu/A -------		
Yield	27.6a[2]	25.9a	.577
	------ % -------		
Moisture	7.3a	7.5a	.436

1. Starter was 131 lbs/A 4-10-47.
2. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Tillage Effects on Availability of Fresh and "Manure Pack" Sources of Dairy Manure on a Coarse Textured Soil[1]

J.F. Moncrief, J.J. Kuznia, M.B. Kells, and A. Eynard[2]

Two sources of dairy manure and a urea-ammonium nitrate solution were evaluated under conservation tillage on an excessively well drained soil. Yields were similar for all sources of nitrogen. Corn responded to potassium in manure however. Tillage reduced ear leaf concentration of potassium but did not affect yields.

There has been a recent effort by many farmers to more precisely utilize manure to minimize losses to groundwater on glacial outwash soils of central Minnesota. Availability of nitrogen from manure sources that contain appreciable amounts of organic nitrogen can be affected by tillage due to lower soil temperatures and changes in soil water. In an effort to evaluate nitrogen available to corn from dairy manure, plots were established on a coarse textured soil in Stearns County, Minnesota.

Methods and Materials

Two manure sources were evaluated: fresh manure from barn gutters and a manure pack around a hay rack in the barnyard. In addition to a 5 lbs/acre of nitrogen applied with the planter, commercial nitrogen treatments had two equal applications (33 lbs/acre) applied during cultivation as urea-ammonium nitrate solution (UAN). Manure treatments had additional nitrogen applied during the second cultivation. Tillage treatments evaluated were: spring moldboard and chisel plowing followed by a light discing, ridge till and no till systems. Manure applications were not made on the no till plots.

Manure was applied in the last two weeks of April prior to chisel plowing but following moldboard plowing. Results of manure spreader calibration are shown in figure 1. Two sets of five plastic sheets two feet wide and ten feet long were laid down side by side and driven over by the manure applicator for each source of manure. Each sheet was weighed and results converted to tons per acre. These data resulted in the spreader pattern in figure one.

Manure was applied to two 38 inch rows for each pass (center six feet of spreader pattern). Adjacent passes were overlapped to give a relatively uniform application. The rate of manure was calculated by adding the outside 2 two foot wide strips on each side of the spreader pattern to account for overlapping passes. Rates are shown in table 1.

The experimental design is a split plot with tillage main plots and manure/fertilizer subplots for each source of manure. Each source of manure was compared with UAN. The two sources of manure were not compared to each other.

Soil cover was estimated by a line transect method and characterized for "in" and "between row" areas at two monitoring sites within each subplot. At each monitoring site treatment responses were evaluated by observations on two adjacent corn rows. Soil cover measurements were made over 10 feet of row with a line with 25 points. "In row" is defined as a four inch strip centered over the row and "between row" the remainder. Early corn growth was estimated by tallying the leaves on the plants within the ten feet of row. Stands were similar estimated by tallying the number of plants in ten feet of row at each monitoring site.

Ear leaf samples were taken at 50% silk emergence and analyzed for nitrogen and potassium.

Grain yields were estimated by combining two rows of corn 300 feet long and weighing to the nearest 5 pounds with a weigh wagon. Subsamples were taken for moisture determination and nitrogen analysis.

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Results and Discussion

The response of corn to tillage without manure applied is shown in tables 2 to 5. Soil cover by soybean residue was similar with all tillage systems demonstrated except the no till system (table 2). The no till and ridge till systems resulted in adequate cover for erosion control. There was no effect of tillage on stand establishment (table 3). There was however about 1/3 leaf less growth with no till grown corn on June 1st.

Yield trends indicate higher yields with no till grown corn and lower with the ridge till system. Chisel and moldboard plowing were intermediate. The contrast in yield between the no till and ridge till systems probably reflects increased drought stress on the prominent ridges at this site. There were no differences in grain moisture indicating that the small early growth differences due to tillage were not measurable by this indicator of corn phenology.

There were no statistical differences in grain protein or N concentration due to tillage although the tendency was for reduced tillage to have lower levels of grain N (table 5).

The response of corn to tillage and barnyard manure is shown in tables 6 to 15. Tillage effects on soil cover trends were not affected by a barnyard manure application (tables 6 and 7). A barnyard manure application did not affect stand establishment or early growth (tables 8 and 9). Although tillage differences in grain yield means were large they were not statistically significant (table 10). There was a statistically significant 8 bu/acre higher yield with barnyard manure. This was likely due to the potassium applied with the manure. Tillage and barnyard manure did not affect grain moisture (table 11).

Tillage did not affect nitrogen concentrations in grain, protein, or N uptake (table 12, 13, and 14). Barnyard manure resulted in lower concentrations of N and protein in grain than the UAN N source however (tables 13 and 14). Barnyard manure resulted in higher N uptake by grain with chisel plowing than UAN (table 15). This is due to the incorporation with this treatment. Moldboard plowing was done before manure application (table 1).

Tillage effects on soil cover are shown in table 16. Barn gutter manure increased soil cover (table 17). Barn gutter manure application resulted in higher corn stands with moldboard plowing and ridge tillage but lower with chisel plowing (table 18). Early growth was increased by UAN with ridge tillage and moldboard systems but decreased with chisel plowing (table 19).
Yields were similar between both sources of nitrogen (table 20). Grain moisture was increased .5% by the barn gutter manure (table 21).

Tillage did not affect N concentrations in grain, protein, or N uptake by grain (table 22). There were no differences in these quality parameters between the two N sources (tables 23, 24, and 25).

STEARNS COUNTY

Table 1. Cultural practices at Stearns County, MN. 1989.

Tillage

No Till
Ridge Till
Spring Chisel Plowed-after manure application
Spring Moldboard Plowed-before manure application
All plots were cultivated on
June 15 and June 30, 1989.

Cropping History

1981-red clover and oats, 1982-corn,
1983-soybeans, 1984-corn, 1985-corn,
1986-soybeans, 1987-corn, 1988-Soybeans

1989 Crop

Corn - Johnson 475 (100 Day)

Planting and Harvest Dates

Plots were planted with a four row Buffalo Till planter equipped with 12" sweeps at a 38"row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 11, 1989	23,900 plants/A	October 19, 1989

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.

1989 Fertilizer

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/A	----	Date Applied
Corn	9-18-9[1]	5 gal/A	5	10	5	May 11, 1988
	28-0-0[2]	11 gal/A	33	0	0	June 15, 1989
	28-0-0[3]	11 gal/A	33	0	0	June 30, 1989

1. Planter placement 1" below the seed.
2. Urea-ammonium nitrate (UAN) solution was surface banded and incorporated by cultivation on all non-manure plots. Solution was surface banded with no incorporation on no till plots.
3. Urea-ammonium nitrate (UAN) solution was surface banded and incorporated by cultivation on all plots manured and non-manured. Solution was surface banded with no incorporation on no till plots.

1989 Manure Analysis

Analysis and rate of application of manure and available nitrogen.

		Total			Total	Available				Manure			Solids			
	Date	NH_4	NO_3	Mineral	Organic	N	K	Nitrogen		Potassium		Density	Rate	Total	Volatile	Fixed
Manure Source	Applied	-------------		%	-------------			lbs/T	lbs/A	lbs/T	lbs/A	lbs/ft³	T/A	--------	%	--------
Barn Gutter[1]	4/13/89	.260	.012	.272	.264	.536	.424	7.3	122	10	167	64.8	16.7	28.88	45.96	54.04
Barnyard[2]	4/25/89	.054	.003	.057	.656	.713	.346	5.7	86	8	120	33.8	15.0	16.50	64.62	35.38

1. Fresh daily manure collected every other day from barn gutters and applied the last two weeks of April.
2. A manure pack collected near a hay rack in the barnyard and applied April 25, 1989.

Rate of applied and available nitrogen[1].

	Nitrogen Fraction					
	Total Mineral	Organic	Total Nitrogen	Total Mineral	Organic	Total Nitrogen
Nitrogen Source	-- Applied	N lbs/acre	--	-- Avail.	N lbs/acre	---
Barn Gutter	91	88	179	91	31	122
Barnyard	19	213	232	19	74	93

1. It is assumed that all of the mineral N will be available during the year of application and 35% of the organic N.

Soil

The soils at the Stearns County site are Fairhaven loam (Typic Hapludolls) which is well drained on 54 percent of the plot. Estherville sandy loam (Typic Hapludolls) which is somewhat excessively drained on 36 percent of the plot, Hawick loamy sand (Entic Hapludolls), 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 highest being 4 percent.

Weed Control

6 lbs/A (.9 lb/A) Lasso II 15 G in a 15" band applied on May 11, 1989.
1.5 pts/A (.75 lbs/A) Prowl + 1.25 lbs/A (1 lb/A) Bladex 80 WP applied to 3-4 leaf corn.

Table 2. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **no manure** applied[1].

	Tillage				
	NoTill[2]	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	33.3a	3.3b	9.3b	4.0b	16.6
Between Row	37.8a	36.8a	6.3b	2.8b	24.3
Average	35.5a	20.0b	7.8c	3.4c	

1. The p value for residue location, tillage, and tillage by location interaction are .005 (n=80), .001 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).
2. The no till sample size is double the other treatments.

Table 3. Effect of tillage on population (n=16) and growth stage (n=80) of corn at Stearns Co. on June 1, 1989 with **no manure** applied.

	Tillage				
	NoTill[1]	Ridge	Chisel	Mldbd	
Population	plants/A X 10^{-3}				Sig.
	20.7a[2]	20.7a	21.1a	20.8a	.958
Growth Stage	leaves/plant				
	1.65b	1.92a	1.96a	2.0a	.001

1. The no till sample size is 32 and 160 for plant population and growth stage respectively.
2. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage on corn yields and moisture at Stearns Co. on October 19, 1989, with **no manure** applied.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	82a[1]	53a	60a	63a	.108
	%				
Moisture	19.5a	19.0a	20.0a	19.7a	.263

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 5. Effect of tillage on corn ear leaf potassium on July 27, % grain N, protein, and grain N uptake on October 19, at Stearns Co. with **no manure** applied.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	% K				Sig.
Ear Leaf K	0.40ab[1]	0.29b	0.53a	0.61a	.085
	%				
Grain N	1.63a	1.69a	1.69a	1.71a	.376
	%				
Protein	10.2a	10.5a	10.5a	10.7a	.376
	lb/A				
Grain N Uptake	63.3a	42.5a	48.1a	51.3a	.180

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 6. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Location	% cover			Avg.
In Row	2.8a	8.8a	4.5a	5.3
Between Row	35.3a	8.5b	1.3b	15.0
Average	19.0a	8.6b	2.9c	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=48), .042 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage, N source and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barnyard manure** applied[1].

	Tillage							
	Ridge		Chisel		Moldboard		Average	
	UAN	Brnyd	UAN	Brnyd	UAN	Brnyd	UAN	Brnyd
Location	% cover							
In Row	2.5	3.0	8.5	9.0	4.0	5.0	5.0	5.7
Between Row	31.0	39.5	6.0	11.0	1.5	1.0	12.8	17.2
Average	16.8	21.3	7.3	10.0	2.8	3.0	8.9	11.4

1. The p value for N source, tillage by N source, N source by location, tillage by location by N source interactions are .280 (n=48), .862 (n=16), .533 (n=24) .362 (n=8) respectively.

Table 8. Effect of tillage on population of corn on June 1, 1989 at Stearns Co. with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	-- plants/A X 10^{-3} -			Ave.
UAN	20.7	20.7	21.1	20.8
Barnyard + UAN	22.0	21.4	19.6	20.9
Average	21.3a	21.0a	20.3a	

1. The p value for N source, tillage, and tillage by N source interactions are .816 (n=24), .178 (n=16), .327 (n=8) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 9. Effect of tillage on early growth of corn on June 1, 1989 at Stearns Co. with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	--- leaves/plant ---			Ave.
UAN	1.93	2.01	2.04	1.99
Barnyard + UAN	1.68	2.01	2.09	1.93
Average	1.80b	2.01a	2.06a	

1. The p value for N source, tillage, and tillage by N source interactions are .407 (n=120), .043 (n=80), .214 (n=40) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 10. Effect of tillage on corn yields at Stearns Co., on October 19, 1989, with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	-------- bu/A ------			Avg.
UAN	46	58	72	59
Barnyard + UAN	51	80	71	67
Average	49a	69a	72a	

1. The p value for tillage, N source, and tillage by N source interactions are .564, (n=4), .025, (n=6), .034 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 11. Effect of tillage on corn moisture at Stearns Co. on October 19, 1989 with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	---------- % --------			Avg.
UAN	18.2	19.7	18.9	19.0
Barnyard + UAN	19.0	18.7	19.5	19.1
Average	18.6a	19.2a	19.2a	

1. The p value for tillage, N source, and tillage by N source interactions are .810, (n=4), .864, (n=6), .373 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 12. Effect of tillage on corn ear leaf potassium on July 27, % grain N, protein, and grain N uptake on October 19, at Stearns Co. with **barnyard manure** applied.

	Tillage			
	Ridge	Chisel	Mldbd	
	------- % K --------			Sig.
Ear Leaf K	0.41a[1]	0.55a	0.93a	.147
	--------- % --------			
Grain N	1.62a	1.66a	1.70a	.525
	--------- % --------			
Protein	10.1a	10.4a	10.6a	.525
	--------- lb/A ------			
Grain N Uptake	37.2a	53.6a	57.3a	.498

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 13. Effect of tillage on corn ear leaf potassium on July 27, grain N on October 19, at Stearns Co. with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	------- % K --------			Avg.
UAN	0.31	0.53	0.71	0.51
Barnyard + UAN	0.52	0.58	1.15	0.75
Average	0.41a	0.55a	0.93a	
	--------% N -------			
UAN	1.66	1.73	1.74	1.71
Barnyard + UAN	1.57	1.58	1.65	1.60
Average	1.62a	1.66a	1.70a	

1. The p value for % K for tillage, N source, and tillage by N source interactions are .147, (n=4), .048, (n=6), .378 (n=2) respectively. The p value for % N for tillage, N source, and tillage by N source interactions are .525, (n=4), .041, (n=6), .731 (n=2). Means within the same row with the same letter are not significantly different (α=.10).

Table 14. Effect of tillage on corn grain protein at Stearns Co. on October 19, 1989, with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Protein		%		Avg.
UAN	10.4	10.8	10.9	10.7
Barnyard + UAN	9.8	9.9	10.3	10.0
Average	10.1a	10.4a	10.6a	

1. The p value for tillage, N source, and tillage by N source interactions are .525, (n=4), .041, (n=6), .731 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 15. Effect of tillage on corn grain N uptake at Stearns Co. on October 19, 1989, with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Grain N Uptake		lb/A		Avg.
UAN	36.5	47.6	59.9	1.71
Barnyard + UAN	37.9	59.6	54.7	1.60
Average	37.2a	53.6a	57.3a	

1. The p value for tillage, N source, and tillage by N source interactions are .498, (n=4), .092, (n=6), .018 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 16. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Location		% cover		Avg.
In Row	4.3a	16.0a	4.0a	8.1
Between Row	52.0a	12.3b	4.5c	22.9
Average	28.1a	14.1b	4.3c	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=48), .114 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 17. Effect of tillage, N source and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barn gutter manure** applied[1].

	Tillage							
	Ridge		Chisel		Moldboard		Average	
	UAN	Brngt	UAN	Brngt	UAN	Brngt	UAN	Brngt
Location				% cover				
In Row	4.0	4.5	10.0	22.0	4.0	4.0	6.0	10.2
Between Row	42.5	61.5	6.5	18.0	4.0	5.0	17.7	28.2
Average	23.3	33.0	8.3	20.0	4.0	4.5	11.8	19.2

1. The p value for N source, tillage by N source, N source by location, tillage by location by N source interactions are .046 (n=48), .153 (n=16), .883 (n=24) .946 (n=8) respectively.

Table 18. Effect of tillage on population of corn on June 1, 1989 at Stearns Co. with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
		plants/A X 10^{-3}		Ave.
UAN	20.7	21.6	20.5	20.9
Barn Gutter + UAN	22.0	18.7	23.4	21.4
Average	21.3a	20.1a	22.0a	

1. The p value for N source, tillage, and tillage by N source interactions are .586 (n=24), .156 (n=16), .008 (n=8) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 19. Effect of tillage on early growth of corn on June 1, 1989 at Stearns Co. with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
		leaves/plant		Ave.
UAN	1.91	1.91	2.04	1.90
Barn Gutter + UAN	1.73	1.65	2.32	1.96
Average	1.82a	1.78a	2.18a	

1. The p value for N source, tillage, and tillage by N source interactions are .392 (n=120), .442 (n=80), .040 (n=40) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 20. Effect of tillage on corn yields at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	bu/A			Avg.
UAN	61	63	54	59
Barn Gutter + UAN	60	67	57	61
Average	60a	65a	55a	

1. The p value for tillage, N source, and tillage by N source interactions are .366, (n=4), .766, (n=6), .954 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 21. Effect of tillage on corn moisture at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	%			Avg.
UAN	19.7	20.3	20.4	20.2
Barn Gutter + UAN	20.8	20.7	20.7	20.7
Average	20.3a	20.5a	20.6a	

1. The p value for tillage, N source, and tillage by N source interactions are .847, (n=4), .056, (n=6), .302 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 22. Effect of tillage on corn ear leaf potassium on July 27, % grain N, protein, and grain N uptake on October 19, at Stearns Co. with **barn gutter manure** applied.

	Tillage			
	Ridge	Chisel	Mldbd	
	% K			Sig.
Ear Leaf K	0.46b[1]	0.72b	1.24a	.088
	%			
Grain N	1.69a	1.63a	1.67a	.683
	%			
Protein	10.6a	10.2a	10.5a	.683
	lb/A			
Grain N Uptake	47.9a	50.1a	43.4a	.421

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 23. Effect of tillage on corn ear leaf potassium on July 27, grain N on October 19, at Stearns Co. with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	% K			Avg.
UAN	0.27	0.54	0.52	0.44
Barnyard + UAN	0.64	0.90	1.97	1.17
Average	0.46b	0.72b	1.24a	
	% N			
UAN	1.71	1.64	1.69	1.67
Barnyard + UAN	1.68	1.63	1.66	1.66
Average	1.69a	1.64a	1.67a	

1. The p value for % K for tillage, N source, and tillage by N source interactions are .147, (n=4), .048, (n=6), .378 (n=2) respectively. The p value for % N for tillage, N source, and tillage by N source interactions are .525, (n=4), .041, (n=6), .731 (n=2). Means within the same row with the same letter are not significantly different (α=.10).

Table 24. Effect of tillage on corn grain protein at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

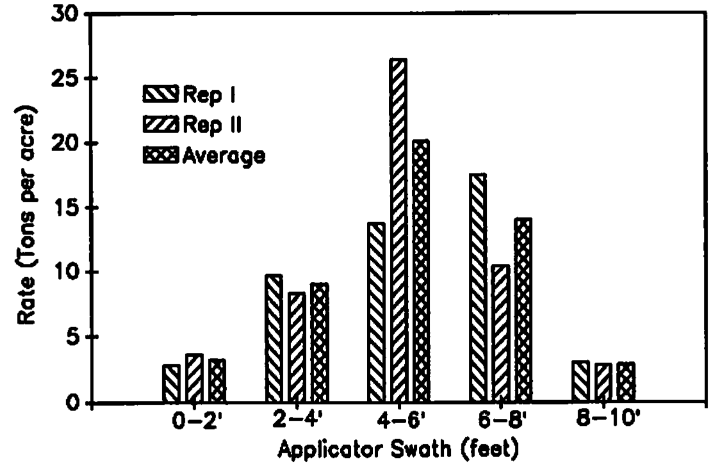
	Tillage			
	Ridge	Chisel	Mldbd	
Protein	%			Avg.
UAN	10.7	10.2	10.5	10.5
Barn Gutter + UAN	10.5	10.2	10.4	10.3
Average	10.6a	10.2a	10.5a	

1. The p value for tillage, N source, and tillage by N source interactions are .683, (n=4), .332, (n=6), .824 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

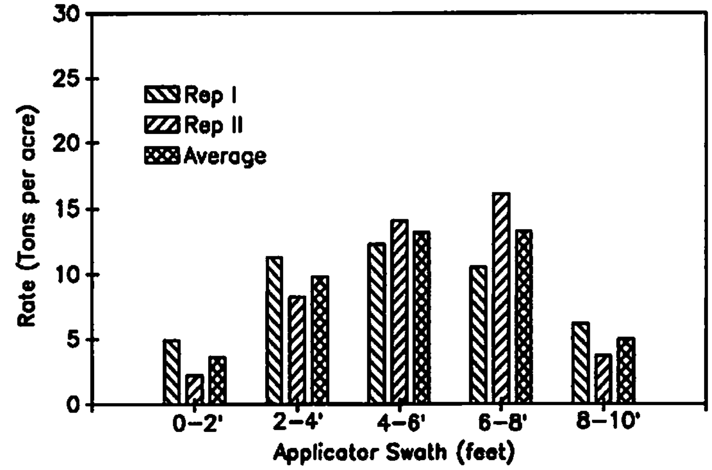
Table 25. Effect of tillage on corn grain N uptake at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Grain N Uptake	lb/A			Avg.
UAN	48.6	48.5	42.8	46.6
Barn Gutter + UAN	47.2	51.7	44.0	47.6
Average	47.9a	50.1a	43.4a	

1. The p value for tillage, N source, and tillage by N source interactions are .421, (n=4), .866, (n=6), .943 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).



BOX TYPE APPLICATOR CALIBRATION WITH FRESH DAIRY MANURE FROM BARN GUTTERS, STEARNS COUNTY, 1989



BOX TYPE APPLICATOR CALIBRATION WITH DAIRY MANURE FROM MANURE PACK NEAR HAY RACK, STEARNS COUNTY, 1989

EFFECT OF TILLAGE AND FREQUENCY OF LIQUID DAIRY MANURE APPLICATION ON THE AVAILABILITY OF N TO CORN, SOIL N DISTRIBUTION AND N CONCENTRATION IN SOIL WATER[1]

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Abstract: A summary of the results of 1989 season of a study to determine the effects of tillage and the frequency of liquid dairy manure application on corn yield, N uptake and soil N distribution initiated in 1982 are summarized in this report. Tillage treatments included no tillage and chisel plowing. N treatments included manure applied at the rate of 202 lb/A annually, biennially, and triennially. Tillage effects were not significant in most yield characteristics except in total dry matter at harvest, no till yielding more dry matter than chisel plowing. Manure applied annually yielded more grain followed by annual fertilizer, biennial manure in the year of application, and biennial manure in the year following application. The residual effects of additional K at the rate of 200 lbs K_2O in previous years was not observed in grain yield but still had an effect on stover dry matter yield. N uptake was higher by 10 lbs/A in no till grown corn than in chisel plowed, by annual manure and fertilizer than by biennial manure, and by additional K application.

Cover by surface residue was higher in no till than chisel plow, in fertilized treatments than in manure treatments, and in between the rows than in the rows. Soil profile was drier in the fall than in the spring. Chisel plowed treatments had about 10 lbs/A more N than no till. About 1/2 to 3/4 of the total inorganic N was in ammonium form. Ammonium-N decreased with depth while nitrate-N increased with depth. There was more N in nitrate form in between the rows than in the rows. Nitrate levels in soil water sampled at 5 ft. depth were higher in chisel plowed treatments than in no till, and in treatments applied with fertilizer and annual manure than the biennial manure. The concentration did not vary much with time between May and September.

INTRODUCTION

The objective of the study is to determine the effects of tillage and frequency of manure application on corn yield, N uptake, and soil nitrogen levels. The site is located on a Timula silt loam soil on the Dale Flueger Farm near Red Wing in Goodhue Co., MN. The study was initiated in 1982.

Liquid dairy manure is injected either annually, biennially or triennially on chisel-plowed treatments and annually or biennially on no-till treatments. A check treatment which does not receive any nitrogen and a fertilized check treatment which until 1988 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. In 1989, the fertilized check received anhydrous ammonia ,instead of ammonium nitrate, injected at the rate of 170 lbs N/A. Most cultural practices are similar to previous years (Table 1).

From 1982-1986 the manure treatments were split with 0 and 200 lbs K_2O/A and the fertilizer treatments with 0, 200, and 400 lbs K_2O/A. 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 whenever applicable.

The experiment is laid out in a randomized complete block split-split plot design with three replications. Tillage is the main plot and N source is the subplot. Manure as N source is further split by the year of N application as a sub-sub plot.

The results of the analyses on yield and soil characteristics done for 1989 are included in this report.

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[2] Graduate research assistant, professor, and associate professors, respectively, Soil Science Department, Univ. of Minnesota, St. Paul, MN, 55108.

RESULTS AND DISCUSSION

Grain Yields, Grain Moisture and Total Dry Matter. Tillage did not significantly affect grain yields and grain moisture (Table 2), but had a significant effect on total dry matter. The total dry matter was higher with no tillage than chisel plowing. Annual manure application had greatest average grain and total dry matter yield , about 30 bu/A more grain yield than the manure treatment in the year after its application. Manure in the year of application and annual fertilizer treatments had intermediate grain yields. Grain moisture at harvest was not affected by tillage, N treatments, or previous application of additional K. The moisture was greater in no till receiving no additional K in previous years than in the treatments receiving additional K, or in chisel plowing (Table 4). Previous K split had a significant effect on total dry matter: those with additional K had higher dry matter than those without it (Table 8).

Plant Population and Stover Yield. Although the plant population at harvest was not affected by tillage, N application, or K rates (Table 5), no tillage had slightly lower population than chisel plowing (Table 3). In general, there was a lower stand in 1989 by about 1500 plants/A than in 1988. Stover dry matter yield was not affected by tillage and N treatments. Additional K resulted in higher average stover dry matter by 0.4 ton/A (Table 8). The stover dry matter was higher in most N treatments receiving additional K except those receiving manure in the previous year when it was higher without additional K (Table 10). The stover moisture at harvest was highest in biennial manure applied in 1989 followed by annual manure and fertilizer, and manure applied in the previous year.(Table 7). The moisture was higher in no till in the year of application of manure. In the other treatments it was greater in chisel plowing (Table 9).

