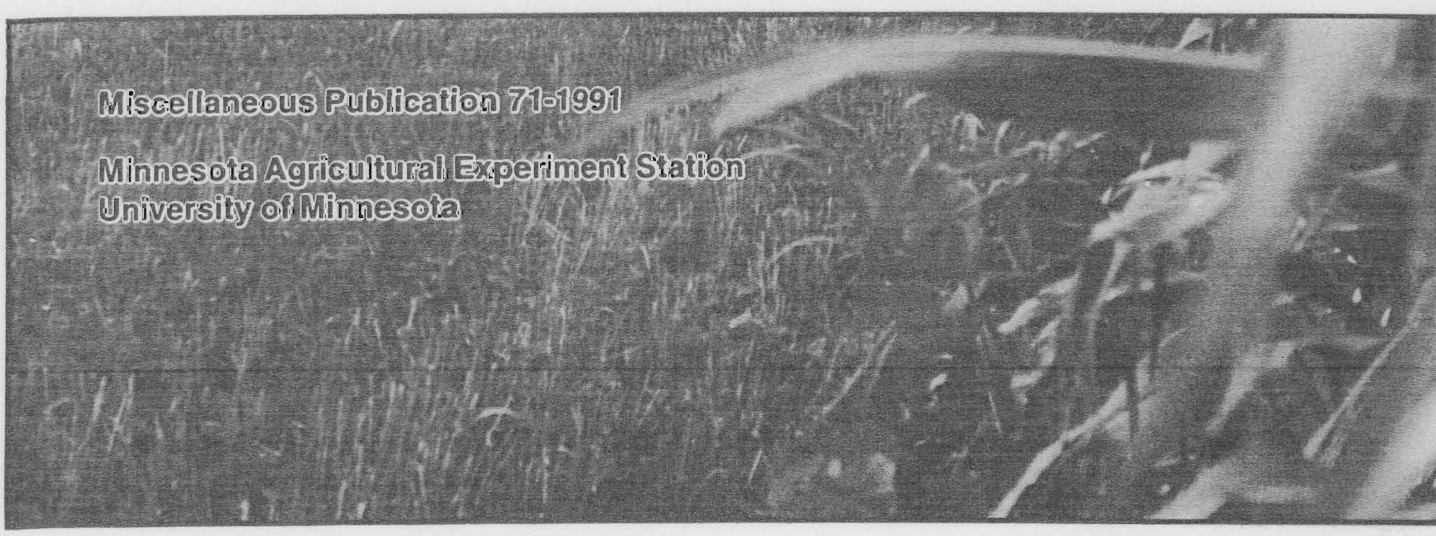
A Report on Field Research in Soils 1991



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Minnesota Agricultural Experiment Station
University of Minnesota

A Report on Field Research in Soils

1991

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SOIL SERIES 132
A Report on Field Research in Soil Science

ACKNOWLEDGEMENTS

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.

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