Harvest Index. An analysis of harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover), shows a significant effect of K treatments (Table 6). Higher stover dry matter associated with previous K addition resulted in a lower harvest index (Table 8). Annual manure produced the highest ratio followed by annual fertilizer and the biennial manure applied in 1988 and 1989, respectively, though the results were not significant.

Grain N, Stover N, and N Uptake. Although no till had higher N concentration in grain and stover (Table 11) the difference was not significant. The total N uptake in grain and stover was significantly higher in no till by 10 lbs/A than chisel plowed treatments. Both grain and stover N was highest in annual fertilizer followed by annual manure, biennial manure in the year of application, and biennial manure in the year after its application, respectively. Since the grain yields and stover yields were higher in the annual manure, the total N uptake with annual manure was higher by 13 lbs/A than with the fertilized treatments. Previous application of K resulted in higher grain N and N uptake in the biennial manure in the year of application but lower grain N and N uptake in the biennial manure in the year following application (Table 13). Grain N was found to be higher in no till without additional K; whereas, it was higher in chisel plow with additional K (Table 14).

Residue Cover. Residue measurements were made both in and between the rows in duplicate in manure, fertilizer and check treatments in both tillages on June 13, 1989. Residue was higher in no tillage than in chisel plowing (Table 15). The anhydrous applied treatments had highest residue followed by those in the year after application of manure, check, and those that received manure 1989 . The difference in residue cover between the fertilized treatments and the other treatments was most pronounced in no till and had about 20% more residue than the other treatment. There was about 10% more residue in between the rows than in the rows.

Soil Profile Moisture. Gravimetric soil moisture determination made on soil samples taken to a depth of 5 ft. in the spring and fall are given in Table 16. The soil samples were taken from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. There was a higher soil moisture in the profile in the spring than in the fall, indicating little recharge by fall precipitation at the time of sampling. At both times of soil sampling, the soil moisture was higher in the upper 3 ft. depth than the depth below. No till treatments had higher moisture in the profile in the spring samples; whereas, the moisture was not affected by tillage in the fall (Table 17).

Soil Profile Nitrogen. Soil samples were taken to a depth of 5 ft. in 1 ft. increment from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. Total inorganic N and ammonium-N determinations were made on these samples. There was more total inorganic soil nitrogen in chisel plow than in no till treatments in the spring, although the difference was not significant (Table 18). About 3/4 of the total inorganic nitrogen was in ammonium form. The total N was highest in fertilizer treatment. Manure in the year of application had about 8 lbs/A more N than manure in the year after application of manure (Table 19). Total N was higher in the top 0-1 ft. and bottom 4-5 ft. increments than those in the middle (Table 20). About 3/4 of N in the top 1 ft. was in ammonium form; whereas, about 1/2 of N in the bottom 4-5 ft. increment was in nitrate form. There was more nitrate N in between the rows in manure and check treatments and more nitrate N in the row in fertilized treatments (Table 21). The total N was more in the rows than in between the rows in the fertilizer and manure in the year of application. The manure in the year after its application and the check had more N in between the rows than in the rows (Table 22). The significance values for various main effects and interactions for soil moisture and N in fall and spring are given in Table 23.

Soil Water N. Suction water samplers were established on manure (annual and biennial) and fertilizer treatments to monitor nitrate-nitrogen in soil water at 5 ft depth. The data obtained in 1989 are presented in Fig. 1. Among the N treatments, both fertilizer and annual manure treatments yielded consistently higher nitrate-nitrogen at 5 ft depth than the biennial manure treatments. The difference was not much in the biennial treatments due to the year of application. The chisel plowing produced considerably higher nitrates in the water than no till system. The nitrate levels, however, were fairly uniform throughout the sampling period indicating little movement of water and N during that period. The suction samplers in the fertilizer treatments were established in the second week of July. There is an initial rise in nitrate levels in these treatments. The lower nitrate levels initially may have been caused by flow of water along the samplers because of the poor contact between the samplers and the soil.

Table 1. Cultural practices at the Fluegers Farm in Goodhue County, MN in 1989.

Tillage	**Cropping History**
No Till	Corn since 1981-P 3906.
Chisel Plow-Chiseled on May 11,1989.	1989 Corn Pioneer 3737

Manure Application

Injected liquid dairy manure at the following rate and analysis on May 9, 1989.

	1989 rate	
	Mean	Std. Dev.
Manure (gal/A)	8300	370
Total-N (lbs/A)	202	11
NH_4-N (lbs/A)	124	14
K (lbs/A)	149	9
Soilids:Total(%)	7.6	0.7
Volatile(%)	62.3	6.0
Fixed(%)	37.7	6.0

Planting Information

A four row 38 inch Hinecker Series 1 Econo Till planter with clearing disks raised.

Planting Date	Rate	Harvested
May 12, 1989	32,000 plants/A	October 4, 1989

Fertilizer

Material Analysis	Tillage	Actual N -lbs/A-	Date Applied	Method of Application
82-0-0	Both tillages	170	May 16, 1989	Injected after planting

(In the previous years, no till and chisel plow received 210 lbs/A and 170 lbs/A, as ammonium nitrate, respectively)

Soil

Timula silt loam (Typic Eutrochrepts, coarse-silty, mixed, mesic), 2 to 12% slope. Soil is well drained.

Insect Control

8.7 lbs/A Counter applied in furrow on May 12, 1989.

Weed Control

3 pt./A Prowl, 2.5 lb/A 90 DF Bladex applied in 20 lb/A carrier on May 23, 1989.

Table 2. Corn grain yield, grain moisture, and total dry matter as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1989.

Frequency[1] & Source of N	K_2O lb/A	GRAIN YIELDS No Till	Chisel	Mean	GRAIN MOISTURE No Till	Chisel	Mean	TOTAL DRY MATTER No Till	Chisel	Mean
		bu/A			%			tons/A		
Manure	0	150.5	135.7	143.1	28.2	24.5	26.3	5.82	4.96	5.40
(Yr. after)	200	135.6	133.4	134.5	24.5	24.5	24.5	5.31	5.11	5.21
	Mean	143.1	134.5	138.8	26.3	24.5	25.4	5.57	5.04	5.30
Manure	0	141.4	155.0	148.2	26.5	23.8	25.2	4.67	5.57	5.12
(Yr. of)	200	160.3	145.4	154.3	23.7	24.8	24.1	6.98	6.36	6.73
	Mean	154.0	149.5	152.0	24.6	24.4	24.5	6.21	6.02	6.13
Manure	0	160.3	159.0	161.8	25.2	21.9	24.1	6.30	6.00	6.20
(Annual)	200	177.5	167.4	174.1	23.5	22.6	23.2	6.82	6.14	6.60
	Mean	170.4	163.2	168.0	24.3	22.2	23.6	6.56	6.07	6.40
Anhydrous Ammonia	200	162.8	166.6	164.7	27.4	25.8	26.6	6.16	6.15	6.16

Pr>F

	Till(T)	Freq.(F)	T*F	K rate(K)	K*T	K*F	K*F*T
Grain Yields	.318	.066	.929	.770	.491	.426	.348
Grain moisture	.322	.291	.910	.174	.023	.756	.857
Total dry matter	.042	.401	.913	.004	.071	.003	.009

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[1] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 3. Tillage effects on corn plant population in Goodhue Co., MN in 1989[1].

Tillage	PLANT POPULATION -plants/A*10^{-3} -
No till	24.3
Chisel	25.9
Pr>F (Till)	.115

[1] Averaged over N and K treatments (Table 2).

Table 4. Effects of tillage and K application on corn grain moisture in Goodhue Co., MN in 1989[1].

K_2O lb/A	GRAIN MOISTURE No Till	Chisel
	%	
0	26.3	23.4
200	24.4	24.4

Pr>F (K rate*Till) .023

[1] Averaged over N and tillage treatments (Table 2).

Table 5. Corn plant population, stover yield, and moisture at harvest as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1989.

Frequency & Source of N	K_2O lb/A	PLANT POPULATION No Till	PLANT POPULATION Chisel	PLANT POPULATION Mean	STOVER DRY MATTER No Till	STOVER DRY MATTER Chisel	STOVER DRY MATTER Mean	STOVER MOISTURE No Till	STOVER MOISTURE Chisel	STOVER MOISTURE Mean
		-- plants/A*10^{-3} ---			------ tons/A -----			------- % --------		
Manure[1]	0	25.9	23.6	24.8	2.35	1.70	2.03	0.47	0.55	0.51
(Yr. after)	200	24.7	25.2	24.9	1.85	1.84	1.85	0.53	0.53	0.53
	Mean	25.3	24.4	24.9	2.10	1.77	1.94	0.50	0.54	0.52
Manure	0	22.2	24.9	23.6	1.70	2.06	1.88	0.58	0.52	0.55
(Yr. of)	200	23.3	26.4	24.6	3.51	2.73	3.20	0.61	0.59	0.60
	Mean	23.0	25.8	24.2	2.90	2.44	2.70	0.60	0.56	0.58
Manure	0	23.9	26.6	24.8	2.31	1.99	2.20	0.54	0.56	0.55
(Annual)	200	25.6	27.1	26.1	2.33	2.24	2.30	0.56	0.56	0.56
	Mean	24.7	26.9	25.4	2.32	2.11	2.25	0.55	0.56	0.56
Anhydrous-Ammonia	200	24.9	27.2	26.1	2.31	2.21	2.26	0.52	0.52	0.52

	Till(T)	Freq.(F)	T*F	K rate(K)	K*T	K*F	K*F*T
Plant population	.115	.463	.558	.484	.850	.932	.707
Stover dry matter	.368	.160	.839	.007	.377	.001	.004
Stover moisture	.839	.002	.054	.066	.284	.281	.155

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[1] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 6. Harvest index of corn as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1989.

Frequency[1] & Source of N	K_2O lb/A	HARVEST INDEX No Till	HARVEST INDEX Chisel	HARVEST INDEX Mean	Source	Pr>F
Manure	0	0.56	0.66	0.61		
(Yr. after)	200	0.64	0.64	0.64	Tillage (T)	.504
	Mean	0.60	0.65	0.63	Freq (F)	.157
Manure	0	0.64	0.63	0.64	T*F	.810
(Yr. of)	200	0.50	0.58	0.54		
	Mean	0.55	0.60	0.57	K Rate(K)	.096
Manure	0	0.63	0.67	0.64	K*T	.508
(Annual)	200	0.66	0.64	0.66	K*F	.004
	Mean	0.65	0.65	0.65		
Anhy. ammon.	200	0.63	0.64	0.63	K*F*T	.005

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[1] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 7. Corn stover yield, stover moisture, total dry matter, grain yield and grain moisture as influenced by N source and frequency of application in Goodhue Co., MN in 1989[1].

Frequency & Source of N	STOV.DRY MATTER ---- tons/A ---	ST. MOISTURE ----- % ----	TOTAL DRY MATTER ---- tons/A ---	GRAIN YIELD ----bu/A----	GRAIN MOISTURE -----%-----
Manure[2] (Yr. after)	1.94	.52	5.30	138.8	25.4
Manure (Yr. of)	2.70	.58	6.13	152.0	24.5
Manure (Annual)	2.25	.55	6.40	168.0	23.6
Anhydrous Ammonia (annual)	2.26	.52	6.16	164.7	26.6
Pr>F (N Source & Freq.)	.160	.002	.401	.066	.291

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[1] Averaged over tillage and K treatments (Table 5).

[2] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 8. Corn stover yield, total dry matter, harvest index, plant population, and grain moisture as influenced by previous K application in Goodhue Co., MN in 1989[1].

K_2O lb/A	STOVER DRY MATTER ----- tons/A ----	TOTAL DRY MATTER -----tons/A-----	HARVEST INDEX	PLANT POPULATION - plants/A*10^{-3} -	GRAIN MOISTURE -------%------
0	2.06	5.66	0.63	24.4	25.0
200	2.46	6.27	0.61	24.4	24.4
Pr>F (K rate)	.007	.004	.096	.484	.174

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[1] Averaged over tillage and N treatments (Table 5).

Table 9. Corn stover moisture as influenced by tillage and N application in Goodhue Co., MN in 1989[1].

Frequency & Source of N	STOVER MOISTURE No Till	 Chisel
	------%	--------
Manure[1] (Yr. after)	50.2	53.8
Manure (Yr. of)	59.9	55.8
Manure (Annual)	55.2	55.9
Anhydrous Ammonia	51.7	52.1
Pr>F (Till.*N Source & Freq.)	.054	

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[1] Averaged over K treatments (Table 5).

Table 10. Corn stover yield, and stover moisture and total dry matter as influenced by K rate, N source and frequency of application in Goodhue Co., MN in 1989[1].

Frequency & Source of N	K_2O lbs/A	STOVER DRY MATTER ------ tons/A ---	STOVER MOISTURE ------ % ------	TOTAL DRY MATTER ---- tons/A ----
Manure[2] (Yr. after)	0	2.03	51	5.39
	200	1.85	53	5.21
Manure (Yr. of)	0	1.88	55	5.12
	200	3.20	60	6.73
Manure (Annual)	0	2.20	55	6.20
	200	2.30	56	6.60
Anhydrous Ammonia	200	2.26	52	6.16
Pr>F (N source & freq.*K)		.001	.281	.003

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[1] Averaged over tillage treatments.

[2] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 11. The effect of tillage on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Tillage	GRAIN N ---%---	STOVER N ----%----	TOTAL N UPTAKE ----lbs/A----
No Till	1.45	.63	135.0
Chisel Plow	1.39	.59	125.0
Pr>F (Till)	.141	.310	.033

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[1] Averaged over N and K treatments (Table 5).

Table 12. The effect of N source and frequency on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Frequency & Source of N	GRAIN N ---%---	STOVER N ---%----	TOTAL N UPTAKE -----lbs/A----
Manure[2] (Yr. after)	1.31	.49	98.4
Manure (Yr. of)	1.42	.59	129.6
Manure (Annual)	1.45	.64	149.1
Anhydrous Ammonia (annual)	1.50	.72	136.5
Pr>F (N source and Freq)	.001	.000	.013

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[1] Average over tillage and K treatments (Table 5).
[2] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 13. The effect of N source and frequency, and K application on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Frequency & Source of N[2]	K_2O lb/A	GRAIN N ---%---	STOVER N ----%----	TOTAL N UPTAKE ---lbs/A----
Manure (Yr. after)	0	1.33	.53	101.1
	200	1.28	.45	95.7
Manure (Yr. of)	0	1.37	.58	109.4
	200	1.46	.60	141.8
Manure (Annual)	0	1.51	.64	149.0
	200	1.40	.64	149.2
Anhydrous Ammonia (annual)	200	1.50	.72	136.5
Pr>F (N source and Freq*K)		.018	.583	.020

---

[1] Averaged over the tillage treatments.
[2] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 14. The effect of tillage and K application on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Tillage	K_2O lb/A	GRAIN N ---%---	STOVER N ----%----	TOTAL N UPTAKE ---lbs/A----
No Till	0	1.48	.62	129.1
	200	1.43	.63	138.3
Chisel Plow	0	1.33	.55	117.1
	200	1.42	.61	129.3
Pr>F (Till*K)		.005	.628	.720

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[1] Averaged over the N treatments (Table 13).

Table 15. Effects of tillage, and N source and frequency, and row position on residue cover in Goodhue Co., MN, on 6/13/89.

N source	Row	Residue (%)	
		No Till	Chisel
Manure(Year after)	In	44.0	15.3
	Bet.	56.0	34.7
Manure(Year of)	In	26.7	27.7
	Bet.	34.0	39.3
Manure(Annual)	In	26.6	40.0
	Bet.	39.8	41.6
Anhydrous amm.	In	74.7	23.7
	Bet.	65.7	43.7
Check	In	33.3	34.7
	Bet.	40.7	36.0

Pr>F

Till(T)	Freq.(F)	T*F	Row(R)	K*R	K*F	K*F*R
.039	.019	.013	.002	.212	.640	.581

Table 16. Gravimetric soil moisture by depth in Goodhue Co., MN in 1989.

Depth (ft.)	Moisture(%, wt./ wt.)	
	April 26-May 2	Oct 24-Nov 2
0-1	23.7	18.1
1-2	23.3	18.1
2-3	22.0	17.0
3-4	19.5	*
4-5	17.5	16.9
Pr>F (Depth)	.000	.000

---

[1] Averaged over N treatments (Table 19) and row position.

* The depth increment in the Fall samples was 3-5 ft.

Table 17. Gravimetric soil moisture as affected by tillage in Goodhue Co., MN[1].

Depth (ft.)	Moisture(%, wt./wt.)			
	April 26-May 2		Oct. 24-Nov. 2	
	No Till	Chisel	No Till	Chisel
0-1	24.0	23.4	18.2	18.0
1-2	23.6	23.0	18.8	17.3
2-3	22.8	21.2	17.2	16.8
3-4	20.9	18.1	*	*
4-5	18.7	16.3	17.5	16.2
Pr>F (Till*Depth)	.022		.695	

---

[1] Averaged over N treatments (Table 19) and row position.

* The depth increment in the Fall samples was 3-5 ft.

Table 18. The effect of tillage on inorganic nitrogen in 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989[1].

Tillage	TOTAL N	NH_4-N	NO_3-N
	----------lbs/A----------		
No Till	104.5	75.0	26.5
Chisel Plow	115.5	81.5	34.0
Pr>F (Till)	.162	.534	.311

---

[1] Averaged over N treatments (Table 19) and row position.

Table 19. The effect of N source and frequency on inorganic nitrogen in the top 5 ft. soil profile in Goodhue Co., MN (April 26- May 2)[1].

N Source & Frequency	TOTAL N	NH_4-N	NO_3-N
	-----------lbs/A-----------		
Manure (Yr. of)[2]	85.5	75.0	10.5
Manure (Yr. after)	93.0	71.0	22.0
Ammonium Nitrate (annual)	151.0	96.0	55.0
Check	69.0	60.5	8.5
Pr>F (N source & Freq)	.162	.534	.311

---

[1] Averaged over tillage and row position.

[2] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 20. Inorganic nitrogen by depth in the top 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989[1].

Depth (ft.)	TOTAL N	NH_4-N	NO_3-N
	------------lbs/A-----------		
0-1	26.0	19.6	6.4
1-2	19.5	16.5	3.1
2-3	19.9	17.6	2.4
3-4	18.1	12.9	5.2
4-5	26.3	13.0	13.3
Pr>F (Depth)	.001	.014	.000

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[1] Averaged over tillage and row position on on selected N treatments (Table 19)

Table 21. Total nitrate-N (averaged over tillage) by row position in the top 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989.

N Source & Frequency	NO_3-N (lbs/A) In Row	NO_3-N (lbs/A) Bet Row
Manure (Yr. of)[1]	9.5	12.0
Manure (Yr. after)	15.5	29.0
Ammonium Nitrate (annual)	74.0	36.5
Check	7.0	10.5
Pr>F (N source and Freq*Row)	.005	

---

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 22. Total inorganic N (averaged over tillage) by row position and depth in the top 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989.

N Source & Frequency	Row	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.	0-5 ft.
		Total inorg. N (lb/A)					
Manure(Yr. of)[1]	In	32.0	14.7	20.5	9.5	15.3	**92.0**
	Bet.	16.1	13.0	19.4	15.6	15.0	**79.1**
Manure (Yr. after)	In	22.9	13.8	18.2	16.3	15.1	**86.3**
	Bet.	41.9	15.8	13.2	12.4	16.2	**99.5**
Ammonium Nitrate (annual)	In	25.9	32.8	23.9	26.1	56.3	**165.0**
	Bet.	30.5	22.4	26.3	23.2	34.4	**136.8**
Check	In	20.5	14.0	16.5	13.6	8.8	**73.4**
	Bet.	13.7	13.8	11.2	14.6	11.7	**65.0**
Pr>F (N source & Freq.*Row*Depth)					.096		

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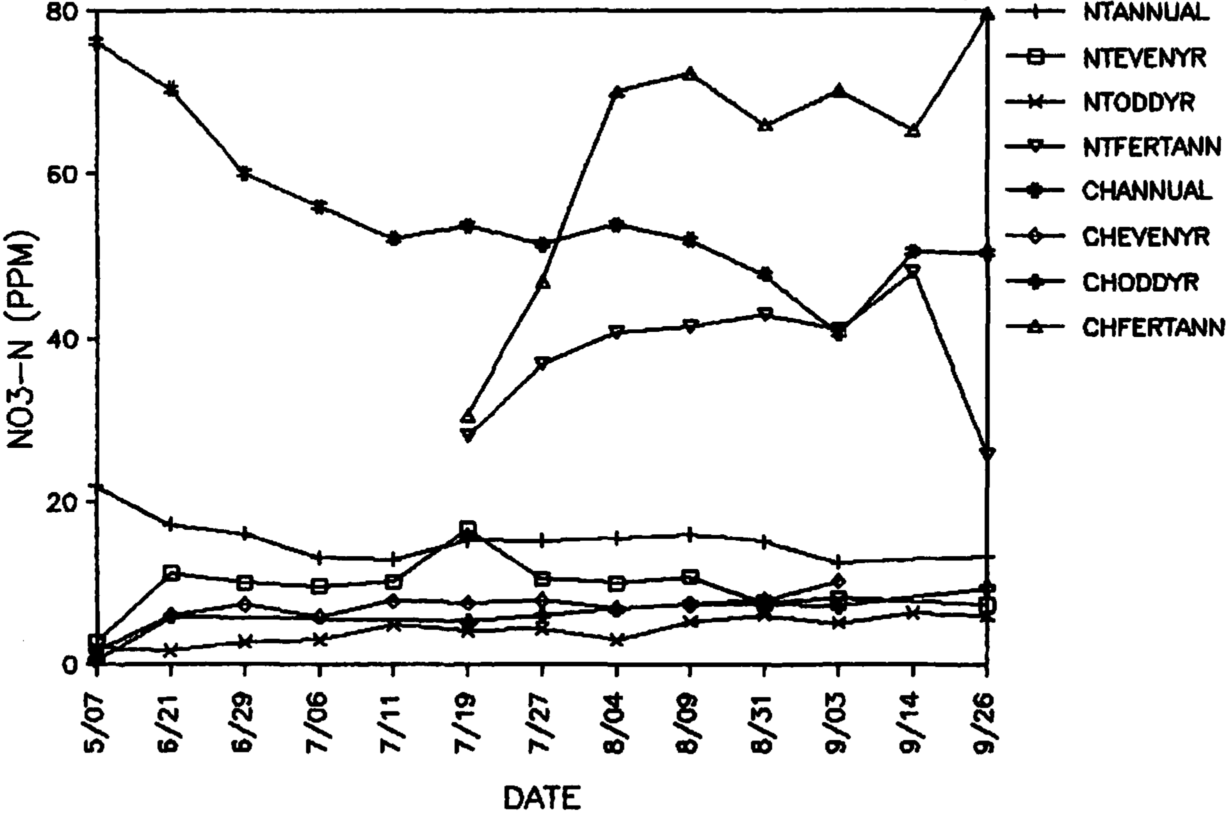
[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 23. Significance table for spring and fall soil moisture, and spring soil N.

	Till(T)	N Freq(F)	T*F	Row(R)	T*R	F*R	T*F*R	Depth(D)	T*D	F*D	T*F*D	R*D	T*R*D	F*R*D	T*F*R*D
Soil moisture															
Spring	.212	.567	.741	.621	.896	.894	.838	.000	.022	.428	.488	.907	.952	.999	.999
Fall	.419	.874	.228	.065	.714	.464	.357	.158	.695	.352	.624	.501	.658	.544	.641
Spring N	.162	.009	.992	.305	.806	.355	.939	.011	.346	.001	.584	.910	.796	.096	.686
NH_4-N	.534	.532	.945	.515	.787	.514	.369	.014	.504	.825	.601	.798	.849	.277	.590
NO_3-N	.311	.000	.323	.484	.967	.005	.530	.003	.755	.000	.220	.351	.578	.562	.506

FIG. 1: WATER ANALYSIS FROM FLUEGERS FARM, 1989



EFFECT OF TILLAGE AND SOURCE OF SWINE MANURE ON SOIL N, CORN YIELD, AND N UPTAKE[1]

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Abstract: The results of the third year of the study initiated in 1987 to evaluate the effects of tillage, and frequency of injected swine manure on corn yield, N uptake and soil N distribution are presented in this report. N applied as anhydrous ammonia at the rate of 170 lb N/A resulted in 25 bu/A more grains than manure from an anaerobic pit applied equivalent to 160 lb N/A or from an open lagoon applied equivalent to 143 lb N/A. Grain yield was not affected by tillage, and was at least 30 bu/A more in the year of application of N treatments than the year following application. Insecticide application produced an additional 8 bu/A grain. Chisel plowing, in the year of application of N treatments and the N treatments applied with manure from lagoon resulted in the greatest response to insecticide. N uptake was higher in fertilizer treatments than in manure treatments.

Surface cover by corn residue was greater in the ridge till system, and in between the rows. Soil moisture in the profile was greater in the spring than in the fall. Total profile N in the spring was greater in fertilizer treatments than in manure treatments, and was more than 1/2 to 2/3 in ammonium form. Nitrate N in soil water samples at 5 ft. depth was higher in fertilized treatments than the manure treatments. Nitrate in water was greater with ridge tillage than in chisel plowed treatments, and did not change much with time between July to September.

INTRODUCTION

In 1987, a study was initiated at the Nord Farm in Goodhue County, MN to evaluate the effects of tillage and manure application on soil N distribution, corn yield and N uptake. This was the third year of initial establishment of the treatments.

Liquid swine manure is injected every other year. In 1987-88, manure from an anaerobic pit receiving manure from farrowing house was applied at two rates: approximately 12,000 and 7,300 gal/A on ridge and chisel till treatments. 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. In 1989, the treatment with lower rate of pit manure was replaced with manure from an open lagoon. The manure applied from an anaerobic pit was equivalent to 168 lb N/A and from an open lagoon was equivalent to 143 lb N/A. Most cultural practices followed were similar from year to year; the 1989 practices are summarized in Table 1.

The experiment is laid out in a randomized complete block split-split plot design with four replications. Tillage is the main plot and N source is the subplot. N source is further split by the year of N application as a sub-sub plot.

The results of yield and soil analyses for 1989 are summarized in this report.

RESULTS AND DISCUSSION

Grain Yield, Grain Moisture and Total Dry Matter. A summary of total grain yield, grain moisture and total dry matter at harvest is given in Table 2. The source of N had highly significant effects on grain yield and total dry matter. Among the biennial treatments the anhydrous ammonia produced about 25 bu/A more grain and 1 ton/A more total dry matter than either of the manure sources (Table 5). Both the grain yield and the total dry matter were higher in the treatments receiving N in 1989 than in previous year (Table 6). Chisel plowing resulted in higher grain yield than ridge tillage in treatments receiving anhydrous ammonia, the increase was not so pronounced in manure treatments (Table 7). The grain moisture and total dry matter was significantly higher in ridge till as compared to chisel plow in the treatments receiving N in 1989; the difference was less obvious for N treatments applied in the previous year (Table 8).

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Plant Population and Stover Yield. The plant population, final stover dry matter and stover moisture at harvest in the biennial treatments were not affected by tillage (Table 3). The source and year of N application had a significant effect on stover dry matter and moisture content at harvest. The anhydrous ammonia application resulted in higher stover yield than the manure application and the stover moisture was higher for manure from the lagoon followed by the manure from the pit and anhydrous ammonia, respectively (Table 5). Higher plant population, and greater stover dry matter and stover moisture were observed in treatments receiving N in 1989 than those receiving in 1988 (Table 6). There was a tillage by year of N application interaction on stover dry matter and stover moisture: the stover dry matter being significantly higher in ridge till in the year of application and stover moisture was higher in the year following application of N treatments (Table 9). The stover moisture was generally higher in the treatments receiving N in 1988 than those receiving in 1989 except for the N from lagoon source where difference due to year of application was less evident (Table 8). The treatments applied with manure from the lagoon in 1989 were applied with manure from the pit source at lower rates in the previous years.

Harvest Index. The harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover combined, Table 4) was significantly affected by tillage, and the year of N application. Chisel plowing resulted in higher index than the ridge tillage and it was also higher for the treatments receiving N in 1989 than in the previous year (Table 2).

Insecticide Effects. In order to assess the effects of insecticide application, all the treatments were further split into insecticide and non-insecticide subplots. In general, the treatments receiving insecticide had significantly higher yield, stover dry matter, and total dry matter at harvest (Table 10). The stover dry matter was higher in ridge tillage than in chisel plowing in absence of insecticide. Insecticide application particularly resulted in higher quantities with chisel plowing than in ridge tillage (Table 11). The insecticide effects were most evident in treatments applied with anhydrous ammonia and manure from the lagoon (Table 12). With insecticide, the grain yield was higher in all the N treatments in chisel plowing and in treatments receiving N from the pit in ridge tillage (Table 13). A higher stand, greater grain yield, and greater total dry matter were observed for the insecticide applied treatments receiving N in 1989 (Table 14). The difference in both grain and silage yield was greater in chisel plowed treatments receiving N in 1989 than any other treatments (Table 15).

Stover N, Grain N, and N Uptake. Tillage had no significant effect on N concentration in grain and stover, and in total N uptake by corn. However, N source and year of application of biennial treatments had highly significant effect on N concentration and N uptake. Biennial application of anhydrous ammonia had higher N in grain and stover, and had higher N uptake than either manure treatments. The manure from the lagoon resulted in higher grain N than manure from pit; the stover N was however higher with manure from the pit. N uptake was not much different in either manure treatments (Table 16). Both grain N and stover N was higher in the year of N application, and N uptake was about 95 lbs/A more in the year of application than in the year following application (Tables 17 and 18).

Surface Residue Cover. Residue measurements were made on June 7, 1989 both in and between the rows in duplicate in the biennial manure and fertilizer treatments in both tillages. Residue was about 50% more in the ridge till than chisel plow (Table 19), and about 50% more in between the rows than in the rows. Residue was not different with respect to row position in the year of application of fertilized treatment while all other treatments had higher residue in between the rows in the year following their application.

Soil Profile Moisture. Gravimetric soil moisture in soil samples taken to a depth of 5 ft. at 1 ft. increment in spring and fall soil samples is given in Table 20. The soil samples were taken from selected treatments in all the four replications in and between the rows separately with 3 cores composites per sample. The moisture was slightly greater in the spring in the top 2 ft. than in the depths below. In the fall, the soil was wetter in the top 0-1 ft. increment and in bottom 4-5 ft. increment than in the middle. The profile was wetter in top 2 ft. in chisel plow than in the ridge till, and in bottom 3 ft. in ridge till than in chisel plow in the spring (Table 21). In fall, ridge till was generally wetter throughout the profile than the chisel plowed treatments. Fertilizer applied treatments were drier in the surface than manure applied or check plots (Table 23). The treatments applied with manure from the pit were drier in the bottom 4 ft. of the profile than other treatments (Table 22). The check plots were generally wetter, and had higher moisture throughout the profile than the other treatments.

Soil Profile Nitrogen. Total inorganic N and ammonium-N determinations were made on the samples taken in and between the rows separately to a depth of 5 ft. at 1 ft. increment on selected treatments. The total inorganic nitrogen in the 5 ft. soil profile was highest in treatments applied with anhydrous ammonia annually, followed by biennial application of the fertilizer, pit manure and check (Table 22). More than 2/3 of nitrogen was in ammonium form in most treatments except in treatments with pit manure applied or anhydrous in the year of application. In these two treatments, the nitrogen was about half in nitrate form.

Chisel plowed treatments had more N than ridge till with pit manure and anhydrous in the year of application (Table 24) while the difference due to tillage was not obvious in check and annual anhydrous treatments. N in ammonium form was more than in nitrate form in chisel plowed treatments with pit manure and in the ridge till with check or annual anhydrous ammonia. Nitrogen in ammonium form was more than nitrate form in the top 3 ft. depth than in the bottom 3 ft. depth. Nitrate nitrogen was more in the surface one ft. depth and bottom 2 ft. increments than in the middle of the profile (Table 25).

Ammonium form of N was more in the rows in the top 3 ft. depth; whereas, nitrate form of N was more in the row than in between the rows below the surface 1 ft. (Table 26). In general, more N was found in the form of ammonia in between the rows, and in the form of nitrate in the rows (Table 27). Total inorganic N was higher in between the rows in the surface 1 ft. increment, but in the rows in the bottom 4-5 ft. depth (Table 28). Chisel plowing had more total N in treatments with pit manure and biennial anhydrous but the tillage effect was not observed in the other treatments (Table 29). The significance values for various main effects and interactions for soil moisture and N in fall and spring are given in Table 30.

Soil Water Sampling. Suction water samplers were established during the middle of July on manure (biennial) and fertilizer (annual) treatments to monitor nitrate-nitrogen in soil water at 5 ft depth . The data obtained in 1989 are presented in Fig. 1. Among the N treatments, both fertilizer treatments yielded consistently higher nitrate-nitrogen at 5 ft depth than the biennial manure treatments. There was not much difference in the biennial treatments due to the year of N application. The ridge till system produces considerably higher nitrate levels than chisel plowing in fertilized treatments. The nitrate levels, however, were fairly uniform throughout the sampling period indicating little movement of water and N during that period.

Table 1. Cultural practices at Goodhue County, MN 1989.

Tillage	**Cropping History**
Ridge Till- cultivated on June 15, 1989	Corn since 1974
Chisel Plow- Chiseled on May 15, 1989	1989-Corn Pioneer 3906

Manure Application

Injected liquid swine manure with following rate and analysis on May 9, 1989.

		Rate of Application (1989)			
		Pit Source		Lagoon Source	
		Mean	Std. Dev.	Mean	Std. Dev.
Manure	(gal/A)	12000	1000	13000	700
Total-N	(lbs/A)	160	33	143	27
NH_4-N	(lbs/A)	106	15	95	20
K	(lbs/A)	76	14	127	20
Solids: Total	(%)	7	6	0.9	0.2
Volatile	(%)	68	4	49	6
Fixed	(%)	32	4	51	6

Planting Information

A six row Deustch Alis planter equipped with wide clearing disks in 1989.

Crop	Date	Rate	Harvested
Corn	May 16,1989	32,000 plants/A	October 11-12, 1989

Fertilizer

Material Analysis	Actual N -lb/A-	Date Applied	Method of Application
82-0-0	170	May 17, 1989	Injected

Soil

Seaton silt loam (Typic Hapludalfs, fine-silty, mixed, mesic), Mt. Carroll silt loam (Mollic Hapludalfs, fine-silty, mixed, mesic) and a Port Byron silt loam (Typic Hapludolls, fine-silty, mixed, mesic).

Insect Control

9 lbs/A (1.35 lb/A) Counter 15G applied in furrow on May 16, 1989.

Table 2. The effect of tillage and N source on corn grain yield, grain moisture and total dry matter in Goodhue Co., MN in 1989.[1]

		GRAIN YIELD			GRAIN MOISTURE			TOTAL DRY MATTER		
		Ridge	Chisel	Mean	Ridge	Chisel	Mean	Ridge	Chisel	Mean
Source of N	Year[2]	-----	bu/A	-----	-------	%	-------	-----	tons/A	----
Manure	Yr.of	131	129	130	21.7	20.4	21.1	5.99	5.49	5.74
(Pit)	Yr.after	77	93	85	21.1	20.8	21.0	3.67	4.30	3.98
	Mean	104	111	108	21.4	20.6	21.0	4.83	4.90	4.87
Manure	Yr.of	125	120	123	22.1	20.6	21.4	5.94	5.22	5.58
(Lagoon)	Yr.after	87	94	91	21.3	21.9	21.6	4.24	4.27	4.26
	Mean	106	107	107	21.7	21.3	21.5	5.09	4.75	4.92
Anhydrous	Yr.of	142	153	148	24.1	21.2	22.7	6.39	6.80	6.60
Ammonia	Yr.after	102	131	117	21.9	21.1	21.5	4.76	5.56	5.16
	Mean	122	142	133	23.0	21.2	22.1	5.58	6.18	5.88

	Pr>F						
	Tillage(T)	N Source(N)	Year(Y)	T*N	T*Y	Y*N	Y*N*T
Grain Yield	.121	.000	.000	.082	.149	.468	.957
Grain moisture	.162	.151	.449	.392	.080	.411	.816
Total dry matter	.819	.007	.000	.297	.098	.700	.779

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[1] Averaged over insecticide treatments.

[2] Year refers to the year of application of the biennial treatments.

Table 3. The effect of tillage and N source on corn plant population at harvest, stover dry matter, and stover moisture at harvest in Goodhue Co., MN in 1989[1].

		PLANT POPULATION			STOVER DRY MATTER			STOVER MOISTURE		
		Ridge	Chisel	Mean	Ridge	Chisel	Mean	Ridge	Chisel	Mean
Source of N	Year[2]	- plants/A*10^{-3} -			-----	tons/A	----	--------	%	------
Manure	Yr.of	26.7	26.0	26.4	2.86	2.44	2.65	49.4	49.5	49.5
(Pit)	Yr.after	24.1	23.8	24.0	1.81	2.09	1.95	51.7	50.5	51.1
	Mean	25.4	24.9	25.2	2.33	2.27	2.30	50.6	50.0	50.3
Manure	Yr.of	26.0	26.9	26.5	2.94	2.41	2.68	52.9	53.9	53.4
(Lagoon)	Yr.after	26.2	25.2	25.7	2.13	2.05	2.09	54.9	52.1	53.5
	Mean	26.1	26.1	26.1	2.54	2.23	2.39	53.9	53.0	53.5
Anhydrous	Yr.of	27.8	26.4	27.1	3.04	3.12	3.08	42.7	48.3	46.2
Ammonia	Yr.after	25.0	27.7	26.4	2.39	2.51	2.45	49.7	49.9	49.8
	Mean	26.4	27.1	26.8	2.72	2.82	2.77	46.2	49.1	48.0

	Pr>F						
	Tillage(T)	N Source(N)	Year(Y)	T*N	T*Y	Y*N	Y*N*T
Population	.900	.120	.007	.743	.319	.200	.014
Stover dry matter	.730	.008	.000	.332	.049	.887	.364
Stover moisture	.623	.001	.006	.222	.015	.048	.414

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[1] Averaged over insecticide treatments.

[2] Year refers to the year of application of the biennial treatments.

Table 4. Corn harvest index as affected by tillage, and N source in Goodhue Co., MN in 1989.

Source of N	Year[2]	HARVEST INDEX[1] Ridge	 Chisel	 Mean
Manure	Yr.of	0.52	0.56	0.54
(Pit)	Yr.after	0.50	0.51	0.51
	Mean	0.51	0.54	0.52
Manure	Yr.of	0.50	0.53	0.52
(lagoon)	Yr.after	0.50	0.52	0.51
	Mean	0.50	0.53	0.51
Anhydrous	Yr.of	0.52	0.54	0.53
Ammonia	Yr.after	0.49	0.55	0.52
	Mean	0.51	0.55	0.53

Source	Pr>F
Tillage (T)	.052
N source (N)	.480
Year (Y)	.010
T*N	.712
T*Y	.833
Y*N	.411
Y*N*T	.201

[1] Averaged over insecticide treatments.
[2] Year refers to the year of application of the biennial treatments.

Table 5. The effect of N source on corn grain yield, stover dry matter, stover moisture, and total dry matter at harvest in Goodhue Co., MN in 1989[1].

Source of N	GRAIN YIELD ---bu/A---	STOVER MOISTURE ----%----	TOTAL DRY MATTER -----tons/A----	STOVER DRY MATTER ------tons/A----
Manure (Pit)	108	50.3	4.86	2.30
Anhydrous	132	47.7	5.87	2.76
Manure (Lagoon)	107	53.5	4.92	2.38
Pr>F (N Source)	.000	.001	.007	.008

[1] Averaged over tillage, insecticide, and year of application of N treatments.

Table 6. The effect of year of N application on corn grain yield, stover dry matter, stover moisture, total dry matter, and plant population at harvest in Goodhue Co., MN in 1989[1].

Year[2]	GRAIN YIELD ---bu/A---	STOVER MOISTURE -------%-------	TOTAL DRY MATTER -----tons/A-----	STOVER DRY MATTER ------tons/A----	PLANT POPULATION -Plants/A*10^{-3} -
Year of	133.4	49.5	5.97	2.81	26.6
Year After	97.5	51.4	4.46	2.16	25.4
Pr>F (Year)	.000	.006	.000	.000	.007

[1] Averaged over tillage, insecticide, and biennial N treatments.
[2] Year refers to the year of application of the biennial treatments.

Table 7. The effect of tillage and N source on corn grain yield in Goodhue Co., MN, in 1989.

Source of N	GRAIN YIELD[1] Ridge Till	 Chisel Plow
	-----------bu/A	---------
Manure (Pit)	104.8	110.8
Anhydrous Ammonia	121.8	142.4
Manure (Lagoon)	106.2	106.9
Pr>F (N Source)	.082	

[1] Averaged over tillage and year of application.

Table 8. The effect of source and year of N application on stover moisture in Goodhue Co., MN in 1989.

Source of N	STOVER MOISTURE[1] ---------% Yr Of[2]	 -------- Yr Aft.
Manure (Pit)	49.4	51.1
Anhydrous	45.6	49.8
Manure (Lagoon)	53.4	53.5
Pr>F (N Source*Year)	.001	

[1]Means of tillage and insecticide treatments. [2] Year of application of the biennial treatments.

Table 9. The effect of tillage and year of N application on corn grain moisture, stover dry matter, stover moisture, and total dry matter at harvest in Goodhue Co., MN in 1989[1].

	GRAIN MOISTURE		STOVER DRY MATTER		STOVER MOISTURE		TOTAL DRY MATTER	
	Ridge	Chisel	Ridge	Chisel	Ridge	Chisel	Ridge	Chisel
Year[2]	------%------		---- tons/A ----		------ % -----		--- tons/A ---	
Yr.of	22.6	20.8	2.95	2.66	48.4	50.6	6.11	5.84
Yr.after	21.4	21.2	2.11	2.22	52.1	50.9	4.22	4.71
Pr>F (Till*Year)	.080		.049		.015		.098	

---

[1] Means of biennial N treatments. [2] Year refers to the year of application of the biennial treatments.

Table 10. The effect of insecticide application on corn grain yield, stover dry matter, and total dry matter at harvest in Goodhue Co., MN in 1989[1].

	GRAIN YIELD	STOVER DRY MATTER	TOTAL DRY MATTER
Insecticide	---bu/A---	----- tons/A ----	----- tons/A ----
Yes	120	2.58	5.42
No	111	2.38	5.02
Pr>F (Insect.)	.001	.005	.002

---

[1] Means of all biennial N, insecticide and tillage treatments.

Table 11. The effect of tillage and insecticide application on corn grain yield, stover dry matter, and total dry matter at harvest in Goodhue Co., MN in 1989[1].

		GRAIN YIELD	STOVER DRY MATTER	TOTAL DRY MATTER
Tillage	Insect.	----bu/A---	----- tons/A -----	----- tons/A ----
Ridge	Yes	113	2.57	5.21
	No	109	2.49	5.13
Chisel	Yes	126	2.60	5.62
	No	114	2.28	4.92
Pr>F (Till*Insect.)		.091	.077	.014

---

[1] Means of all biennial N and insecticide treatments.

Table 12. The effect of N source and insecticide application on corn grain yield, stover dry matter, and total dry matter at harvest in Goodhue Co., MN in 1989[1].

		GRAIN YIELD	STOVER DRY MATTER	TOTAL DRY MATTER
Source of N	Insect.	------bu/A----	----- tons/A ---- -	----- tons/A ----
Manure(Pit)	Yes	108	2.33	4.91
	No	108	2.27	4.81
Anhydrous	Yes	136	2.80	5.93
	No	129	2.74	5.82
Manure(Lagoon)	Yes	115	2.62	5.40
	No	98	2.15	4.44
Pr>F (N source*Insect.)		.014	.027	.007

---

[1] Means of all the tillage treatments.

Table 13. The effect of tillage, N source and insecticide application on corn grain yield, stover dry matter, and total dry matter at harvest in Goodhue Co., MN in 1989[1].

Source of N	Insect.	GRAIN YIELD Ridge	 Chisel	STOVER DRY MATTER Ridge	 Chisel	TOTAL DRY MATTER Ridge	 Chisel
		-----bu/A-----		----- tons/A ----		-----tons/A ----	
Manure(Pit)	Yes	98.0	117.8	2.21	2.46	4.50	5.32
	No	111.9	103.9	2.46	2.07	5.16	4.46
Anhydrous	Yes	126.2	145.2	2.71	2.89	5.61	6.25
	No	117.5	139.7	2.73	2.75	5.54	5.10
Lagoon	Yes	114.8	115.5	2.78	2.46	5.51	5.29
	No	97.5	98.3	2.29	2.01	4.68	4.20
Pr>F (Till*N source*Insect.)		.018		.149		.038	

---

[1] Means of tillage, and year of application.

Table 14. The effect of year of N and insecticide application on corn grain yield, plant population, grain moisture, and total dry matter at harvest in Goodhue Co., MN in 1989[1].

Year[2]	Insect.	GRAIN YIELD ----bu/A---	PLANT POPULATION - plants/A*10^{-3} -	TOTAL DRY MATTER ----- tons/A ----	GRAIN MOISTURE ------%-------
Year of	Yes	140.1	27.3	6.31	21.4
	No	126.8	26.0	5.64	21.9
Year after	Yes	99.1	25.2	4.52	21.5
	No	95.9	25.5	4.41	21.1
Pr>F (Year*Insect.)		.032	.034	.028	.056

---

[1] Means of tillage, and year of application.

[2] Year refers to the year of application of the biennial treatments.

Table 15. The effect of tillage, year of N and insecticide application on corn grain yield and stover dry matter at harvest in Goodhue Co., MN in 1989[1].

Year[2]	Insect.	GRAIN YIELD Ridge	 Chisel	STOVER DRY MATTER Ridge	 Chisel
		----bu/A-----		---- tons/A ----	
Year of	Yes	137.3	142.9	2.95	2.96
	No	128.2	125.4	2.95	2.36
Year after	Yes	88.8	109.4	2.18	2.25
	No	89.2	102.5	2.03	2.19
Pr>F (Till*Year*Insect.)		.091		.016	

---

[1] Means of all biennial N treatments.

[2] Year refers to the year of application of the biennial treatments.

Table 16. The effect of N source on corn grain and stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Source of N	GRAIN N	STOVER N	TOTAL N UPTAKE
	---%---	----%----	----lbs/A----
Manure(Pit)	1.048	.495	88.16
Anhydrous	1.369	.639	125.03
Manure(Lagoon)	1.108	.431	87.98
Pr>F (N source)	.002	.000	.001

---

[1] Means of tillage, and year of N application.

Table 17. The effect of the year of N application on corn grain and stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Year[2]	GRAIN N	STOVER N	TOTAL N UPTAKE
	---%---	---%----	----lbs/A-
Year of	1.314	.588	125.70
Year After	1.036	.458	74.39
Pr>F (Year)	.000	.000	.000

---

[1]Means of tillage and biennial N treatments. [2] Year of application of biennial treatments.

Table 18. The effect of the year of N application on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Source of N	Year[2]	GRAIN N ---%---	STOVER N ----%----	TOTAL N UPTAKE ---lbs/A----
Manure	Yr.of	1.150	.439	103.89
(lagoon)	Yr.after	1.066	.424	72.08
Manure	Yr.of	1.240	.537	109.95
(Pit)	Yr.after	0.855	.438	58.46
Anhydrous	Yr.of	1.553	.766	159.54
Ammonia	Yr.after	1.186	.504	88.22
Pr>F (N Source*Year)		.027	.000	.005

---

[1] Averaged over tillage, and insecticide treatments.
[2] Year refers to the year of application of the biennial treatments.

Table 19. Corn residue as affected by N source and year of application in Goodhue Co., MN on 6/7/89[1].

		Residue (%)			
		Ridge		Chisel	
Source of N	Row	Yr Of[2]	Yr Aft	Yr Of	Yr Aft
Manure	In	39	55	18	23
(Pit)	Bet.	60	64	32	37
Manure	In	41	46	18	17
(lagoon)	Bet.	63	49	54	39
Anhydrous	In	58	39	52	22
Ammonia	Bet.	60	63	51	63

Pr>F

Till(T)	N Sour.(N)	Year(Y)	T*N	T*Y	Y*N	Y*N*T	Row(R)	T*R	N*R	Y*R	T*Y*R	T*N*R	N*Y*R	T*N*Y*R
.082	.130	.505	.242	.604	.121	.963	.0001	.171	.635	.582	.272	.421	.001	.844

---

[1] Residue counts made on insecticide applied treatments.
[2] Yr refers to the year of application of the biennial treatment.

Table 20. Gravimetric soil moisture by depth in Goodhue Co., MN in 1989[1].

Depth (ft.)	Moisture(%,wt./wt.) April 24-25	 November 2-9
0-1	25.0	22.0
1-2	24.8	20.9
2-3	21.5	20.0
3-4	20.8	20.8
4-5	21.3	22.7
Pr>F (Depth)	.000	.000

Table 21. Gravimetric soil moisture by tillage and depth in Goodhue Co., MN[1].

Depth (ft.)	Moisture(%,wt./wt.)			
	April 24-25		November 2-9	
	Ridge	Chisel	Ridge	Chisel
0-1	24.9	25.2	22.1	21.8
1-2	24.6	25.0	20.5	21.2
2-3	21.8	21.3	20.3	19.8
3-4	21.9	19.8	21.7	20.0
4-5	21.9	20.6	22.6	22.8
Pr>F (Till*Depth)	.023		.006	

---

[1] N treatments sampled are listed in Table 22.

Table 22. The effect of the year of N application inorganic nitrogen in the top 5′ soil profile in Goodhue Co., MN on April 24-25, 1989.

Source of N	Year[1]	TOTAL N	NH_4-N	NO_3-N
		------------	lbs/A	--------
Manure(Pit)	Year of	63.2	42.2	21.0
Check	Annual	60.9	43.7	17.2
Anhydr. amm.	Annual	68.8	50.9	16.9
Anhydr. amm.	Year of	64.4	44.0	20.4
Pr>F (N source)		.059	.152	.729

---

[1] Year refers to the year of application of the biennial treatment, the samples taken in insecticide applied plots only.

Table 23. The effect of N source and frequency on soil moisture in Goodhue Co., MN on November 2-9, 1989.

Source of N	Year[1]	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.
		-----------moisture(%, wt./wt.)				-------------
Manure (Pit)	Yr.of	22.0	19.3	18.9	20.9	23.2
Anhydrous Ammonia	Yr.of	21.6	20.2	20.2	21.0	23.3
Anhydrous Ammonia	Yr.after	22.6	20.8	19.6	21.2	22.6
Anhydrous Ammonia	Annual	21.4	21.4	19.7	20.8	22.0
Check	Annual	22.2	22.5	21.7	20.3	22.3
Pr>F (N Source*Depth)				.0024		

---

[1] Year application of the biennial treatments, the means are across the tillages, and in treatments applied with insecticides.

Table 24. The effect of tillage and the year of N application on inorganic N in the top 5′ soil profile in Goodhue Co., MN on April 24-25, 1989.

Frequency & Source of N	Year[1]	TOTAL N Rdge	TOTAL N Chsel	NH_4-N Rdge	NH_4-N Chsel	NO_3-N Rdge	NO_3-N Chsel
		----------------------		------lbs/A		----------	
Manure(Pit)	Year of	62.5	64.5	39.5	45.0	23.0	19.0
Check	Annual	61.5	60.5	49.0	38.5	12.5	22.0
Anhydr. amm.	Annual	69.0	68.0	50.5	51.5	18.5	15.5
Anhydr. amm.	Year of	61.0	67.5	48.5	39.5	12.5	28.5
Pr>F (Till*N Source)		.425			.137		.041

Table 25. The inorganic nitrogen by depth in the top 5′ soil profile in Goodhue Co., MN on 4/24-25/1989

Depth (ft.)	TOTAL N	NH_4-N	NO_3-N
	------------	lbs/A	----------
0-1	14.0	10.2	3.8
1-2	12.6	9.5	3.2
2-3	13.4	10.3	3.0
3-4	11.8	7.8	3.9
4-5	12.5	7.4	4.9
Pr>F (Depth)	.001	.000	.167

---

[1] Year of application of the biennial treatment (1988 = year of); samples taken in insecticide applied treatments, and averaged over the row position.

Table 26. The inorganic nitrogen by depth and row position in the top 5′ soil profile in Goodhue Co., MN on April 24-25, 1989[1].

Depth (ft.)	Row Position	TOTAL N	NH_4-N	NO_3-N
		----------	lbs/A	---------
0-1	In	12.8	9.4	3.4
	Bet.	15.2	11.0	4.2
1-2	In	12.5	8.3	4.2
	Bet.	12.7	10.6	2.2
2-3	In	13.0	9.7	3.3
	Bet.	13.8	11.0	2.8
3-4	In	11.8	8.2	3.6
	Bet.	11.8	7.5	4.3
4-5	In	13.6	7.5	6.1
	Bet.	11.5	7.3	3.8
Pr>F (Depth*Row)		.001	.338	.215

---

[1] Averaged over tillages and selected N treatments (Table 24) with insecticide.

Table 27. The inorganic nitrogen by row position in the top 5' soil profile in Goodhue Co., MN on April 24-25, 1989[1].

Row Position	TOTAL N	NH_4-N	NO_3-N
	lbs/A		
In Row	63.5	43.0	20.5
Bet. Row	65.0	47.5	17.5
Pr>F (Row)	.440	.110	.251

[1] Averaged over tillages, selected N treatments (Table 24) with insecticide.

Table 28. The total inorganic nitrogen by depth and row position in the top 5' soil profile in Goodhue Co., MN on April 24-25, 1989[1].

Depth (ft.)	TOTAL N (lb/A) In Row	TOTAL N (lb/A) Bet. Row
0-1	12.8	15.2
1-2	12.5	12.7
2-3	13.0	13.8
3-4	11.8	11.8
4-5	13.6	11.5
Pr>F (Depth*Row)	.079	

[1] Averaged over tillages, selected N treatments (Table 24) with insecticide.

Table 29. Total inorganic N by tillage N source and depth in the top 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989[1].

		Total inorg. N (lb/A)					
N source	Tillage	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.	0-5 ft.
Manure(pit, yr of)[2]	Ridge	14.0	13.4	12.1	11.7	11.3	62.5
	Chisel	12.1	12.4	14.6	12.4	12.8	64.3
Check (annual)	Ridge	13.7	11.6	14.3	11.5	10.3	61.4
	Chisel	11.9	13.6	12.0	12.1	10.8	60.4
Anhy. (annual)	Ridge	15.2	11.7	12.2	13.1	16.7	68.9
	Chisel	15.4	13.1	14.8	10.8	14.0	68.1
Anhy. (yr of, 88)	Ridge	13.9	12.4	11.7	11.5	11.8	61.3
	Chisel	16.0	12.8	15.2	11.2	12.7	67.8
Pr>F (Till*N source*Depth)				.0788			

[1] Averaged over the row position.

[2] Manure applied in the spring of 1988 (yr of).

Table 30 . Significance table for spring and soil moisture, and spring soil N.

	Till(T)	N Source(N)	T*N	Row(R)	T*R	N*R	T*N*R	Depth(D)	T*D	N*D	T*N*D	R*D	T*R*D	N*R*D	T*N*R*D
Soil moisture															
Spring	.639	.583	.596	.317	.404	.937	.773	.000	.023	.656	.485	.982	.937	.988	.959
Fall	.758	.776	.408	.302	.528	.991	.981	.000	.006	.002	.123	.923	.602	.996	.997
Spring N	.520	.059	.425	.440	.594	.525	.441	.001	.355	.079	.079	.001	.342	.006	.917
NH_4-N	.661	.152	.137	.111	.500	.171	.205	.000	.987	.893	.704	.338	.306	.516	.337
NO_3-N	.591	.729	.104	.251	.398	.334	.686	.167	.637	.733	.832	.215	.408	.100	.431

FIG. 1: WATER ANALYSIS FROM NORDS FARM, 1989

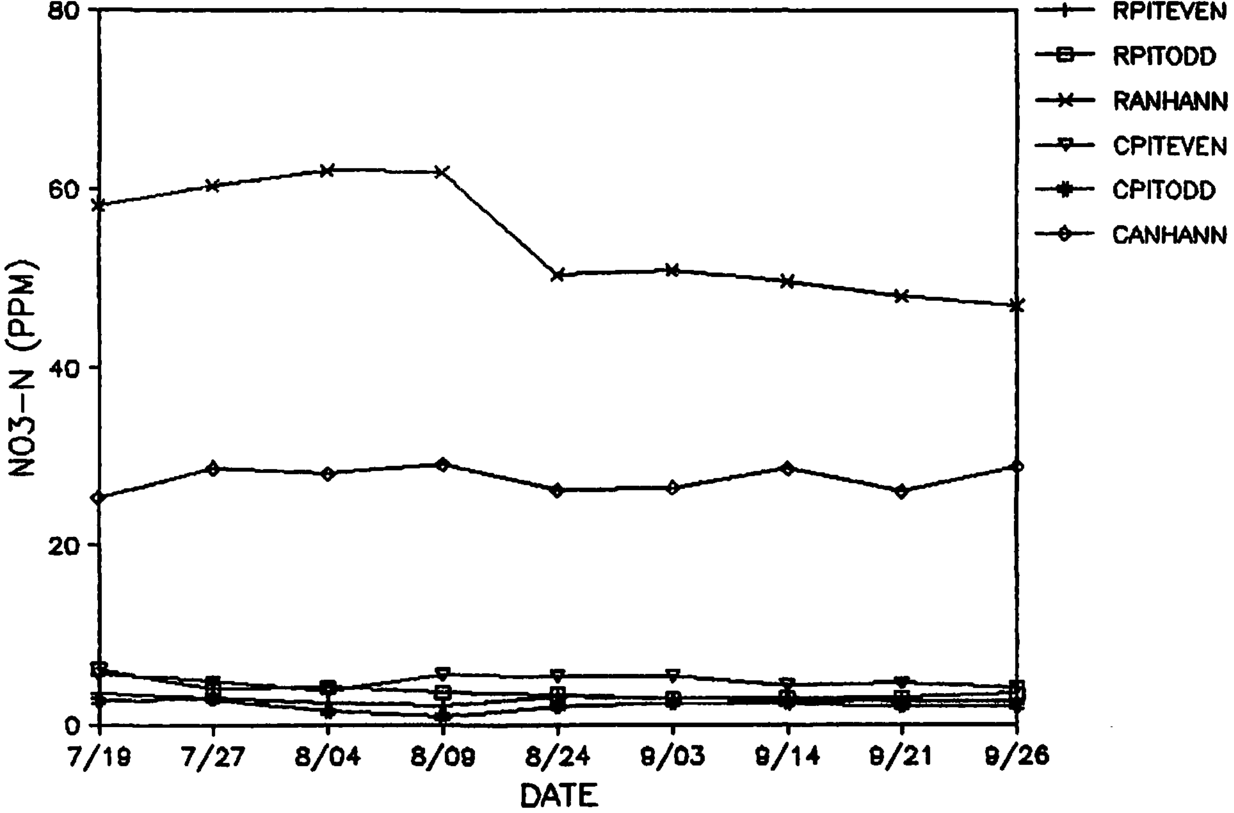


FIG. 2. EFFECT OF TILLAGE AND SOIL DEPTH
ON SOIL WATER ON APRIL 24–25, 1989, NORD FARM

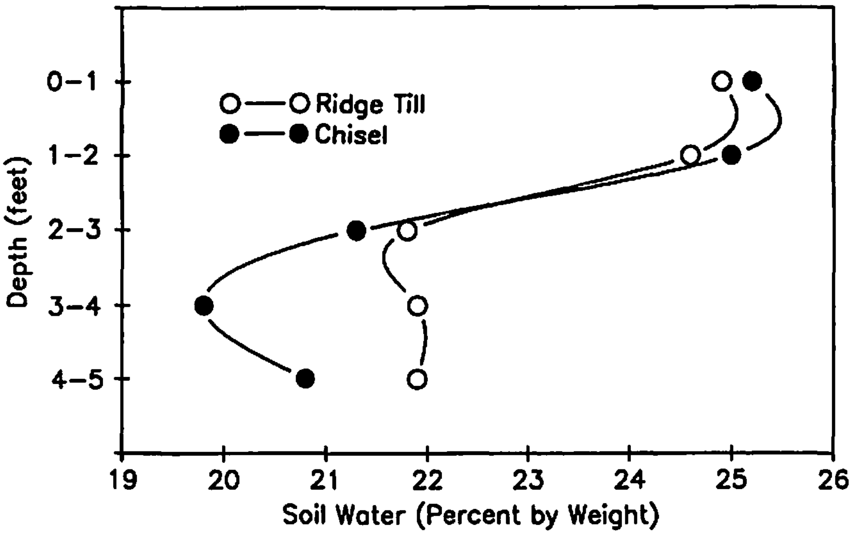
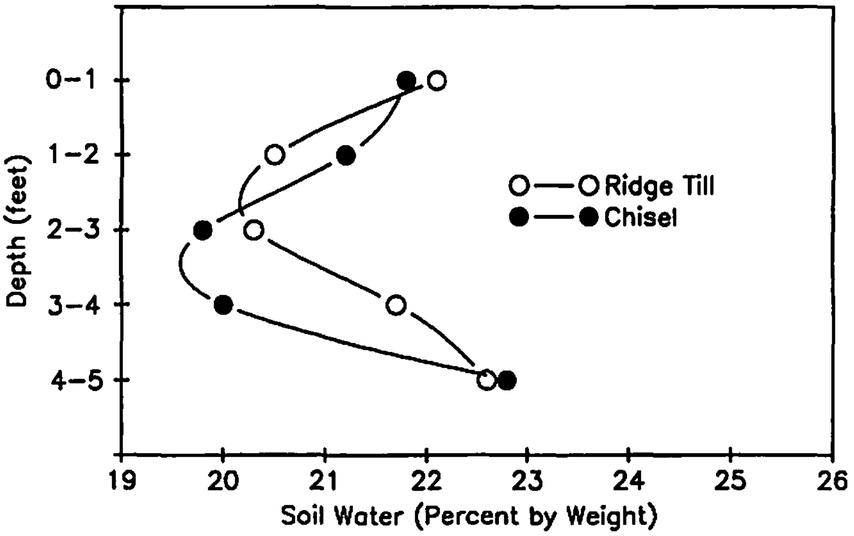


FIG. 3. EFFECT OF TILLAGE AND SOIL DEPTH
ON SOIL WATER ON NOVEMBER 2–7, 1989, NORD FARM



Tillage System Effects on Corn and Soybean Growth and Yield on a Well Drained Silt Loam Soil[1]

J.F. Moncrief, T.L. Wagar and J.J. Kuznia[2]

Tillage was evaluated for corn and soybean production on a well drained silt loam soil for a sixth year. Corn and soybean yields were lower with ridge till and no till systems. This is the first time tillage has reduced corn yields. Soybean yield reductions appeared to be related to stand establishment with ridge tillage and increased density of velvet leaf under no till conditions.

This study is in it's sixth year. The purpose is to evaluate tillage system effects corn and soybean growth and yield. The soil at this site was developed in loess and is well drained.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications for both corn and soybeans. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with a six row head.

Results and Discussion

Soil cover by soybean and corn residue is shown in table 4 and 5 respectively. Soil cover by corn reside ranged from 8 to 80%. Soil cover by soybean residue ranged from 10 to 56%. Although corn stands were not affected by tillage early growth was delayed when "in row" cover was greater than 20% (table 6). Similarly soybean stands were not affected by tillage but early growth was delayed when "in row" cover was greater than 20% (table 7). The planter at this site did not have row cleaning tillage tools. Early growth of both corn and soybeans was delayed due to inadequate removal of crop residue in the row area.

Grain yields were affected by tillage system for both corn and soybeans (tables 8 and 9). Chisel plowing and spring discing resulted in higher yields. Stands were inadequate with the ridge till soybeans. Both no till and ridge till plots had velvet leaf at harvest that was not present in the other two systems. The authors do not have an explanation for the reduction in corn yields with these two systems. This is the only year of the six that tillage affected corn yields.

WABASHA COUNTY

Table 1. Cultural practices for Wabasha County, MN in 1989.

Tillage
- No Till
- Ridge Till
- Spring Disc-seedbed prepared with a field cultivator on May 10, 1989.
- Chisel Plow-seedbed prepared with a field cultivator on May 10, 1989.

All corn plots except no till were cultivated June 24, 1989.
Corn was ridged on June 28, 1989.

Cropping History
- 1983-Sweet Clover
- 1984-1988 Corn-Soybean rotation

Crops 1989
- Corn-Pioneer 3737
- Soybeans-Pioneer 1677

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[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Wabasha County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, SWCD, MES field staff. Without their assistance this project would have not 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. Tim L. Wagar is an area Crops and Soils Extension Agent stationed at Rochester, MN.*

Planting and Harvest Date

The planter used on all corn plots and ridge till soybean plots was a John Deere Maxemerge six row 30" row spacing planter equipped with 2" fluted coulters. The planter used on no till, spring disc, and chisel plow soybean plots was a Kinze No Till Drill with 10" row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 10, 1989	28,000 plants/A	October 24, 1989
Soybeans	May 23, 1989	205,000 plants/A	October 24, 1989

Fertilization History For Corn

Material Analysis	Rate	Actual N	 P_2O_5	 K_2O	Date Applied
		---	lbs/A	----	
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
5-14-42[1]	95 lbs/A	5	13	40	May 5, 1988
2-0-0	183 lbs/A	150	0	0	April 22, 1988

1. Nitrogen was not applied to chisel plowed plots in 1984.
2. Placement 2" beside and 2" below seed.

Fertilizer Applied to Corn in 1989

Material Analysis	Rate	Actual N	 P_2O_5	 K_2O	Date Applied
		--	lbs/A	---	
6-15-40[1]	110 lbs/A	7	17	44	May 10, 1989
82-0-0	159 lbs/A	130	0	0	Spring Pre-plant

1. Placement 2" beside and 2" below seed.

Soil

Fayette silt loam (Typic Hapludalfs, fine-silty, mixed, mesic).

Weed Control

Corn

2 qt/A (2 lbs/A) Lasso + 2 qt/A (2 lbs/A) Bladex broadcast with the planter on May 10, 1989.

Soybeans

1 qt/A (.75 lb/A) Roundup + .5 pt/A (.25 lb/A) 2,4-D May 23, 1989.

1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on June 13, 1989.

1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 3 qt/A 28% on June 22, 1989.

Velvetleaf was present in visually significant amounts in the no till and ridge till soybean plots at harvest.

Soil Test

Table 2. Soil test results for corn to be planted following soybeans on April 16, 1987.

		Tillage				
Nutrient	Sig. of Tillage	No Till	Disc	Ridge	Chisel	Avg
		--------		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				
Nutrient	Sig. of Tillage	No Till	Disc	Ridge	Chisel	Avg
		--------		lbs/A		-------------
P	(.602)	62	66	67	60	64
K	(.075)	215	187	200	177	195

Table 4. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Wabasha Co. on June 16, 1989[1].

	Tillage				
	NoTill	Disc	Ridge	Chisel	
Location	% cover				Avg.
In Row	55.8a	6.3c	25.5b	12.0c	24.9
Between Row	56.0a	6.0c	43.8b	10.8c	29.1
Average	55.9a	6.1c	34.6b	11.4c	

1. The p value for residue location, tillage, and tillage by location interaction are .080 (n=64), .001 (n=32), .013 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage and position relative to the row on soil covered by corn residue in soybeans at Wabasha Co. on June 16, 1989[1].

	Tillage				
	NoTill	Disc	Ridge	Chisel	
Location	% cover				Avg.
In Row	82.3a	17.0c	48.5b	8.3d	35.8
Between Row	80.8a	12.8c	66.8b	10.0c	34.5
Average	81.5a	14.9c	57.6b	9.1c	

1. The p value for residue location, tillage, and tillage by location interaction are .090 (n=48), .001 (n=32), .018 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage on corn population and early growth at in Wabasha Co.

	Tillage				
	NoTill	Disc	Ridge	Chisel	
	plants/A X 10^{-3}				Sig.
6/16/89	30.3a[1]	28.9a	31.3a	30.2a	.183
(n=16)	leaves/plant				
6/22/89	4.7c	5.3a	4.9b	5.3a	.001
(n=80)					

1. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage on soybean population and early growth at Wabasha Co.

	Tillage				
	NoTill	Disc	Ridge[2]	Chisel	
	plants/A X 10^{-3}				Sig.
6/16/89	154.9a[1]	141.9a	61.8	141.9a	.556
(n=12)	nodes/plant				
6/22/89	2.1b	2.2b	1.9c	2.4a	.001
(n=80)					

1. Means within the same row with the same letter are not significantly different (α=.10).
2. The ridge till treatment was excluded from statistical analysis of population because a different planter was used.

Table 8. Effect of tillage on corn yields and moisture at Wabasha Co. on October 24, 1989[1].

	Tillage				
	NoTill	Disc	Ridge	Chisel	
	bu/A				Sig.
Grain Yield	158b	173a	160b	172a	.005
	%				
Moisture	14.0a	14.2a	14.4a	14.2a	.972

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 9. Effect of tillage on soybean yields and moisture at Wabasha Co. on October 24, 1989[1].

	Tillage				
	NoTill	Disc	Ridge	Chisel	
	bu/A				Sig.
Grain Yield	44b	47a	39b	47a	.020
	%				
Moisture	7.2a	7.4a	7.2a	8.7a	.338

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Tillage System, Applied Nitrogen, and Cultivation Effects on Corn Growth and Yield on a Well Drained Silt Loam Soil Following Alfalfa[1]

J.F. Moncrief, T.L. Wagar and J.J. Kuznia[2]

Tillage and cultivation were evaluated on the nitrogen response by second year of corn grown after alfalfa. Grain yields were reduced under no till condition but two other conservation tillage systems resulted in similar grain yields to those with moldboard plowing. Conservation tillage reduced nitrogen uptake by corn. There was an average cultivation response due mainly to Woolly Cupgrass control of 25 bushels per acre.

This study is in it's second of corn following alfalfa. The purpose is to evaluate tillage system interactions and row cultivation on corn growth and yield as well as changes in weed density. Also of interest is the effect of tillage on the amount of nitrogen available following alfalfa. The soil at this site was developed in loess and is well drained.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications. Each main tillage plot is split with four N rates which are further split with row cultivation. Nitrogen was applied as broadcast urea on April 29, 1989. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each nitrogen subplot. Weed measurements were made by visually estimating the amount of cover by weeds by species and assigning ratings based on a 1 to 5 range with: 1=<15%, 3=15-25%, 4=25-50%, 5=50-75%, and 6=>75%. Grain and stover yields were estimated by hand harvesting grain and chopping stover in two 15 ft. rows. Subsamples were taken for moisture and nitrogen analysis.

Results and Discussion

Soil cover by corn residue is shown in tables 2 and 3. Soil cover by corn residue before cultivation in the row ranged from 2 to 33%. Soil cover by residue between the row before cultivation ranged from 4 to 55%. Cultivation reduced cover 10% to 20% in conservation tillage treatments (table 3).

Soil cover in the row by corn residue was correlated with reduced early growth. Differences were small when soil cover in the row was less than 25% (table 4). Growth was reduced .8 leaves with 33% soil cover in the row under no till conditions. Cultivation also reduced growth slightly (.09 leaf).

Although corn stand establishment was affected by tillage (July 5, table 5), they were not affected by cultivation. Stands later at harvest (Oct. 3, table 17) were further reduced under no till conditions.

The major weed present at this site is Woolly Cupgrass. Conservation tillage options increased the density of this weed (table 7). Bromegrass was limited to the no till plots (table 10). Bromegrass showed a small but significant response to applied nitrogen (table 8). Yellow nutsedge was the only weed present that was reduced due to cultivation the year before (table 9). Moldboard plowing reduced foxtail densities over other tillage systems. Woolly Cupgrass was higher under no till conditions(table 13). Woolly Cupgrass responded the most to cultivation (table 14). Foxtail was reduced more due to cultivation under conservation tillage systems (table 16). Woolly Cupgrass responded similarly to cultivation under all tillage systems.

Grain yields were reduced in corn grown with a no till system (table 17). Grain moisture was increased with this system. This reflects the influence of soil cover in the row. Nitrogen had a small but statistically significant affect on grain moisture also (table 18, 1.5%). Corn responded to 75 lbs/acre of applied N. The average yield and stand response to cultivation was 25 bu/acre and 2.6 thousand plants per acre respectively (table 19).

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[1] *This project is supported by the U.S. Fish and Wildlife Service, the Soil Conservation Service, the Minnesota Extension Service, and the Winona County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by MES, SCS, and SWCD field staff. Without their assistance this project would have not 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. Tim L. Wagar is an area Crops and Soils Extension Agent stationed at Rochester, MN.*

Tillage affected nitrogen uptake by grain and stover (table 20). Nitrogen uptake generally increased with increasing tillage. Cultivation also increased N uptake by corn (table 22). Without cultivation corn grain yield responded to higher levels of applied nitrogen (table 23). This was also true of total nitrogen uptake (table 24).

In the spring of the year soil water levels were higher with the no till system (table 25). It appears that there was more consumption of soil water with the moldboard plowing system which resulted in lower levels of soil water in the fall (table 25). Differences in soil water in the fall due to tillage in the fall were below two feet.

WINONA COUNTY

Table 1. Cultural practices at Winona County, MN. 1989.

Tillage

No Till
Spring Disc-May 8,1989
Spring Chisel Plowed-May 8, 1989
Spring Moldboard Plowed-May 8, 1989
All plots were split with cultivation on June 28, 1989.

Planting Information for 1989 Crop Year

A two row Hiniker Series 1 EconoTill planter with 30" row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 9, 1989	32,000 plants/A	October 2, 1989

Cropping History

1979-81 Alfalfa, 1982-83 Corn,
1984 Oats and Alfalfa,
1985-87 Alfalfa, 1988 Corn

Manure History

20 loads of solid dairy manure (300 bu. spreader) in 1980, 1982, & 1983

1989 Crop

Corn Pioneer 3737

Fertilizer 1988

			Actual						
	Material		N	P_2O_5	K_2O	S	Zn		
Crop	Analysis	Rate	lbs/A					Date Applied	Method of Application
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

Fertilizer 1989

			Actual				
	Material		N	P_2O_5	K_2O		
Crop	Analysis	Rate	lbs/A			Date Applied	Method of Application
Corn	7-21-7	15 gals/A	11	33	11	May 9, 1989	Starter 2" x 2" with planter
	46-0-0	65 lbs/A	33	0	0	May 8, 1989	Broadcast
	46-0-0	130 lbs/A	64	0	0	May 8, 1989	Broadcast
	46-0-0	196 lbs/A	89	0	0	May 8, 1989	Broadcast

Soil

Seaton silt loam (Typic Hapludalfs, fine-silty, mixed, mesic), 3-6% slope, soil is well drained.

Weed Control

3 pt/A (1.5 lb/A) Prowl + 2 lb/A (1.8 lb/A) Bladex 90 DF applied on May 23, 1989.
1 pt/A (.5 lb/A) Banvel applied on June 13, 1989.
Main tillage plots were split with cultivation on June 28, 1989.

Insect Control

6.4 lbs/A (.96 lb/A) Counter 15G at planting.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue in corn at Winona Co. on May 23, 1989[1].

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Location	% cover				Avg.
In Row	32.5a	15.5b	23.8c	2.0d	18.4
Between Row	55.5a	19.0c	32.8b	3.5d	27.7
Average	44.0a	17.3c	28.3b	2.8d	

1. The p value for residue location, tillage and tillage by location interaction are .003 (n=64), .001 (n=32), .570 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage and cultivation on position relative to the row on soil covered by corn residue in corn at Winona Co. on July 5, 1989[1].

	Tillage									
	No Till		Disc		Chisel		Moldboard		Average	
	In Row	Btwn Row	In Row	Btwn Row	In Row	Btwn Row	In Row	Btwn Row	In Row	Btwn Row
	% cover									
Cultivation	34.3	33.9	9.9	10.0	13.0	20.3	4.6	4.4	15.4	16.5
No Cultvation	38.0	56.8	11.8	25.3	13.1	34.9	3.3	5.3	17.1	30.5
Average	36.1	45.3	10.8	17.6	13.1	27.6	3.9	4.8	16.0	23.8

1. The p value for residue cultivation, tillage by cultivation, cultivation by location, tillage by cultivation by location are .015 (n=256), .092 (n=64), .001 (n=128), .947 (n=32) respectively.

Table 4. Effect of tillage on early growth of corn at Winona Co. on July 5, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	leaves/plant				Avg.
Cultivation	7.69	8.19	8.01	8.51	8.10
No Cultivation	7.73	8.28	8.22	8.51	8.19
Average	7.71c	8.24ab	8.11b	8.51a	

1. The p value for tillage, cultivation and tillage by cultivation interactions are .005 (n=320), .089 (n=640), .144 (n=160) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage and cultivation on corn population at Winona Co. on July 5, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	plants/Ax10^{-3}				Avg.
Cultivation	22.0	25.8	24.6	23.7	24.0
No Cultivation	19.9	25.4	25.0	23.1	23.4
Average	21.0b	25.6a	24.8a	23.4a	

1. The p value for cultivation, tillage and tillage by cultivation interaction are .458 (n=128), .010 (n=64), .658 (n=32) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of N rate and cultivation on corn population at Winona Co. on July 5, 1989[1].

	N Rate (lbs/A)			
	11	44	75	100
	plants/Ax10^{-3}			
Cultivation	23.7	24.2	25.2	22.9
No Cultivation	22.5	24.1	23.0	23.9
Average	23.1a	24.1a	24.1a	23.4a

1. The p value for N rate and cultivation by N rate interactions are .392 (n=64), .072 (n=16), respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage on weed severity[1] prior to cultivation in corn at Winona Co. on June 28, 1989[2].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	Sig.
Weeds	Rating				
Quackgrass	0.32	0.00	0.06	0.00	
Foxtail	0.00	0.22	0.38	0.00	
Woolly Cupgrass	3.94a	2.50b	2.94b	2.00c	.001
Bromegrass	2.03	0.00	0.03	0.13	
Y.Nutsedge	0.10a	1.19a	1.13a	0.22a	.187
Horsetail	0.03a	0.19b	0.38b	0.09b	.001
Pigweed	0.10	0.00	0.00	0.00	
C. Thistle	0.00	0.09	0.00	0.00	
Alfalfa	0.71	0.00	0.00	0.00	

1. Weed severity ratings on scale 0 to 5, (0 =none, 5=severe).
2. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 8. Effect of N rate on weed severity[1], in corn at Winona Co. on June 28, 1989[2].

Weeds	N Rate (lb/A) 11	44	75	100	Sig.
	Rating				
Woolly Cupgrass	2.7a	2.8a	2.9a	3.0a	.553
Y.Nutsedge	0.6a	0.7a	0.6a	0.7a	.270
Bromegrass	0.2b	0.7a	0.5a	0.7a	.019

1. Weed severity ratings on scale 0 to 5, (0=none, 5=severe).
2. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 9. Effect of cultivation on weed severity[1], in corn at Winona Co. on June 28, 1989[1].

Weeds	Cultivation	No Cultivation	Sig.
	Rating		
Woolly Cupgrass	2.84a	2.81a	.962
Y.Nutsedge	0.44b	0.89a	.025
Bromegrass	0.64a	0.43a	.182
Foxtail	0.13a	0.17a	.398
Horsetail	0.08a	0.27a	.288
Alfalfa	0.19a	0.16a	.474

1. Weed severity ratings on scale 0 to 5, (0=none, 5=severe).
2. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 10. Effect of tillage and N rate on weed severity[1], of corn at Winona Co. on June 28, 1989.

	Tillage																
	No Till				Disc				Chisel				Moldboard				
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				
Weed	11	44	75	100	11	44	75	100	11	44	75	100	11	44	75	100	Sig.[2]
Bromegrass	0.7	2.4	2.1	2.8	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.0	0.0	.014
Horsetail	0.0	0.0	0.1	0.0	0.8	0.0	0.0	0.0	0.0	0.8	0.0	0.8	0.4	0.0	0.0	0.0	.010

1. Weed severity ratings on scale 0 to 5, (0=none, 5=severe), n=8.
2. The p value for the tillage by N rate interaction.

Table 11. Effect of N rate and cultivation from the previous year on weed severity[1], in corn at Winona Co. on June 28, 1989.

	N Rate (lbs/A)								
	11		44		75		100		
Weed	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Sig.[2]
	Rating								
Woolly Cupgrass	2.7	3.1	2.8	2.8	2.7	2.4	2.9	3.2	.065
Bromegrass	0.1	0.8	0.8	0.9	0.3	0.6	0.3	0.5	.001

1. Weed severity ratings on scale 0 to 5, (0 =none, 5=severe), n=16.
2. The p value for the N rate by cultivation interaction.

Table 12. Effect of tillage, N rate, and cultivation on weed severity[1], in corn at Winona Co. on June 28, 1989[2].

	Tillage															
	No Till				Disc				Chisel				Moldboard			
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)			
	11	44	75	100	11	44	75	100	11	44	75	100	11	44	75	100
	Bromegrass rating															
Cultivation	0.3	2.8	3.3	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
No Cultivation	1.3	2.0	1.0	2.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.0	0.0
	Nutsedge rating															
Cultivation	0.0	0.0	0.0	0.0	0.8	0.3	1.3	0.8	0.8	1.3	0.8	1.0	0.0	0.0	0.3	0.0
No Cultivation	0.0	0.0	0.8	0.0	2.3	2.8	0.0	1.5	1.0	1.0	1.5	1.8	0.0	0.5	0.5	0.5

1. Weed severity ratings on scale 0 to 5, (0=none, 5=severe).
2. The p value for tillage by N rate by cultivation interaction for bromegrass and nutsedge are .001, .014 respectively, n=4.

Table 13. Effect of tillage on weed severity[1], in corn at Winona Co. on August 31, 1989.

	Tillage				
	NoTill	Disc	Chisel	Mldbd	Sig.
Weed		Rating			
Foxtail	2.3a	2.0a	2.2a	1.3b	.007
W. Cupgrass	4.3a	2.4b	2.4b	2.0b	.011
Velvetleaf	1.1a	1.0b	1.0b	1.0b	.016

1. Weed severity ratings on scale 0 to 5, (0 =none, 5=severe).
2. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 14. Effect of cultivation on weed severity[1], in corn at Winona Co. on August 31, 1989.

Weed	Cultivation	No Cultivation	Sig.
	Rating		
Foxtail	1.4	2.5	.001
W. Cupgrass	1.8	3.7	.001
Velvetleaf	1.0	1.0	.454

1. Weed severity ratings on scale 0 to 5, (0=none, 5=severe), n=64.

Table 15. Effect of N rate on foxtail weed severity[1], in corn at Winona Co. on August 31, 1989[2].

	N Rate (lbs/A)				
	11	44	75	100	
Weed		Rating			Sig.
Foxtail	2.19b	1.84b	1.81b	1.97ab	.075
W Cupgrass	2.67a	2.66a	2.84a	2.89a	.369
Velvetleaf	1.06a	1.00a	1.00a	1.06a	.131

1. Weed severity ratings on scale 0 to 5, (0=none, 5=severe).
2. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 16. Effect of tillage and cultivation on weed severity[1], in corn at Winona Co. on August 31, 1989.

	Tillage								
	No Till		Disc		Chisel		Moldboard		
	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	
Weed									Sig.[2]
Foxtail	2.06	2.50	1.13	2.88	1.37	3.06	1.00	1.63	.084
W Cupgrass	3.50	5.00	1.38	3.38	1.38	3.50	1.00	3.00	.227
Velvetleaf	1.19	1.06	1.00	1.00	1.00	1.00	1.00	1.00	.454

1. Weed severity ratings on scale 0 to 5, (0 =none, 5=severe), n=16.
2. The p value for tillage by cultivation interaction.

Table 17. Effect of tillage on corn grain yield, moisture, stover yield, moisture and final stand at Winona Co. on October 3, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
		bu/A			Sig.
Grain Yield	82b	134a	140a	146a	.001
		%			
Moisture	28.7a	24.7b	24.6b	25.0b	.001
		ton/A			
Stover Yield	2.42b	2.83a	2.98a	2.96a	.001
		%			
Moisture	41.6a	44.1a	42.9a	42.5a	.300
		plants/A$\times 10^{-3}$			
Final Stand	19.3b	25.0a	25.4a	25.0a	.003

1. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 18. Effect of N rate on corn grain yield, moisture, stover yield, moisture and final stand at Winona Co. on October 3, 1989[1].

	N Rate (lbs/A)				
	11	44	75	100	
		bu/A			Sig.
Grain Yield	109b	126a	135a	132a	.001
		%			
Moisture	26.9a	25.8ab	25.1b	25.2b	.087
		ton/A			
Stover Yield	2.68a	2.79a	2.89a	2.83a	.321
		%			
Moisture	42.7a	42.0a	42.8a	43.6a	.655
		plants/A$\times 10^{-3}$			
Final Stand	22.8a	23.8a	24.5a	23.5a	.243

1. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 19. Effect of cultivation on corn grain yield, moisture, stover yield, moisture and final stand at Winona Co. on October 3, 1989, n=64.

	Cultivation	No Cultivation	
	bu/A		Sig.
Grain Yield	138	113	.003
	%		
Moisture	26.1	25.5	.209
	ton/A		
Stover Yield	2.80	2.79	.759
	%		
Moisture	43.4	42.1	.244
	plants/Ax10^{-3}		
Final Stand	25.0	22.4	.001

Table 20. Effect of tillage on % grain N, protein, grain N uptake, % stover N, stover N uptake, and total N uptake at Winona Co. on October 3, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	%				Sig.
Grain N	1.39a	1.33b	1.35ab	1.32b	.071
	%				
Grain Protein	8.7a	8.3b	8.5ab	8.2b	.071
	lbs/A				
Grain N Uptake	53.7b	85.2a	89.9a	91.6a	.001
	%				
Stover N	0.94a	0.89a	0.95a	0.82a	.216
	lbs/A				
Stover N Uptake	45.9b	49.9b	56.6a	48.6b	.068
	lbs/A				
Total N Uptake	99.7c	135.2b	146.5a	140.2ab	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 21. Effect of N rate on % grain N, protein, grain N uptake, % stover N, stover N uptake, and total N uptake at Winona Co.on October 3, 1989[1].

	N Rate (lbs/A)				
	11	44	75	100	
	%				Sig.
Grain N	1.27d	1.34c	1.37b	1.42a	.001
	%				
Grain Protein	7.9d	8.3c	8.5b	8.9a	.001
	lbs/A				
Grain N Uptake	65.2c	80.0b	86.9a	88.3a	.001
	%				
Stover N	0.79c	0.88b	0.91b	1.02a	.001
	lbs/A				
Stover N Uptake	41.9c	49.1b	52.2b	57.9a	.001
	lbs/A				
Total N Uptake	107.1c	129.1b	139.2a	146.2a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 22. Effect of cultivation on % grain N, protein, grain N uptake, % stover N, and stover N uptake, and total N uptake at Winona Co. on October 3, 1989, n=64.

	Cultivation	No Cultivation	
	%		Sig.
Grain N	1.38	1.32	.009
	%		
Grain Protein	8.6	8.2	.009
	lbs/A		
Grain N Uptake	90.0	70.3	.001
	%		
Stover N	0.93	0.87	.010
	lbs/A		
Stover N Uptake	51.9	48.7	.191
	lbs/A		
Total N Uptake	141.8	119.0	.002

Table 23. Effect of cultivation an N rate on corn grain yield, moisture, stover yield, moisture and final stand at winona Co. on October 3, 1989, n=16.

	Cultivation				No Cultivation				
	N Rate (lbs/A)				N Rate (lbs/A)				
	11	44	75	100	11	44	75	100	
	bu/A								Sig.[1]
Grain Yield	126	142	144	140	92	110	125	123	.027
	%								
Moisture	27.7	26.0	25.2	25.4	26.2	25.5	25.0	25.1	.884
	ton/A								
Stover Yield	2.66	2.90	2.81	2.84	2.71	2.68	3.00	2.81	.292
	%								
Moisture	43.6	42.6	43.6	44.1	41.9	41.4	42.0	43.1	.998
	plants/Ax10^{-3}								
Final Stand	24.7	25.4	25.3	24.6	21.1	22.3	23.7	22.5	.312

1. The p value for cultivation by N rate interaction.

Table 24. Effect of cultivation and N rate on % grain N, protein, grain N uptake, % stover N, and stover N uptake, and total N uptake at Winona Co. on October 3, 1989, n=64.

	Cultivation				No Cultivation				
	N Rate (lbs/A)				N Rate (lbs/A)				
	11	44	75	100	11	44	75	100	
	%								Sig.[1]
Grain N	1.30	1.39	1.40	1.44	1.24	1.28	1.34	1.40	.447
	%								
Grain Protein	8.1	8.7	8.7	9.0	7.7	8.0	8.4	8.8	.447
	lbs/A								
Grain N Uptake	77.0	93.0	94.8	95.0	53.4	67.1	79.1	81.6	.015
	%								
Stover N	0.84	0.88	0.97	1.02	0.73	0.88	0.84	1.03	.115
	lbs/A								
Stover N Uptake	44.8	51.7	53.5	57.6	39.0	46.4	50.9	58.3	.702
	lbs/A								
Total N Uptake	121.8	144.6	148.3	152.6	92.5	113.5	130.0	139.9	.031

1. The p value for cultivation by N rate interaction.

Table 25. Effect of tillage on the average soil moisture to a depth of five feet in Winona Co. 1989[1].

	Tillage				
	No Till	Disc	Chisel	Moldboard	
	%wt/wt				Sig.
5/3/89[2]	20.4a	19.5b	19.5b	19.5b	.027
11/8/89	18.3a	18.0a	18.0a	17.0b	.035

1. Means within the same row with the same letter are not significantly different (α=.10, n=40).
2. Soil samples were taken before tillage.

Table 26. Effect of tillage and cultivation on soil moisture in Winona Co. November 8, 1989.[1]

	Tillage			
	No Till	Disc	Chisel	Moldboard
	%wt/wt			
Cultivation	18.5	17.7	18.1	17.0
No Cultivation	18.0	18.4	17.8	17.0

1. The p value of the tillage by cultivation interaction is .063, n=20.

Table 27. Effect of cultivation on soil moisture at Winona Co.[1].

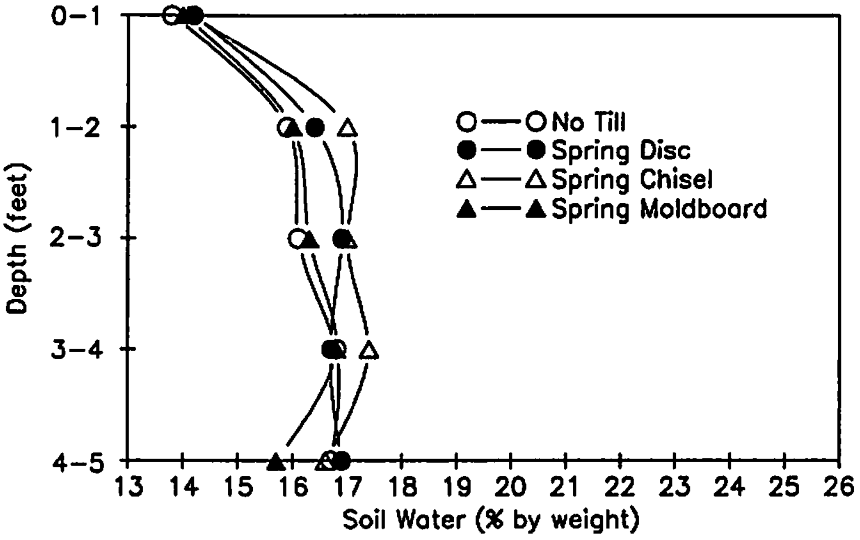
	Cultivation	No Cultivation	
	%wt/wt		Sig.
5/3/89	19.6b	19.9a	.086
11/8/89	17.8a	17.8a	.869

1. Means within the same row with the same letter are not significantly different (α=.10, n=80).

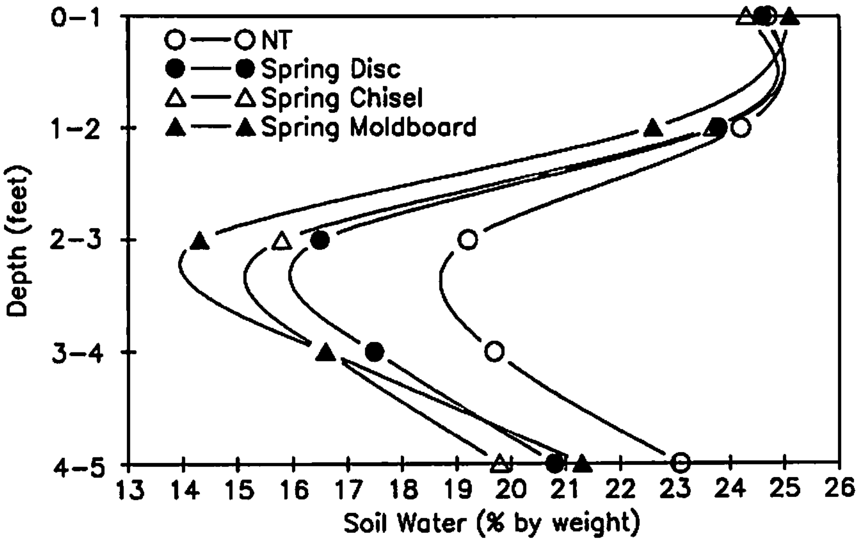
Table 28. Effect of tillage and depth on soil water at Winona Co. 1989.

	Tillage									
	No Till		Disc		Chisel		Moldboard		Depth	
	Spring[1]	Fall[2]	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Depth (feet)	% wt/wt									
0-1	19.9	19.8	19.1	19.7	19.3	19.8	19.5	20.0	19.5bc	19.8a
1-2	20.2	18.6	19.6	19.1	19.6	19.1	19.4	17.8	19.7ab	18.7b
2-3	20.2	16.6	20.3	16.8	20.3	16.5	20.1	14.1	20.3a	16.0e
3-4	20.9	17.6	20.0	16.9	19.9	17.0	19.6	15.8	20.1a	16.8d
4-5	20.8	18.8	18.5	17.6	18.0	17.4	18.6	17.4	19.0c	17.8c
Average	20.4	18.3	19.5	18.0	19.5	18.0	19.5	17.0	19.7	20.7

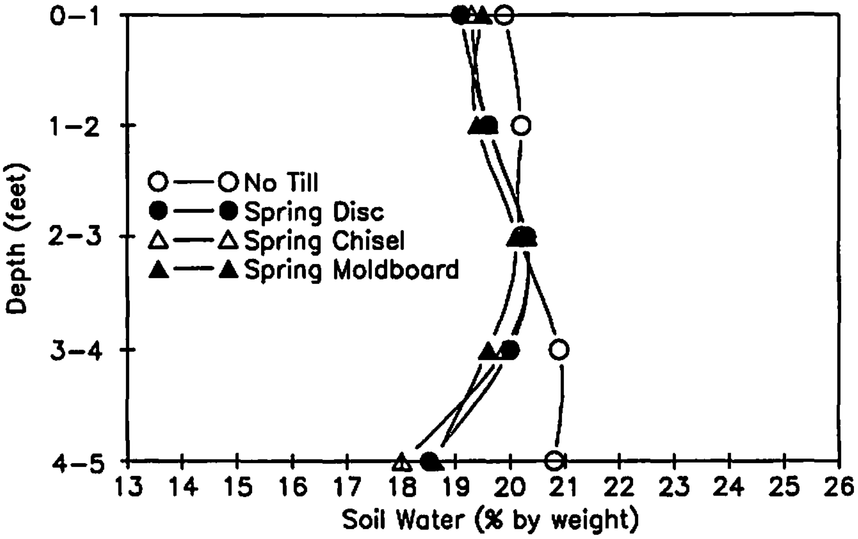
1. Soil samples were taken before tillage. The p value of spring sampling (May 3, 1989) for the tillage by depth interaction is .516, n=8, and for depth .004, n=32.
2. The p value of fall sampling (November 8, 1989) for the tillage by depth interaction is .082, n=8, and for depth .001, n=32.



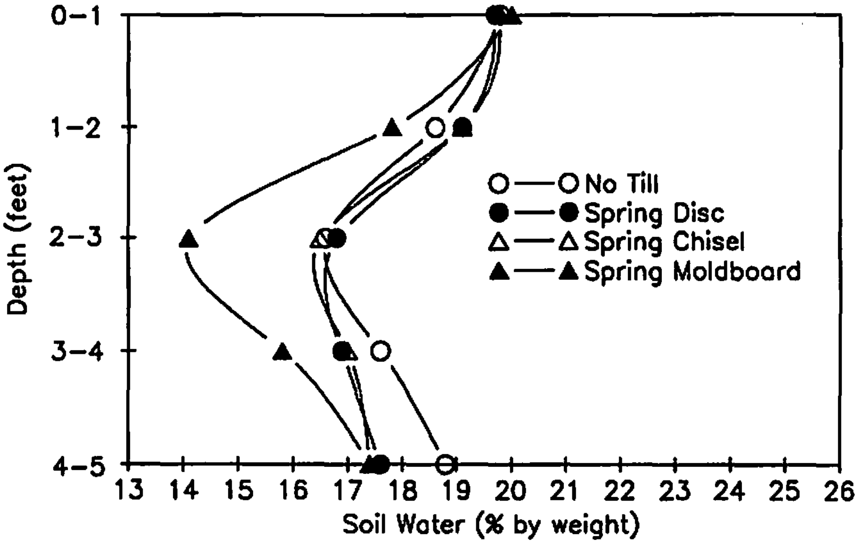
THE EFFECT OF TILLAGE ON SOIL WATER AT WINONA CO., MN.
ON APRIL 21, 1988



THE EFFECT OF TILLAGE ON SOIL WATER AT WINONA CO., MN.
ON NOVEMBER 9, 1988



THE EFFECT OF TILLAGE ON SOIL WATER AT WINONA CO., MN.
ON MAY 3, 1989



THE EFFECT OF TILLAGE ON SOIL WATER AT WINONA CO., MN.
ON NOVEMBER 8, 1989

Tillage System Effects on Corn Phenology Nitrogen Response, and Yield Under Irrigation[1]

J.F. Moncrief, M.J. Wiens, and J.J. Kuznia[2]

Tillage effects on nitrogen response of third year of corn following alfalfa were evaluated. Conservation tillage reduced early growth of corn and stand establishment. Corn responded to higher rates of applied nitrogen when grown under conservation tillage.

This is the third year of corn following alfalfa. The purpose is to evaluate tillage system effects on the amount of nitrogen available to corn from alfalfa. The soil at this site is excessively well drained. This site is irrigated. In the first year of corn there was a prominent effect of tillage on the nitrogen response by corn, in the second this effect was subtle, and this year the tillage effect on N response was intermediate.

Methods and Materials

The experimental design is a randomized complete block with three tillage treatments and four replications. All main tillage plots were split with four N rates. Crop residue was measured using a line transect technique. Soil cover by crop residue was characterized in and between the row. "In row" is defined as the four inch width centered over the row. "Between row" is defined as the remainder. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each nitrogen subplot. Crop residue measurements were also made at these monitoring sites. Leaves were tallied on ten plants in these two adjacent rows until 12 leaves were present. Grain yields were estimated by hand harvesting one row 50 ft. long. After ears were removed stover was chopped and weighed and a subsample of both grain and stover taken for moisture determination and chemical analysis.

Results and Discussion

Soil cover by corn residue is shown in table 2, 3, and 4. The fluted coulter on this planter influenced the soil cover in the row very little (table 2). In row soil cover ranged from 10 to 92 percent. Past nitrogen treatments did not affect the amount of soil cover (table 3 and 4).

Early growth responses to tillage, and nitrogen are shown in tables 5 and 6 respectively. In row cover by corn residue delayed the growth of corn compared to moldboard plowing by about 1/2 to 1 1/2 leaves for the disc and no till treatments respectively. This delay persisted over the period of observation (5/22-7/10).

Nitrogen from previous years affected the early growth by increasing the growth as the nitrogen rate increased from 84 to 206 lbs/acre. Check plots (small amount with planter) had the same growth as the high rate until 6/19 (almost two weeks after the first nitrogen application on 6/6) when higher nitrogen treatments overtook this treatment. At the end of the observation period (7/10) check plot growth was much less than higher nitrogen treatments. A couple of representative dates in table 7 shows that the higher growth in the N check plots was more pronounced with the conservation tillage systems.

Plant emergence and stand establishment are shown in tables 8,9, and 10. Corn emergence was delayed about one and two weeks under discing and no till conditions respectively. There was slight reductions in stand with corn grown under discing conditions and much larger reductions under no till conditions (table 8). Stands were also slightly higher in the N check plots (table 9). Tillage also affected the stand response to prior nitrogen treatments (table 10). Nitrogen check plots emerged quicker and had higher final stands under no tillage conditions. The highest N rate had lower stands under moldboard plowing conditions.

Visual N deficiency of corn are shown in tables 11, 12, and 13. Visual estimates of N deficiency symptoms showed higher levels of N stress at a given N rate with conservation tillage. Visual symptoms decreased at higher nitrogen rates with conservation tillage (table 13).

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[1] *This project is supported by the Staples Technical College Irrigation Center, the Soil Conservation Service, the Minnesota Extension Service, and the Soil and Water Conservation Districts of Wadena and Todd County Soil and Water Conservation Districts.*

[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. Mel J. Wiens is a Research Plot Coordinator at the Staples Technical College, Irrigation Center, Staples, MN. 56479*

Tillage effects on silk emergence were similar to plant emergence (table 14). Nitrogen also affected silk emergence similarly to plant emergence (table 15). And finally the tillage and nitrogen interaction effect on silk emergence was similar to plant emergence (table 16).

Main effects of tillage and nitrogen on grain and stover yields and moisture are shown in tables 17 and 18. Tillage and nitrogen interacted in their effects on most of these variables. Interactions are shown in table 19. The nitrogen response was linear under no till conditions. The response was similar with discing and moldboard plowing.

Tillage and N rate effects on N uptake are shown in tables 20, 21, and 22. Again, in several cases there was an interaction between these two variables and N uptake. Response under no till conditions was much different than the discing and moldboard systems. Tillage affects on nitrogen availability appears to be small between the spring discing and moldboard plowing systems. Although reduced availability under no till conditions are large this system was used as a check as an extreme and would probably not be a viable system for a farmer.

WADENA COUNTY

Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1989.

Tillage

No Till
Spring Disc-May 9, 1989
Spring Moldboard Plow-May 9, 1989

Previous Crop

1984-86 Alfalfa, 1987-Corn, 1988-Corn

1989 Crop Corn-Pioneer 3790

Planting and Harvest Date

The planter is a John Deere Max-Emerge planter equipped with 2" fluted coulters.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 10, 1989	35,600 plants/A	October 10, 1989

Fertilizer 1987

Material Analysis	Rate[3]	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.
3. The resulting N rates are: 16, 51, 83, and 118 lbs/A.

Fertilizer 1988

Material Analysis	Rate[3]	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.
3. The resulting N rates are: 20, 83, 137, and 204 lbs/A.

Fertilizer 1989

Material Analysis	Rate[3]	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		---- lbs/A			---	
20-7-20-7[1]	95 lbs/A	19	7	19	7	May 10, 1989
46-0-0[2]	0 lbs/A	0	0	0	0	June 6, 1989
46-0-0[2]	137 lbs/A	33	0	0	0	June 6, 1989
46-0-0[2]	254 lbs/A	64	0	0	0	June 6, 1989
46-0-0[2]	400 lbs/A	95	0	0	0	June 6, 1989
46-0-0[2]	0 lbs/A	0	0	0	0	June 30, 1989
46-0-0[2]	137 lbs/A	32	0	0	0	June 30, 1989
46-0-0[2]	254 lbs/A	64	0	0	0	June 30, 1989
46-0-0[2]	400 lbs/A	92	0	0	0	June 30, 1989

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in.
3. The resulting N rates are: 19, 84, 147, and 206 lbs/A.

Soil

The soil at this site is a Verndale sandy loam (Udic Argiborolls, coarse-loamy, mixed) with a slope of 0 to 2 percent. The soil is well drained.

Weed Control

2 pt/A (2 lb/A) Dual + 1.5 qt/A (1.5 lbs/A) Bladex on May 12, 1989.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue in corn at Wadena Co. on May 15, 1989[1].

	Tillage			
	NoTill	Disc	Mldbd	
Location	----- % cover ------			Avg.
In Row	92.2a	42.8b	9.5c	48.1
Between Row	97.6a	45.9b	10.3c	51.3
Average	94.9a	44.3b	9.9c	

1. The p value for residue location, tillage and tillage by location interaction are .198 (n=192), .001 (n=128), .943 (n=64) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of N rate and position relative to the row on soil covered by corn residue in corn at Wadena Co. on May 15, 1989[1].

	N Rate (lbs/A)			
	19	84	147	206
Location	-------- % cover --------			
In Row	43.8	50.5	47.4	50.9
Between Row	49.9	52.8	50.3	52.0
Average	46.8	51.7	48.8	51.4

1. The p value for residue for N rate and N rate by location interaction are .481 (n=96), .813 (n=48) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage, residue position and N rate on soil covered by corn residue in corn at Wadena Co. on May 15, 1989[1].

	Tillage								
	NoTill		Disc		Moldboard		No Till	Disc	Moldbd
	In Row	Btwn Row	In Row	Btwn Row	In Row	Btwn Row	Average		
N Rate	% cover								
19 lb/A	84.0	95.8	39.3	42.8	8.0	11.3	89.9	41.0	9.6
84 lb/A	95.8	99.3	44.8	48.8	11.0	10.5	97.5	46.8	10.8
147 lb/A	95.0	96.8	37.0	44.5	10.3	9.5	95.9	40.8	9.9
206 lb/A	94.0	98.5	50.0	47.8	8.8	9.8	96.3	48.9	9.3

1. The p value for tillage by N rate by location interaction is .898 (n=16) and the p value for tillage by N rate interaction is .981 (n=32).

Table 5. Effect of tillage on early growth of corn at Wadena Co[1].

	Tillage			
	NoTill	Disc	Mldbd	
Date	---- leaves/plant --			Sig.
5/22/89	0.64c	1.48b	1.80a	.001
5/25/89	0.68c	1.69b	2.06a	.001
5/30/89	0.88c	2.12b	2.74a	.001
6/2/89	1.00c	2.55b	2.90a	.001
6/6/89	1.89c	3.36b	3.96a	.001
6/9/89	2.53c	4.01b	4.74a	.001
6/13/89	3.17c	4.99b	5.78a	.001
6/15/89	3.63c	5.31b	6.03a	.001
6/19/89	4.18b	6.52a	6.35a	.080
6/22/89*	6.12c	7.96b	8.65a	.001
6/26/89	6.95c	8.47b	9.32a	.001
6/29/89	7.43c	9.12b	10.21a	.001
7/3/89	8.40c	10.36b	11.39a	.001
7/10/89	10.21c	11.36b	11.95a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=64. *n=32).

Table 6. Effect of N rate on early growth of corn at Wadena Co[1].

	N Rate (lbs/A)				
	19	84	147	206	
Date	-------- leaves/plant --------				Sig.
5/22/89	1.32a	1.27a	1.30a	1.34a	.636
5/25/89	1.54a	1.39b	1.46a	1.52a	.003
5/30/89	1.99a	1.83c	1.88bc	1.97ab	.027
6/2/89	2.25a	2.06c	2.12bc	2.17ab	.010
6/6/89[2]	3.15a	2.89b	3.07a	3.18a	.001
6/9/89	3.87a	3.70b	3.71b	3.77ab	.094
6/13/89	4.67a	4.51b	4.66ab	4.74a	.096
6/15/89	5.00a	4.96a	4.92a	5.08a	.182
6/19/89	5.57a	5.60a	5.75a	5.81a	.849
6/22/89*	7.33c	7.54b	7.69ab	7.75a	.001
6/26/89	7.95c	8.22b	8.45a	8.37ab	.001
6/29/89[2]	8.52c	8.79b	9.17a	9.21a	.001
7/3/89	9.41c	10.06b	10.33b	10.41a	.001
7/10/89	10.65d	11.19c	11.35b	11.51a	.039

1. Means within the same row with the same letter are not significantly different (α=.10, n=48, *n=24).
2. N application on 6/6 and 6/30.

Table 7. Effect of tillage and N rate on early growth of corn at Wadena Co (n=16).

	Tillage												
	No Till				Disc				Moldboard				
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				
	19	84	147	206	19	84	147	206	19	84	147	206	
Date	leaves/plant												Sig.[1]
6/6/89	2.13	1.64	1.83	1.99	3.40	3.16	3.44	3.46	3.92	3.88	3.96	4.09	.019
6/9/89	2.83	2.49	2.32	2.50	4.06	3.95	4.03	4.01	4.73	4.64	4.77	4.81	.041
7/10/89	9.47	10.14	10.49	10.75	10.56	11.44	11.61	11.81	11.90	11.97	11.94	11.97	.001

1. The p value for the tillage by N rate interaction.

Table 8. Effect of tillage on corn population at Wadena Co[1].

	Tillage			
	NoTill	Disc	Mldbd	
Date	plants/Ax10^{-3}			Sig.
5/22/89	21.2c	39.6b	45.4a	.001
5/25/89	34.1c	40.7b	46.4a	.001
5/30/89	36.4c	44.4b	46.8a	.001
6/2/89	38.7c	45.0b	46.9a	.001
6/6/89	39.8c	45.6b	47.3a	.001
6/9/89	40.1c	45.3b	47.0a	.001
6/13/89	39.8c	45.2b	46.9a	.001
6/15/89	39.9c	45.3b	46.9a	.001
6/19/89	39.8c	45.1b	46.9a	.001
6/22/89*	39.6b	46.3a	47.2a	.001
6/26/89	39.6c	45.5b	47.1a	.001
6/29/89	39.7c	45.5b	47.0a	.001
7/3/89	39.7c	45.3b	46.9a	.001
7/10/89	39.8c	45.4b	47.1a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=64, *n=32).

Table 9. Effect of N rate on corn population at Wadena Co[1].

	N Rate				
	19	84	147	206	
Date	plants/Ax10^{-3}				Sig.
5/22/89	39.8a	33.1b	33.8b	34.8b	.001
5/25/89	42.6a	38.5b	40.0b	40.5b	.016
5/30/89	44.6a	41.1b	41.9b	42.5b	.016
6/2/89	44.7a	42.6a	43.5a	43.3a	.212
6/6/89	45.5a	43.2b	44.6ab	43.6b	.064
6/9/89	45.4a	42.9b	44.5ab	43.9ab	.059
6/13/89	45.4a	42.8b	44.3ab	43.6b	.032
6/15/89	45.4a	42.8c	44.4ab	43.5bc	.030
6/19/89	45.4a	42.4c	44.5ab	43.6bc	.010
6/22/89*	44.6a	43.1a	45.2a	44.6a	.442
6/26/89	45.3a	43.1a	44.2a	43.9a	.121
6/29/89	45.5a	42.9b	44.1ab	43.8b	.051
7/3/89	45.3a	42.7c	44.4ab	43.6bc	.043
7/10/89	45.4a	42.8b	44.4ab	43.8ab	.039

1. Means within the same row with the same letter are not significantly different (α=.10, n=48, *n=24).

Table 10. Effect of tillage and N rate on population of corn at Wadena Co (n=16).

	Tillage												
	No Till				Disc				Moldboard				
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				
	19	84	147	206	19	84	147	206	19	84	147	206	
Date	plants/Ax10^{-3}												Sig.[1]
5/22/89	30.9	17.8	17.1	19.1	41.7	35.5	40.3	40.7	46.7	46.0	44.1	44.6	.104
6/6/89	42.7	38.1	40.6	37.7	46.0	42.8	46.4	47.3	47.9	48.6	46.7	45.8	.024
6/9/89	42.9	37.9	40.8	38.8	45.4	43.0	46.0	47.2	47.8	47.7	46.7	45.8	.060
6/13/89	42.7	38.2	40.0	38.3	45.8	42.6	46.1	46.5	47.6	47.5	46.7	45.8	.104
6/15/89	42.9	38.2	40.2	38.2	45.6	42.6	46.4	46.5	47.8	47.4	46.6	45.8	.084
6/19/89	42.6	38.2	40.1	38.4	45.7	41.5	46.6	46.6	47.8	47.4	46.7	45.7	.038
6/26/89	42.6	38.1	39.5	38.3	45.6	43.1	46.4	47.0	47.8	48.0	46.7	46.2	.072

1. The p value for the tillage by N rate interaction.

Table 11. Effect of tillage on corn plant color at Wadena Co[1].

	Tillage			
	NoTill	Disc	Mldbd	
Date	color scale[2]			Sig.
6/26/89	2.6c	3.2b	3.9a	.009
7/10/89	3.0b	3.8a	4.1a	.003

1. Means within the same row with the same letter are not significantly different (α=.10, n=16).
2. Color scale is 1=yellow, 5=green.

Table 12. Effect of N rate on corn plant color at Wadena Co[1].

	N Rate lb/A				
	19	84	147	206	
Date	color scale[2]				Sig.
6/26/89	2.3c	3.2b	3.7ab	3.8a	.001
7/10/89	2.3c	3.8b	4.1ab	4.4a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=12).
2. Color scale is 1=yellow, 5=green.

Table 13. Effect of tillage and N rate on plant color of corn at Wadena Co (n=4).

	Tillage												
	No Till				Disc				Moldboard				
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				
	19	84	147	206	19	84	147	206	19	84	147	206	
Date	color scale												Sig.[1]
6/26/89	1.3	2.8	3.0	3.5	2.3	3.0	4.0	3.5	3.5	3.8	4.0	4.5	.051
7/10/89	1.3	3.0	3.8	4.0	2.3	4.3	4.3	4.5	4.3	4.3	4.3	4.8	.015
Average	1.3	2.9	3.4	3.8	2.3	3.7	4.2	4.0	3.9	4.1	4.2	4.7	

1. The p value for the tillage by N rate interaction.

Table 14. Effect of tillage on silk emergence at Wadena Co[1].

	Tillage			
	NoTill	Disc	Mldbd	
Date	%			Sig.
7/28/89	9.7c	66.5b	85.8a	.001
7/31/89	30.9c	82.9b	93.9a	.001
8/3/89	43.5c	88.4b	99.2a	.001
8/7/89	73.8c	96.0b	99.8a	.001
8/9/89	77.2b	98.1a	99.9b	.001
8/15/89	92.4b	100.0a	100.0a	.001
8/18/89	96.6b	100.0a	100.0a	.014

1. Means within the same row with the same letter are not significantly different (α=.10, n=64).

Table 15. Effect of N rate on silk emergence at Wadena Co[1].

	N Rate (lbs/A)				
	19	84	147	206	
Date	%				Sig.
7/28/89	31.3c	55.9b	63.3a	65.5a	.001
7/31/89	53.9c	69.7b	73.6b	79.8a	.001
8/3/89	60.9c	78.4b	82.0b	86.8a	.001
8/7/89	77.5c	92.0b	94.2ab	95.7a	.001
8/9/89	82.4b	94.1a	93.5a	96.8a	.001
8/15/89	94.0b	99.2a	98.4a	98.3a	.001
8/18/89	96.9b	99.8a	98.9a	100.0a	.003

1. Means within the same row with the same letter are not significantly different (α=.10, n=48).

Table 16. Effect of tillage and N rate on silk emergence of corn at Wadena Co (n=16).

	Tillage												
	No Till				Disc				Moldboard				
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				
	19	84	147	206	19	84	147	206	19	84	147	206	
Date	%												Sig.[1]
7/28/89	1.0	7.3	15.2	15.1	29.6	69.8	82.0	84.8	63.3	90.8	92.6	96.5	.002
7/31/89	11.0	25.0	39.0	48.6	64.5	87.9	84.6	94.7	86.3	96.1	97.1	96.1	.001
8/3/89	12.5	43.5	51.0	67.0	73.3	91.8	95.0	93.5	96.9	100.0	100.0	100.0	.001
8/7/89	44.4	79.0	83.6	88.2	89.0	97.0	99.2	98.8	99.1	100.0	100.0	100.0	.001
8/9/89	52.5	83.6	82.3	90.3	95.1	98.8	98.4	100.0	99.5	100.0	100.0	100.0	.001
8/15/89	82.2	97.5	95.2	94.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.001
8/18/89	90.4	99.4	96.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.001

1. The p value for the tillage by N rate interaction.

Table 17. Effect of tillage on corn grain yield, moisture, stover yield, moisture, and plants with ears at Wadena Co. on October 10, 1989[1].

	Tillage			
	NoTill	Disc	Mldbd	
	bu/A			Sig.
Grain Yield	75c	135b	148a	.001
	%			
Moisture	26.4a	21.6b	21.7b	.001
	ton/A			
Stover Yield	2.13b	2.63a	2.91a	.011
	%			
Moisture	49.8a	48.1a	49.1a	.567
	plants/Ax10^{-3}			
Plants With Ears	23.3b	31.1a	33.0a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=16).

Table 18. Effect of N rate on corn grain yield, moisture, stover yield moisture, and plants with ears at Wadena Co. on October 10, 1989[1].

	N Rate (lbs/A)				
	19	84	147	206	
	bu/A				Sig.
Grain Yield	54d	112c	145b	165a	.001
	%				
Moisture	22.3c	24.2a	23.5ab	23.0bc	.007
	ton/A				
Stover Yield	1.50d	2.59c	2.89b	3.14a	.001
	%				
Moisture	51.1a	50.0a	48.5ab	46.6b	.075
	plants/Ax10^{-3}				
Plants With Ears	26.0c	29.2b	30.0ab	31.2a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=12).

Table 19. Effect of tillage and N rate on grain yield, moisture, stover yield, moisture and final stand of corn at Wadena Co., (n=4).

	Tillage												
	No Till				Disc				Moldboard				
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				
	19	84	147	206	19	84	147	206	19	84	147	206	
	bu/A												Sig.[1]
Grain Yield	28	58	91	123	64	123	168	183	69	156	176	190	.001
	%												
Moisture	23.7	27.9	27.1	26.9	21.3	22.5	21.7	20.9	22.0	22.0	21.5	21.2	.018
	ton/A												
Stover Yield	1.11	2.12	2.35	2.96	1.65	2.58	2.99	3.07	1.79	3.10	3.34	3.40	.074
	%												
Moisture	49.5	50.7	50.8	48.3	53.2	50.7	47.3	42.5	51.1	48.6	47.6	49.2	.235
	plants/Ax10^{-3}												
Plants With Ears	17.1	22.8	25.1	28.2	27.8	30.7	32.1	33.8	33.2	34.2	32.8	31.7	.005

1. The p value for the tillage by N rate interaction.

Table 20. Effect of tillage on % grain N, protein, grain N uptake, % stover N, stover N uptake, and total N uptake at Wadena Co. on October 10, 1989[1].

	Tillage			
	NoTill	Disc	Mldbd	
	%			Sig.
Grain N	1.04c	1.11b	1.18a	.009
	%			
Grain Protein	6.52c	6.94b	7.40a	.009
	lbs/A			
Grain N uptake	39.0c	74.3b	86.6a	.001
	%			
Stover N	0.40	0.41	0.45	.163
	lbs/A			
Stover N uptake	17.1c	22.0b	27.5a	.012
	lbs/A			
Total N uptake	56.1c	100.2b	114.1a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=16).

Table 21. Effect of N rate on % grain N, protein, grain N uptake, % stover N, stover N uptake, and total N uptake at Wadena Co. on October 10, 1989[1].

	N Rate (lbs/A)				
	19	84	147	206	
	%				Sig.
Grain N	0.92d	1.04c	1.19b	1.31a	.001
	%				
Grain Protein	5.72d	6.49c	7.44b	8.17a	.001
	lbs/A				
Grain N uptake	23.6d	56.2c	83.5b	103.3a	.001
	%				
Stover N	0.37c	0.35b	0.43b	0.52a	.001
	lbs/A				
Stover N uptake	10.6d	18.3c	25.8b	33.1a	.001
	lbs/A				
Total N uptake	34.9d	74.5c	109.3b	136.5a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=12).

Table 22. Effect of tillage and N rate on % grain N, protein, grain N uptake, % stover N, stover uptake and total N uptake at Wadena Co. on October 10, 1989, (n=4).

	Tillage												
	No Till				Disc				Moldboard				
	N Rate (lbs/A)				N Rate (lbs/A)				N Rate (lbs/A)				
	19	84	147	206	19	84	147	206	19	84	147	206	
	%												Sig.[1]
Grain N	0.91	1.00	1.07	1.21	0.90	1.02	1.22	1.30	0.94	1.10	1.29	1.40	.229
	%												
Grain Protein	5.66	6.22	6.66	7.58	5.63	6.36	7.60	8.15	5.87	6.89	8.05	8.78	.229
	lbs/A												
Grain N uptake	11.4	27.4	46.0	70.7	27.8	59.6	96.9	113.1	31.1	81.6	107.6	126.2	.186
	%												
Stover N	0.45	0.32	0.35	0.48	0.37	0.34	0.43	0.50	0.29	0.38	0.52	0.59	.001
	lbs/A												
Stover N uptake	9.9	13.8	16.5	28.3	11.7	17.2	25.6	30.8	10.5	24.0	35.2	40.3	.004
	lbs/A												
Total N uptake	21.7	41.1	62.6	99.0	43.5	76.8	122.5	143.9	41.5	105.6	142.8	166.5	.072

1. The p value for the tillage by N rate interaction.

The Effect of Tillage on Corn Phenology and Response to Applied Nitrogen Following Alfalfa Under Irrigated Conditions: a Three Year Summary[1]

J.F. Moncrief, M.J. Wiens, and J.J. Kuznia[2]

The purpose of this study is to evaluate the impact of tillage on the amount of nitrogen available to corn following alfalfa. The study was conducted on an excessively well drained soil under irrigation. Tillage reduced the amount of nitrogen available to corn during the first year. In the second year nitrogen responses were similar between tillage systems. During the third year there was a reduction in nitrogen available under conservation tillage systems. Tillage also affected corn emergence and phenology. Soil cover by corn residue was much more detrimental to corn development than alfalfa residue. When residue levels were greater than 40% there were large delays in emergence and development.

There has been a recent emphasis of farmers to adopt conservation tillage systems to meet the conservation compliance provisions of the 1985 Food Security Act. There has also been concern that nitrate-nitrogen losses to groundwater have been occurring on the sandy soils of central Minnesota. This study was conducted to investigate the effect of management of crop residues for erosion control on corn development and nitrogen availability from alfalfa.

Corn is one of the most sensitive crops to the effects of crop residues in the row area. This is primarily for the following reasons: 1.) poor seed to soil contact which reduces the rate of imbibition of soil water, 2.) reduced soil temperatures, and 3.) alleopathic inhibition of germination and early growth.

Most of the sensitive soils to erosion and contamination by nitrate are being farmed for milk production. One factor that is needed to reduce nitrogen losses to groundwater are more precise nitrogen credits from preceding alfalfa crops. This may include tillage affects on nitrogen available from alfalfa, soil organic matter, and fertilizer.

Methods and Materials

Experimental Design

The design is a split plot with tillage main plots and nitrogen subplots with four replications. There are three tillage and four nitrogen treatments.

Soil

The soil at this site is a Verndale (Udic Argiborolls, coarse-loamy, mixed) sandy loam with a slope of 0 to 2 percent. Organic matter is 2.8 percent in the top 10 inches. There is very little organic matter below this depth. The surface 20 inches is a sandy loam texture and below this coarse sand.

Alfalfa

Alfalfa density was measured on April 28, 1987 by a stratified random technique. Crown density was measured in four one meter square samples at randomly selected one meter rectangular coordinates within each proposed tillage plot. Crowns were identified as viable or non viable based on visible signs of growth at this time.

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[1] Support for this project was provided by the U.S.D.A., Soil Conservation Service, the Minnesota Department of Agriculture, Energy and Sustainable Agriculture Program, and the Staples Area Technical College, Irrigation Center. Their support is greatly appreciated. A special thanks to Ms. Becky Sheets who was responsible for much of the data collection.

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Table 1. Alfalfa crown density on proposed tillage plots on April 28, 1987 before establishment of tillage and nitrogen treatments (n=16).

Tillage	Viable	Non Viable	Total
	----Crowns/ft.^{2}-----		
No Till	1.68	.98	2.66
Spring Disc	1.97	1.02	2.99
Moldboard	1.87	1.09	2.95

Tillage

All tillage was done in the spring of each year. Three tillage systems were evaluated: moldboard plowing with plow packer attached, double discing with light tandem finishing disc, and no tillage. There was no row cultivation. Moldboard plowing was approximately 6 inches deep and had no secondary tillage, discing was 3 to 4 inches deep. The planter used was a conventional four row planter equipped with 2 inch fluted coulters ahead of disc openers for seed placement and separate disc openers for dry fertilizer placement 2 inches beside the seed. Row spacing was 30 inches.

A single cross hybrid was used (Pioneer 3790).

Nitrogen

Nitrogen was applied in two applications in 1987 and 1988, a small amount of nitrogen was applied with the planter and the remainder was applied at the time indicated in table 3. In 1989 a small amount of nitrogen was applied with the planter and the remainder split between two equal applications at the times indicated in table 3. Nitrogen was applied as urea. Broadcast applications preceded irrigation of .3 to .5 inches of water to minimize immobilization and volatilization losses. Irrigation was kept to a minimum to minimize leaching as urea before fertilizer was hydrolyzed to ammonium.

Table 2. Dates of planting, harvest, and first frost.

	Planting	Harvest	Frost
1987	5/11	10/1	10/2
1988	4/27	9/29	10/2
1989	5/10	10/10	9/23

Table 3. Dates of nitrogen application, rates, and corn growth.

	1987	1988	1989	Nitrogen Rates[1]		
Planting	5/11	4/27	5/10	1987	1988	1989
				---lbs/acre---		
Growth	8 leaf	8 leaf	3 leaf	16	20	26
Date	6/16	6/1	6/1	51	63	90
				83	117	150
Growth			9 leaf	118	184	208
Date			6/30			

1. Nitrogen applied as urea with the planter or broadcast ahead of .3 to .5 inches of irrigation. The first rate is planter applied nitrogen, the remaining rates are planter applied plus broadcast.

Cover by Crop Residue

Two rows at two locations (stratified random technique) were located within each nitrogen subplot and ten feet lengths marked with flags after planting. These were used as monitoring sites throughout the season. A line transect method (a ten foot line with 25 points) was used to measure soil cover in and between the row. "In row" is defined as four inches centered over the row, the remainder is defined as between the row.

Emergence and Early Growth

At the same monitoring sites during emergence plants were counted every other or third day. Leaves were also counted and recorded until about 12 leaves. Leaves were estimated to the nearest 1/4 leaf.

Silk Emergence

At anthesis plants with emerged silk were tallied within monitoring sites daily until all plants had emerged silk.

Color Evaluation

After pollination color of plants were evaluated based on a scale of from one to five with five being the darkest green and one being light green or yellow.

Grain and Stover Yields

A fifty foot row within each plot was hand harvested, shelled, and weighed to estimate yields. About a 500 gm. subsample was taken to estimate moisture. Samples were weighed in the field and dried to constant weight at 60°C and weighed again. Dry weight was assumed to be at 0 moisture.

The same fifty foot row was chopped and weighed after grain was picked to estimate stover yields.

Nitrogen Analysis

Stover and grain samples were ground to pass a 1mm sieve and analyzed for total nitrogen with a micro Kjeldahl technique.

Results and Discussion

Tillage Effects on Corn Phenology

Growing Degree Days and Precipitation

Growing degree days are shown in figure 1. Accumulation of growing degree days in 1988 and 1987 were very similar until about 30 days after planting. Temperatures were lower in 1989 but final cumulative growing degree days were similar at the end of the season.

Precipitation was very much below normal in 1987 and 1988.

Soil Cover

Soil cover is shown in table 4. It is surprising that the amount of soil cover resulting from tillage treatments was similar for the three years of the study. Soil cover was similar following alfalfa and corn for a given tillage system. There was also very little effect of the planter mounted fluted coulter on removal of crop residue from within the row.

Table 4. The effect of tillage on soil cover by crop residue in and between the row[1].

	Tillage					
	No Till		Disc		Moldboard	
	In	Btw	In	Btw	In	Btw
Year	%					
1987	92	97	48	41	13	11
1988	84	90	64	57	9	6
1989	92	98	43	46	10	10
Avg.	89	95	51	48	10	9

[1] "In row" is defined as being a 4 inch strip centered over the row. "Between row" is defined as the remainder.

Emergence

Emergence is shown in figure 2. In 1987 although soil cover ranged from 10 to 90% in the corn row over the range of tillage systems studied emergence was affected very little by tillage. Tillage had a statistically significant effect on stand on the eighth, ninth, and tenth day following planting only. About eighty percent of plants were emerged within a three day period (eight days following planting). Alfalfa plant residues had very little effect on corn emergence and emergence was rapid. Final stands were similar.

In 1988 corn grown under no till conditions were just beginning to emerge about 10 days after planting while those grown with moldboard plowing were completely emerged. Disc and no till treatment corn were fully emerged at 17 and 21 days following planting respectively. Unlike 1987 following alfalfa at similar residue levels, tillage expanded the emergence period 11 days following corn in 1988. Final stands were also similar in 1988.

In 1989 corn under moldboard plowing was fully emerged by 11 days after planting. Disc and no till treatment corn were emerged by 20 and 23 days after planting respectively. Final stands were similar for the disc and moldboard systems. No till grown corn had final stands reduced about 15%. At these plant densities grain yields would not be expected to be affected.

Alfalfa residue in 1987 at similar levels of soil cover as corn in subsequent years had very little influence on the rate of emergence or final stand. Corn residue delayed emergence in 1988 although final stands were similar between treatments. In 1989 "in row" cover by corn residue from the prior two years had more of an influence on emergence and reduced final stands. This provides evidence as to the importance of crop rotation on minimizing influences of "in row" cover by crop residue.

Early Growth

Early growth is shown in figure 3. Similar to emergence tillage had only a small effect on leaf development in 1987. The three tillage lines are almost congruent. Although differences are small they are in many cases statistically significant however. It took about 44 days to reach for moldboard plow grown corn to reach 12.0 leaves. Disc and no till treatments had corn with 11.8 and 11.1 leaves respectively.

In 1988 tillage effects were apparent from emergence and larger than in 1988. These differences also persisted. At 44 days after planting corn grown with moldboard plowing had reached 11.1 leaves. Disc and no till grown corn was at 9.7 and 8.6 leaves respectively.

In 1989 "in row" cover by corn residue had a large effect on corn growth. Moldboard and disc systems were closer in early growth than the previous year. No till grown corn was delayed by almost two leaves. It also took moldboard grown corn 62 days to reach 12 leaves rather than the 44 days in the previous two years. This is supported by the plotted growing degree days in figure 1.

Alfalfa crop residues in the corn row had a statistically significant but very small influence on early growth of corn. Corn residues had greater influence at similar cover levels. It appears that there is a somewhat additive affect which increases tillage influences on early growth when growing corn after corn. Corn growth was similar in 1987 and 1988. In 1989 early growth was 40 % slower.

Silk Emergence

Silk emergence is shown in figure 4. It took 4 days for 90 % silk emergence in 1987. In 1987 tillage effects on silk emergence showed a trend that was similar to emergence and early growth. Day 72 is the only day with statistically significant differences due to tillage. There is very little influence of tillage on silk emergence.

In 1989 silk emergence took over 20 days for no till grown corn. Moldboard, disc, and no till grown corn had 90 % silk emergence at 82, 88, and 97 days after planting respectively. There were large influences by tillage system on silk emergence date in this year.

Similar to tillage influences on emergence and early growth, silk emergence was influenced very little in 1987 but had large differences in 1989.

Grain Moisture

Tillage influences on grain moisture are shown in figure 5. Tillage increased grain moisture in all three years of the study. Differences in 1987 were very small (1.0%). In 1988 and 1989 although corn grown with the discing treatment had less than 1% higher grain moisture than moldboard plowing, no till grown corn following corn resulted in about 6% higher grain moisture. This is consistent with the tillage effect on corn emergence, early growth and silk emergence.

Tillage Effects on Nitrogen Response

Visual Deficiency Symptoms

The effect of tillage and applied nitrogen on visual symptoms of nitrogen deficiency in 1987 and 1989 are shown in figure 6 and 7 respectively. In 1987 there was very little difference in greenness due to nitrogen application with corn grown with moldboard plowing. Disc and no till grown corn exhibited visual symptoms of nitrogen deficiency. At the 118 pound per acre rate these two systems still showed less greenness than corn grown with moldboard plowing.

In 1989 corn showed nitrogen deficiency with all tillage systems when only 28 pounds per acre nitrogen was applied with the planter. When additional nitrogen was applied moldboard and disc treatments had similar color at the July 10 observation. No till grown corn still had visibly less green color even when over 200 pounds per acre nitrogen was applied. The second nitrogen application was applied on June 30 after the first observation but 10 days before the second. Corn grown with the moldboard and disc systems showed very little nitrogen stress at the second observation (July 10) with broadcast applications.

Grain Yields

Tillage and nitrogen effects on grain yields are shown in figure 8. When only 16 to 28 pounds per acre of nitrogen was applied with the planter yields were 169, 95, 54 bushels per acre for 1987, 1988, and 1989 respectively. This reflects the amount of nitrogen that was available from alfalfa and soil organic matter for first, second, and third year corn following alfalfa. Tillage did not to appear to effect the apparent available nitrogen from alfalfa to corn with only small amount of planter applied nitrogen (figure 9).

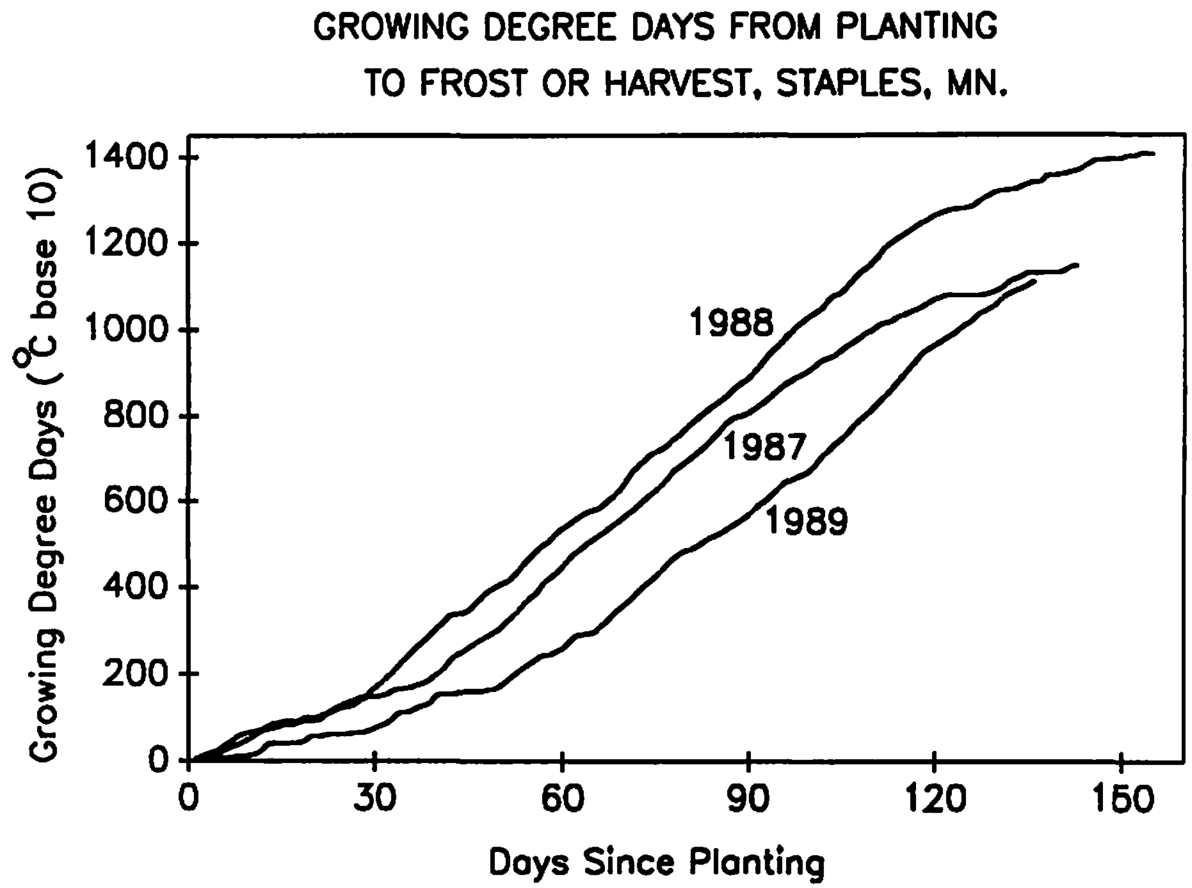
Grain yield responses showed prominent tillage and nitrogen interactions in 1987 and 1989. In 1988, although there were statistically significant tillage effects, they did not interact with applied nitrogen. First year corn did not respond to applied nitrogen when alfalfa was followed with moldboard plowing. As tillage was reduced there was less nitrogen available to first year corn. In 1989 there was a similar tillage effects. The response to applied nitrogen by no till corn in 1989 was linear.

Summary

Corn grown after alfalfa with conservation tillage systems and a planter equipped with fluted coulters resulted in high levels of "in row" cover by crop residues. Soil cover in the row with alfalfa residues had little effect on corn phenology. Similar amounts of soil cover by corn residue in the row had large effects on delayed corn phenology. This was documented by delayed emergence, vegetative growth, silk emergence and grain moisture.

Corn grown with these conservation tillage systems also required higher rates of nitrogen following alfalfa.

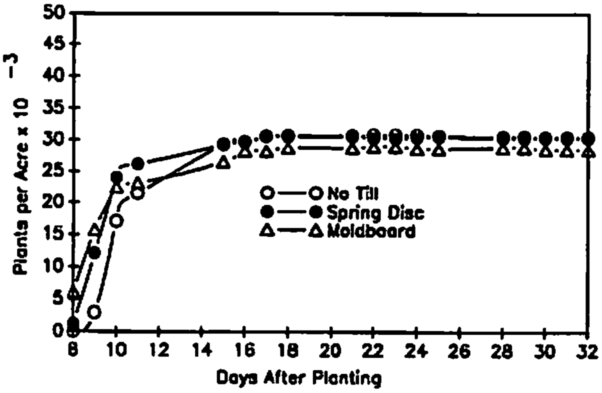
Differences between moldboard plowing and spring discing were small. A no till approach produced large differences in delayed corn phenology and higher rates of applied nitrogen.



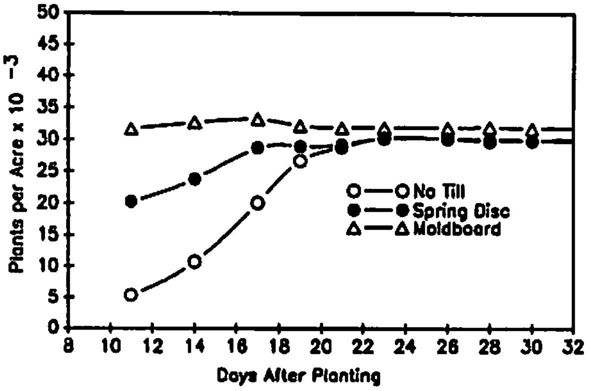
GROWING DEGREE DAYS FROM PLANTING TO FROST OR HARVEST, STAPLES, MN.

Figure 1. Cumulative growing degree days between planting and either frost or harvest, which ever came first.

THE EFFECT OF TILLAGE ON EMERGENCE
OF FIRST YEAR CORN FOLLOWING ALFALFA
STAPLES, MN., 1987



THE EFFECT OF TILLAGE ON EMERGENCE
OF SECOND YEAR CORN FOLLOWING ALFALFA
STAPLES, MN., 1988



THE EFFECT OF TILLAGE ON EMERGENCE
OF THIRD YEAR CORN FOLLOWING ALFALFA
STAPLES, MN., 1989

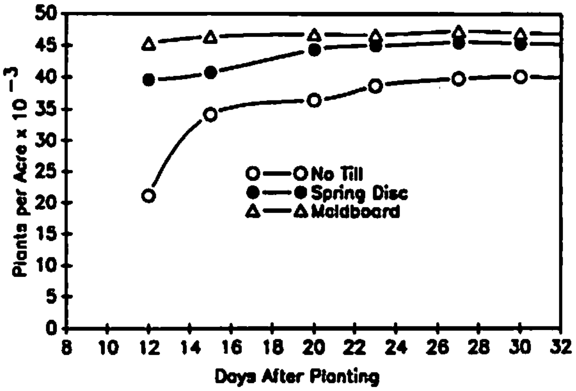
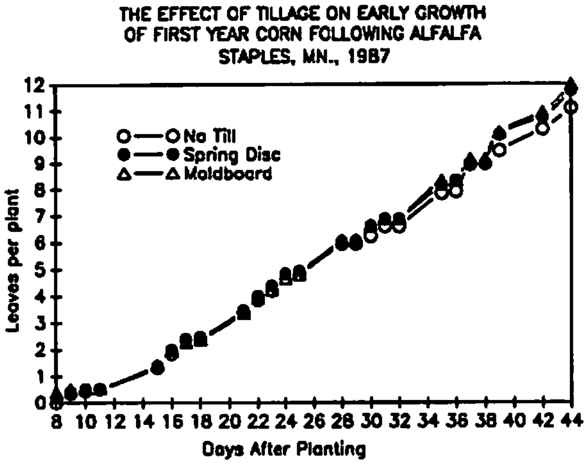
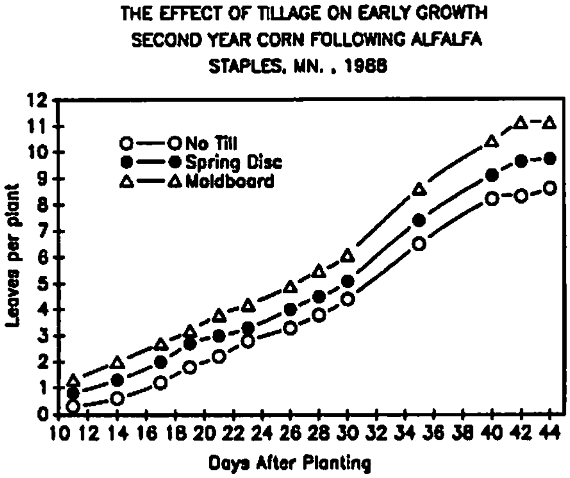


Figure 2. The effect of tillage on the rate of corn emergence following alfalfa.





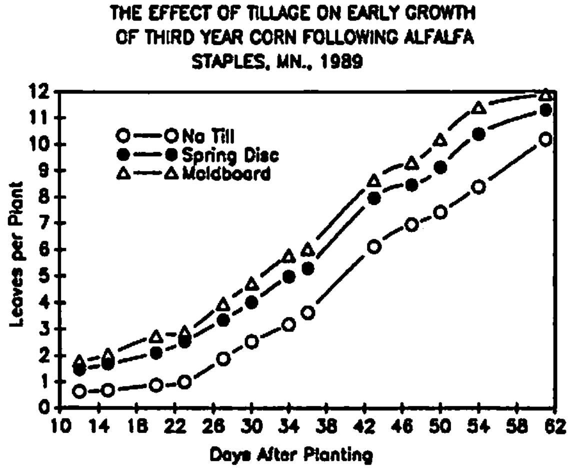
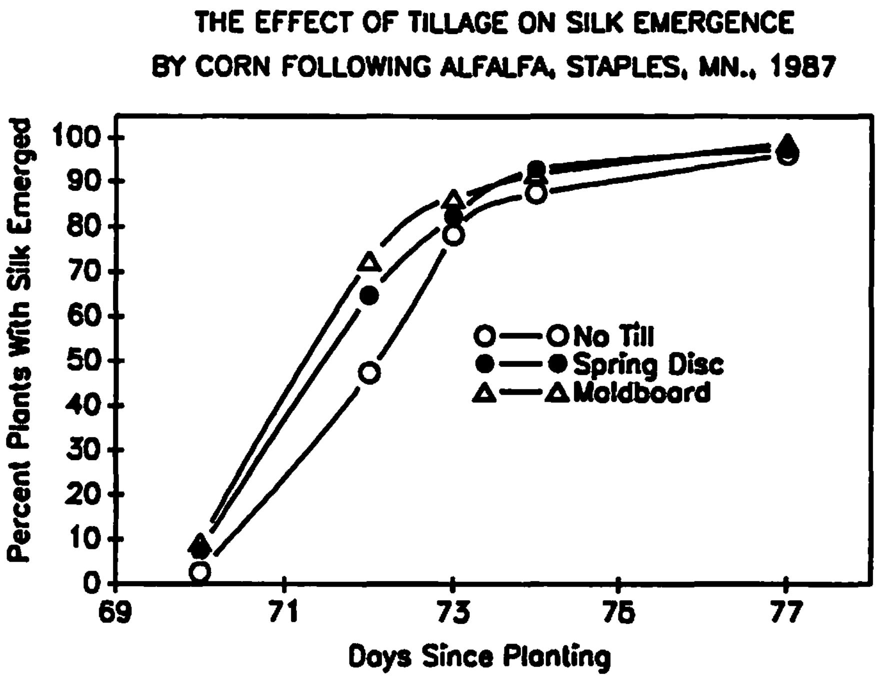


Figure 3. The effect of tillage on early growth of corn following alfalfa.


THE EFFECT OF TILLAGE ON SILK EMERGENCE BY CORN FOLLOWING ALFALFA, STAPLES, MN., 1987

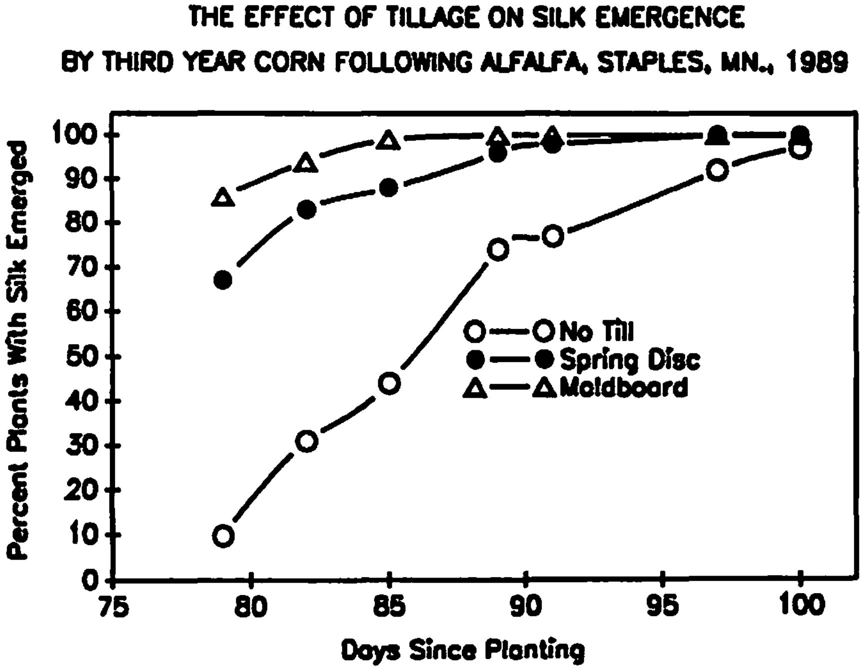

THE EFFECT OF TILLAGE ON SILK EMERGENCE BY THIRD YEAR CORN FOLLOWING ALFALFA, STAPLES, MN., 1989

Figure 4. The effect of tillage on the rate of silk emergence by first and third year corn following alfalfa.

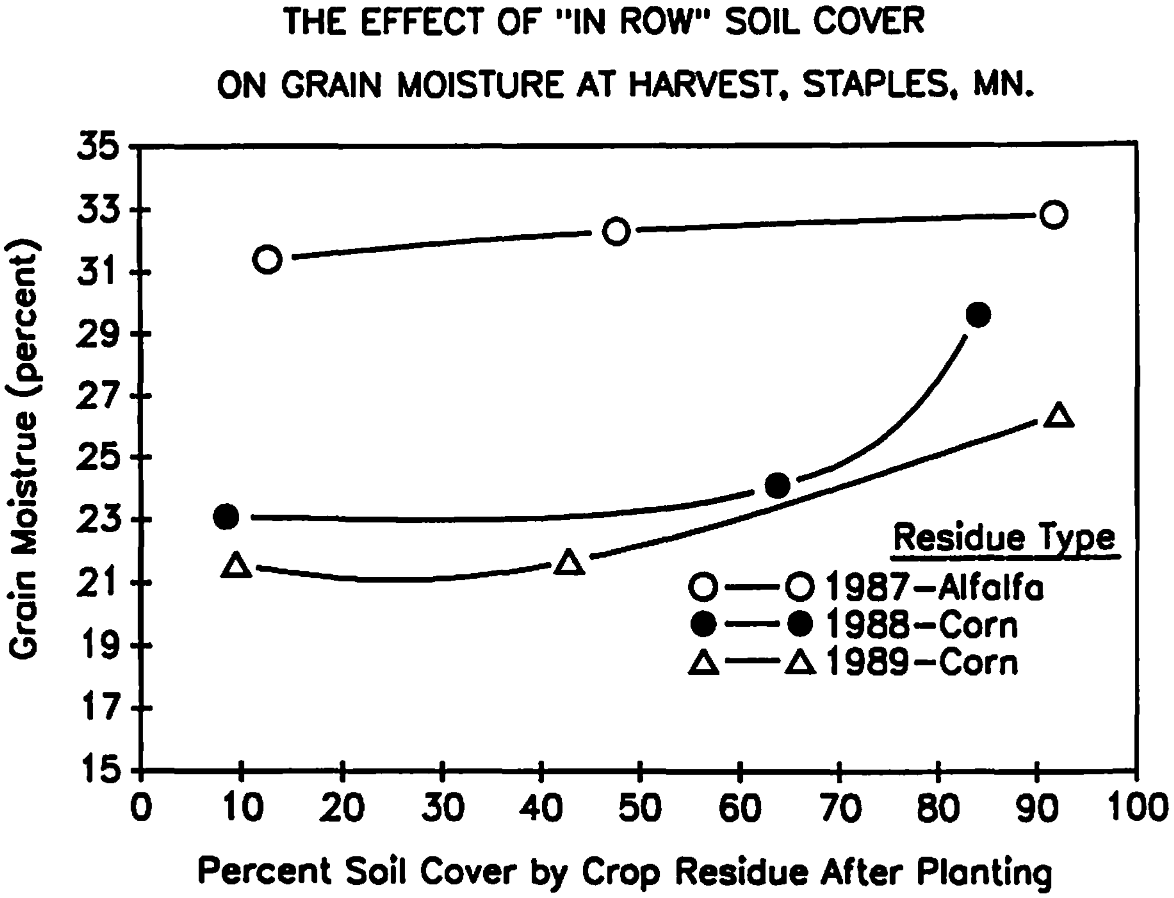
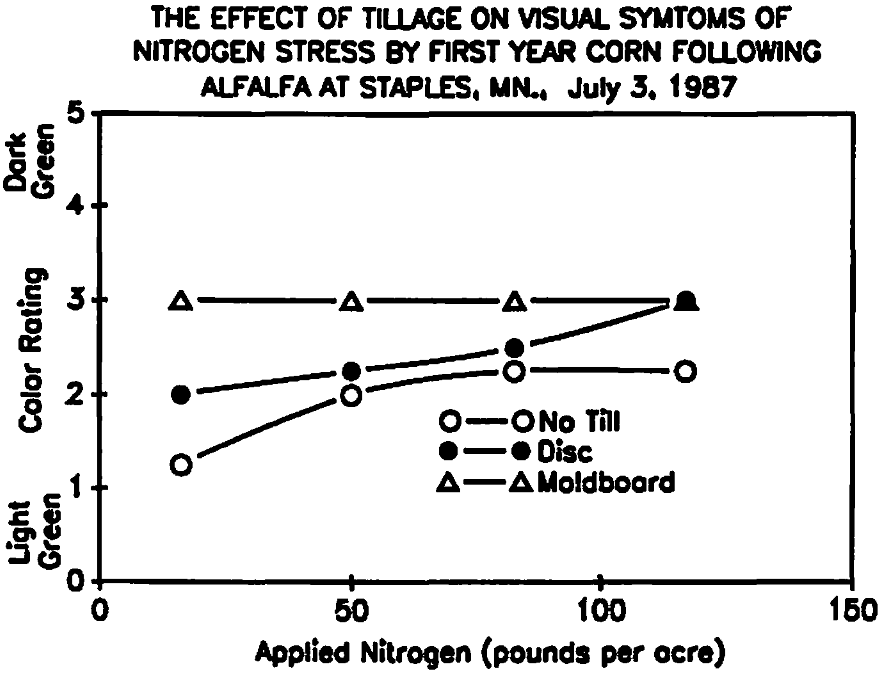


Figure 5. The effect of soil cover in the row by crop residue on corn grain moisture levels at harvest.



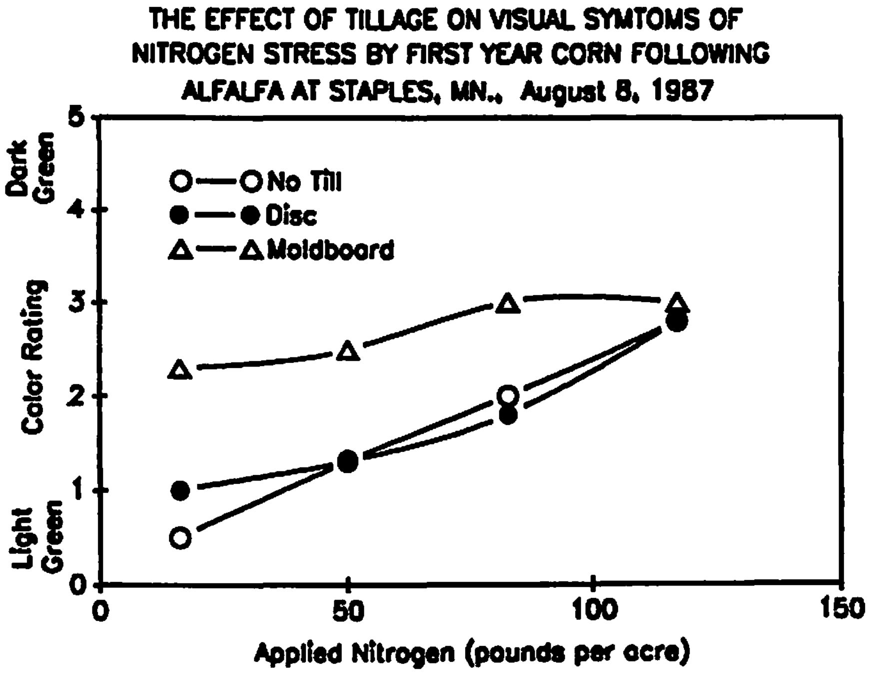
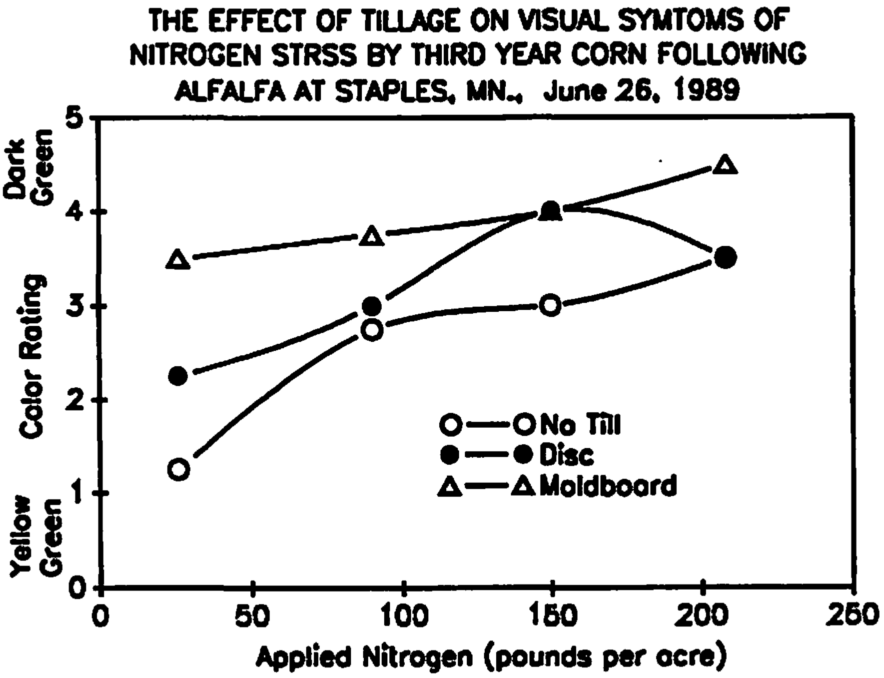


Figure 6. The effect of tillage and applied nitrogen on visual symptoms of nitrogen deficiency by first year corn following alfalfa.



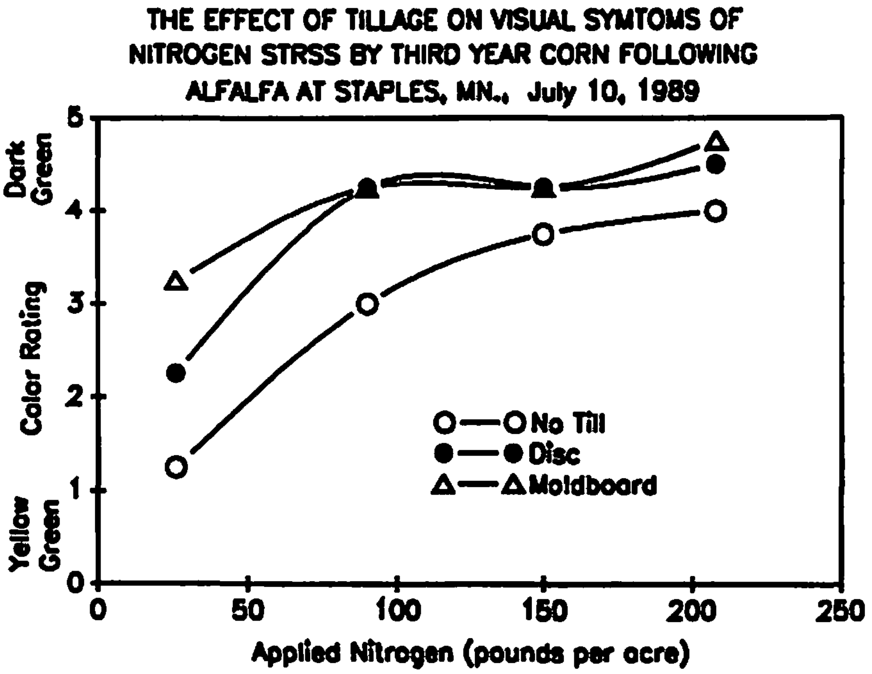
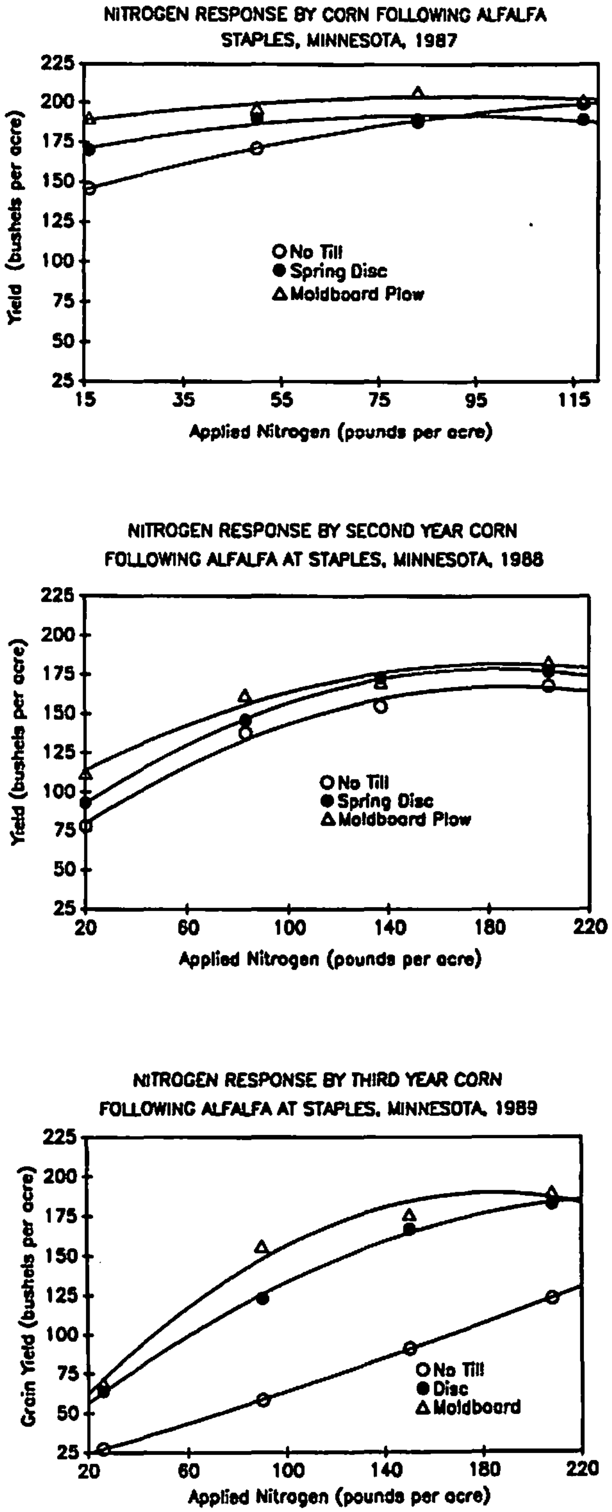


Figure 7. The effect of tillage and applied nitrogen on visual symptoms of nitrogen deficiency by second year corn following alfalfa.



NITROGEN RESPONSE BY CORN FOLLOWING ALFALFA STAPLES, MINNESOTA, 1987

NITROGEN RESPONSE BY SECOND YEAR CORN FOLLOWING ALFALFA AT STAPLES, MINNESOTA, 1988

NITROGEN RESPONSE BY THIRD YEAR CORN FOLLOWING ALFALFA AT STAPLES, MINNESOTA, 1989

Figure 8. The effect of tillage and applied nitrogen on the grain yield response by corn following alfalfa.

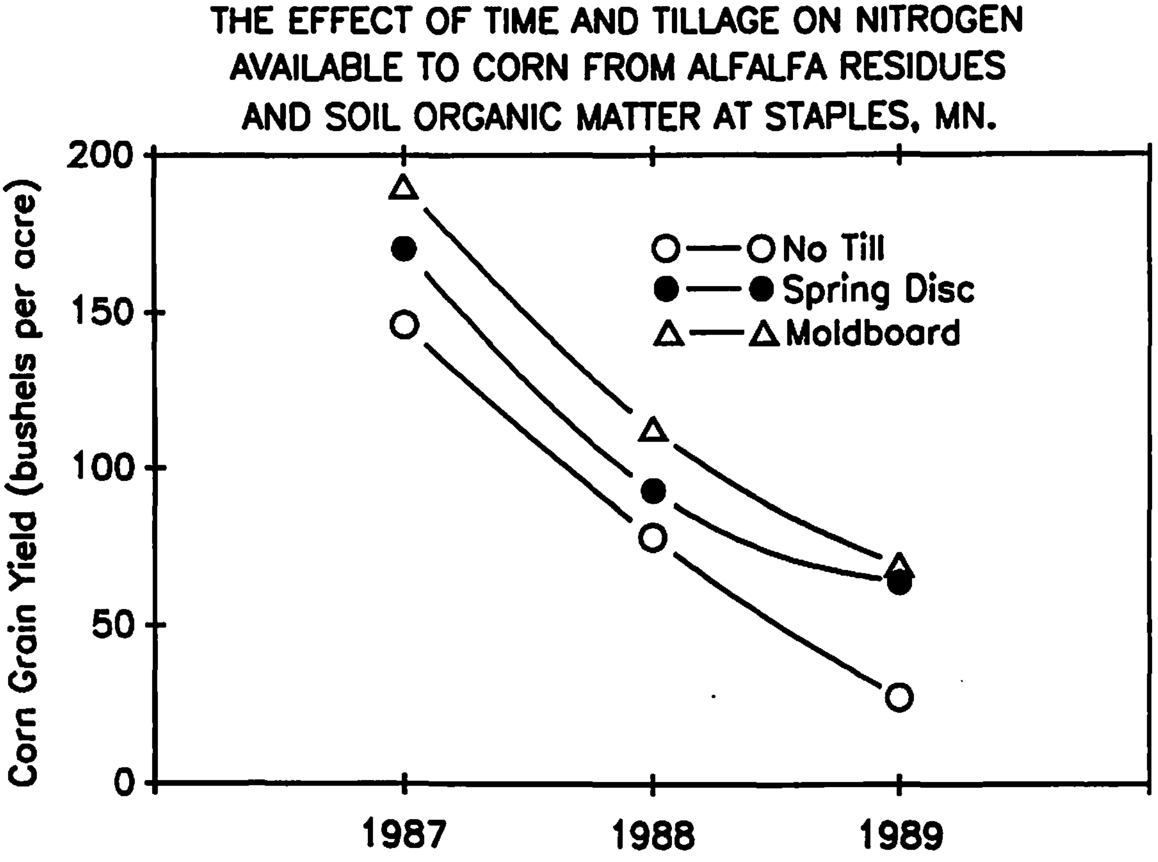


Figure 9. The decrease over time of nitrogen available to corn following alfalfa.

CORN-TILLAGE RESIDUE MANAGEMENT, LANCASTER, WI. 1989

J.B. Swan, A.E. Peterson, W.H. Paulson, R.L. Higgs, and D.L. Linden[1]

ABSTRACT: Growing conditions were generally favorable in 1989 and corn yields for continuous corn ranged from 135 bu/A for no-till bare to 171 bu/A for the no-till normal residue treatment. Corn residue significantly increased yields on the no-till treatments. No-till bare treatments had significantly lower plant populations than no-till normal treatments. Surface residue treatments emerged later, silked later, and had higher grain moisture at harvest than comparable tillage treatments without surface residue. Surface residue decreased planting depth on conventional (moldboard), chisel and Bush Hog tillage treatments. Depth to residuum again affected grain yields with lowest Rep avg. yield (153 bu/A) on the shallowest depth (29 inches in Rep. 1) and greatest Rep. avg. yields (165 bu/A) on the 46-inch depth (Rep. 3). Exactly 1.00 inch of rainfall occurred after planting prior to installing the runoff plots, and final 20-minute infiltration rates were all below 0.6 in/hr. on the treatments without surface cover (no-till bare and normal moldboard). Infiltration rates on mulch treatments ranged from 1.28 to 2.72 in/hr.

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., 1987a). A simulation model (NTRM) 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., 1987b). 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 (Stricka, 1984, and Swan et al., 1990). 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 loss from cropland in Minnesota, ranging from 4.0 to 6.6 t/A/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 the 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 and 80 percent surface cover. Plots are approximately 90 to 100 feet in width and 80 feet in length. Row width was 36 inches in 1989. Pioneer 3737 was planted April 27 at 31,000 plants per acre. The conventional (moldboard) treatment was plowed on April 25, chisel and conventional tillage plots were both disked on April 25, and corn residue was applied on April 25 and 26. No-till was 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 90-inch area over the row. Fluted coulters were used on all four rows on the other tillage treatments.

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Nitrogen (250 lbs/A) was broadcast as urea. Starter fertilizer at planting was 200 lbs/A of 6-24-24. The insecticide was 7 1/2 lbs/A of Counter. Pre-emergence herbicide was applied on April 26 before planting (2.5 of Bladex 80W and 2.5 pt/A of Dual 8E). A post emergence application of 1 pt/A of Banvel was made on May 24.

Percent cover was determined from slides taken June 6, 1989. 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 Bush Hog treatments in Rep 3. for mulch added, bare and normal treatments. Soil temperature was measured at depths of 1, 6, 11, 16, and 50 cm. Yields for individual plots were determined by hand harvesting 60-foot of row (two subsamples each consisting of paired 15-foot lengths of row) in October.

Ten plot frames (45 3/4 by 45 3/4 inches) were emplaced the first week in May after exactly 1.00 inches of precipitation. Infiltration measurements were made on Bush Hog mulch, no-till bare and mulch, and conventional normal and mulch treatments during the period June 5 through June 8. Tensiometer measurements were made within the plot frame at depths of 3, 7, and 16 inches.

Results-Corn Yields and Crop Height:

Although precipitation was below normal in April, May, June, and July, and was 3.52 inches below normal for the April-October growing season, corn yields ranged from 135 to 171 bu/A. Above average rainfall in August and close to normal air temperatures in 1989 contrasted dramatically with the severe drought and temperature extremes experienced in 1988. Grain yields of individual treatments were significantly different at the 1 percent level, and grain yields were significantly different at the 5 percent level between reps. Grain yields on the no-till bare treatment were significantly reduced compared to all other treatments. Yields on the no-till normal treatments were also significantly greater than the no-till mulch TW treatment. Normal and mulch treatments on the Bush Hog, Chisel, and conventional tillage treatments were not significantly different although plant population was reduced 1400 to 2600 plants per acre on the mulch treatments compared to the normal residue treatments. Plant population was significantly different at the 1 percent level and was not significantly different between reps. Plant population on the no-till normal, no-till mulch coulter, chisel normal and conventional normal treatments were significantly greater than on the no-till bare coulter, no-till mulch TW, and conventional mulch treatments. Tillage and residue effects on grain moisture were not significant.

Corn height reductions on no-till bare, relative to other no-till treatments, were measured starting July 3, 67 days after planting. Height reductions occurred later (about July 17) on the Bush Hog normal treatment. Except for the no-till bare and Bush Hog normal treatments, final corn heights for all other treatments ranged between 180-192 cm. These results contrast markedly with 1988 when a reversal of crop height for high and low cover treatments occurred on all treatments.

Seedbed Conditions and Corn Growth:

Surface residue reduced average seed depth and increased the standard deviation of seed depths on Bush Hog, chisel, and conventional tillage treatments. Compared to the no-till bare treatment, no-till mulch slightly increased seed depth. The no-till mulch TW treatment had lower standard deviation of seed depth than the no-till bare treatments. The effect of mulch on seed depths appeared to be less on no-till than on tilled treatments. Emergence (75%) was delayed from 5 to 8 days by mulch additions, while silking (50%) was delayed 1 to 2 days by mulch additions (Tables 1 and 4). Differences in grain moisture due to treatment were not significant.

Effect of Treatments on Infiltration Rate:

Large differences in "final" (40-60) minute average infiltration rates were measured between treatments in 1989 (Tables 5 and 6). Final infiltration rates from conventional tillage mulch treatments were approximately 5 times the rates for conventional tillage normal treatments. For the nine-year period of measurement, mulch has approximately doubled the infiltration rate on conventional tillage. Infiltration rates on the Bush Hog mulch treatment were also much greater than the conventional normal treatments. On the no-till treatments, double mulch increased final infiltration rates by nearly a factor of 6 in 1989. For the six years of data (1984-1989), double mulch increased the infiltration rate an average of 50 percent on the no-till treatment.

Matric potential measurements on the conventional mulch treatment were frequently positive indicating a flow restricting layer below the plow layer. Negative potential measurements at the three-inch depth under the conventional normal treatment indicate the presence of a surface crust, which is confirmed by the reduced infiltration rates. So little water entered the no-till bare treatment that half the tensiometers at the three-inch depth did not indicate any water entering due to infiltration. The erratic nature of the tensiometer measurements on the no-till mulch is in accord with other measurements and observations of the major role of macropores in infiltration on this treatment.

The results again illustrate the requirements 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 has not been 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. Ten-year yield results (1979-1989) show nearly equal yields for conventional, chisel and no-till treatments (Table 8). In 1986, 1987, 1988, and 1989, 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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Table 1. Effect of tillage and residue management on, planting depth, emergence, silking date, population, grain moisture and yield - 1989, Lancaster, WI.

Treatments			Percent Cover		Planting Depth		Days Post Plant to 75% Emerg	Date 50% Silked July	Ave. Popln at Harvest PL/A	Ave.* Grain Yield Bu/A	Ave. Grain Moisture %
Tillage	Residue	In-Row Residue Mgt.	In-Row	Entire Area	Avg mm	S.D. mm					
No-Till	Normal	C			20.8	6.7	24.8	21.5	ab 27,230	a 171.4	18.1
	(N)	TW			22.1	4.9			a 28,560	ab 167.4	19.0
	Bare	C			25.9	6.4	23.5	22.8	e 22,690	d 134.8	17.6
	(O)	TW			26.5	6.4			cde 23,780	d 137.1	17.5
	Mulch	C			27.6	7.0	28.3	22.8	abc 26,620	ab 170.2	18.2
	(2X)	TW			27.8	4.4			de 23,410	c 153.0	18.4
Bush Hog	Normal(N)	C			28.9	5.5	25	21.3	abcd 26,260	bc 162.9	17.9
	Mulch(2X)	C			23.0	8.5	29	23.5	bcde 24,870	abc 159.6	18.4
Chisel	Normal(N)	C			31.0	5.0	25.7	21	abc 26,680	abc 156.5	17.5
	Mulch(X)	C			22.6	6.2	33.5	23.3	cde 23,900	abc 161.1	17.6
Conv.	Normal(N)	C			30.0	4.9	25.3	21.3	abc 26,920	abc 158.6	17.9
	Mulch(X)	C			21.4	8.4	33	23.8	de 23,290	ab 170.2	18.7
	Significance Level								0.01	0.01	NS

*Subplots with population <23,500 omitted

Table 2. 1989 Weather Summary, Univ. of Wisconsin, Lancaster Agricultural Research Station.

Month	Precipitation		Growing Degree Days		Air Temperatures			
	Total	Departure	1989	Departure	Avg. Max.	Avg. Min.	Avg. Daily	Departure
	- - - inches - - -		- - - - - - - - - -	- - - - - - - - - -	- - - - - - °F	- - - - - -	- - - - - -	- - - - - -
April	2.28	-0.72	-	-	56.4	34.1	45.2	-1.8
May	2.34	-1.07	245	-67	67.9	45.1	56.5	-1.5
June	2.44	-1.90	497	-22	78.1	54.3	66.2	-0.9
July	2.51	-1.82	701	+37	85.6	62.2	73.9	+2.2
Aug	5.16	+0.71	591	-2	80.0	58.4	69.2	+0.2
Sept	3.31	-0.24	272	-83	70.2	47.3	58.8	-2.2
Oct.	3.71	+1.32	-	-	61.8	38.4	50.1	+0.1
Total Growing Season	21.75	-3.52	2306	-122				

Last date in spring with minimu temperature:
32° or less 5/7
28° or less 5/7

First day in fall with minimum temperature:
32° or less 9/23
28° or less 10/13

Table 3. Average yields and depth of clay residuum by replicate and monthly precipitation for 1981 through 1989, Lancaster, WI.

	Replicate Number				Monthly Precipitation			
	1	2	3	4	May	June	July	August
Year	Bu/A				inches			
1981	146.8	146.7	142.1	147.1	0.83	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	56.2	64.6	62.6	0.87	0.42	1.80	2.92
1989	152.8	159.3	165.0	157.1	2.34	2.44	2.51	5.16
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 of 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 - Aug. 31 (45 days).
***1985 - 1.59 inches precipitation from May 28 to July 25 (57 days).
Largest rain was 0.36 inches.

Table 4. Influence of tillage method and residue management on rate of emergence, 1989, Lancaster, WI.

Treatment		Percent Emergence								
		Days Post Plant								
Tillage	Residue	20	22	24	26	28	31	35	40	48
No-Till	Normal	1	20	67	86	97	100	100	100	100
	Bare	7	41	81	89	98	100	100	100	100
	Mulch	0	4	22	50	73	92	94	97	100
Bush Hog	Normal	2	14	57	79	97	99	100	100	100
	Mulch	0	1	13	42	63	79	84	91	100
Chisel	Normal	2	15	54	79	94	97	100	100	100
	Mulch	0	1	20	34	60	69	79	84	100
Conv	Normal	4	16	59	83	98	99	100	100	100
	Mulch	0	1	11	26	52	61	90	95	100
GDD from plant Date April 27										

April 17 = Day 1

Table 5. 1989 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	4.24	0.12	0.88	0.64	0.40	0.16	0.16	0.40	0.40	0.40	0.40	0.40	0.16	0.16
		W	4.32	0.11	0.96	0.72	0.72	0.48	0.48	0.48	0.48	0.96	0.48	0.24	0.24	0.48
	Mulch	E	4.00	0.42	1.60	1.36	1.60	1.60	1.12	1.12	1.12	1.60	1.36	1.36	1.36	1.60
		W	4.00	0.35	2.56	2.08	2.08	2.08	2.08	1.84	1.60	1.84	2.08	2.08	2.08	2.08
Conv.	Normal	E	4.16	0.45	2.00	1.04	0.80	0.80	0.56	0.32	0.32	0.80	0.80	0.80	0.56	0.56
		W	3.84	0.28	1.56	1.44	0.48	0.48	0.36	0.24	0.24	0.24	0.12	0.24	0.24	0.24
	Mulch	E	3.68	1.23	3.20	2.48	2.48	2.48	2.24	2.00	2.48	2.48	2.72	2.72	2.72	2.72
		W	4.16	0.42	2.48	2.24	2.00	1.76	2.24	2.24	1.76	2.00	1.76	1.52	1.52	2.00
Bush Hog	Mulch	E	3.92	0.71	3.20	2.36	2.12	2.00	1.76	1.28	1.04	1.04	1.40	1.40	1.52	1.28
Ro-Till		W	4.00	1.50	2.64	2.64	2.52	2.52	2.52	2.52	2.16	2.16	2.16	2.16	2.04	2.04

Table 6. Infiltration rate 55 minutes after runoff begins (paired observations), Lancaster, 1989.

Tillage	Treatment Residue	1981	1982	1983	1984	1985	1986	1987	1988	1989	Avg.
		inches/hour									
No Till	Bare	--	--	--	1.68	1.00	1.24	1.26	0.84	0.32	--
	Mulch	1.46	1.10	3.53*	0.60	3.02	2.10	1.22	0.82	1.75	1.73
Conv	Bare	0.97	1.52	0.54	1.70	1.40	1.83	1.15	1.80	0.45	1.26
	Mulch	2.72	2.34	1.49	2.90	2.14**	2.25	4.81	2.58	2.21	2.60
		Ratio									
Conv. Bare/Conv. Mulch		0.36	0.65	0.36	0.58	0.65	0.81	0.24	0.70	0.20	0.48
No Till Mulch/Conv. Bare		1.51	0.72	6.53	0.35	2.16	1.15	1.06	0.46	3.89	1.37

* 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 - 1989 Lancaster.

				cm soil depth			
Treatment			Infilt	7.5	7.5	17.5	40
Tillage	Residue	Rep.	in./hr	- - - - - - cm H_2O - - - - - -			
No-Till	Bare	E	0.28	-12	-222	+12	-290
		W	0.36	-39	-438	-48	-392
	Mulch	E	1.42	-14	-18	+13	-54
		W	2.08	-13	-5	+4	-8
Conv	Normal	E	0.68	-30	-38	-1	-104
		W	0.21	-10	-3	-1	-
	Mulch	E	2.12	0	-7	+10	+15
		W	1.70	0	+4	-17	-54

Table 8. 1979 - 1989 Continuous corn tillage yield results, Lancaster, WI.

Tillage Treatment	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	79-83	79-89
with normal residue	- bu/A - - - - - - - - - - - - - - - - -												
Ridge plant	162	157	157	147	100	---	---	---	---	---	---	145	---
No-Till (slot plant)	163	146	151	141	85	108	120	165	177	59	171	137	135
Chisel	160	150	167	154	95	115	125	159	168	57	157	145	137
Conventional	169	159	168	151	89	121	133	164	168	43	159	147	139
Paraplow*	---	---	---	---	---	106	125	162	---	---	---	---	---
Bush Hog	---	---	---	---	---	---	---	---	172	54	163	---	---

* Fall 1983 and Fall 1984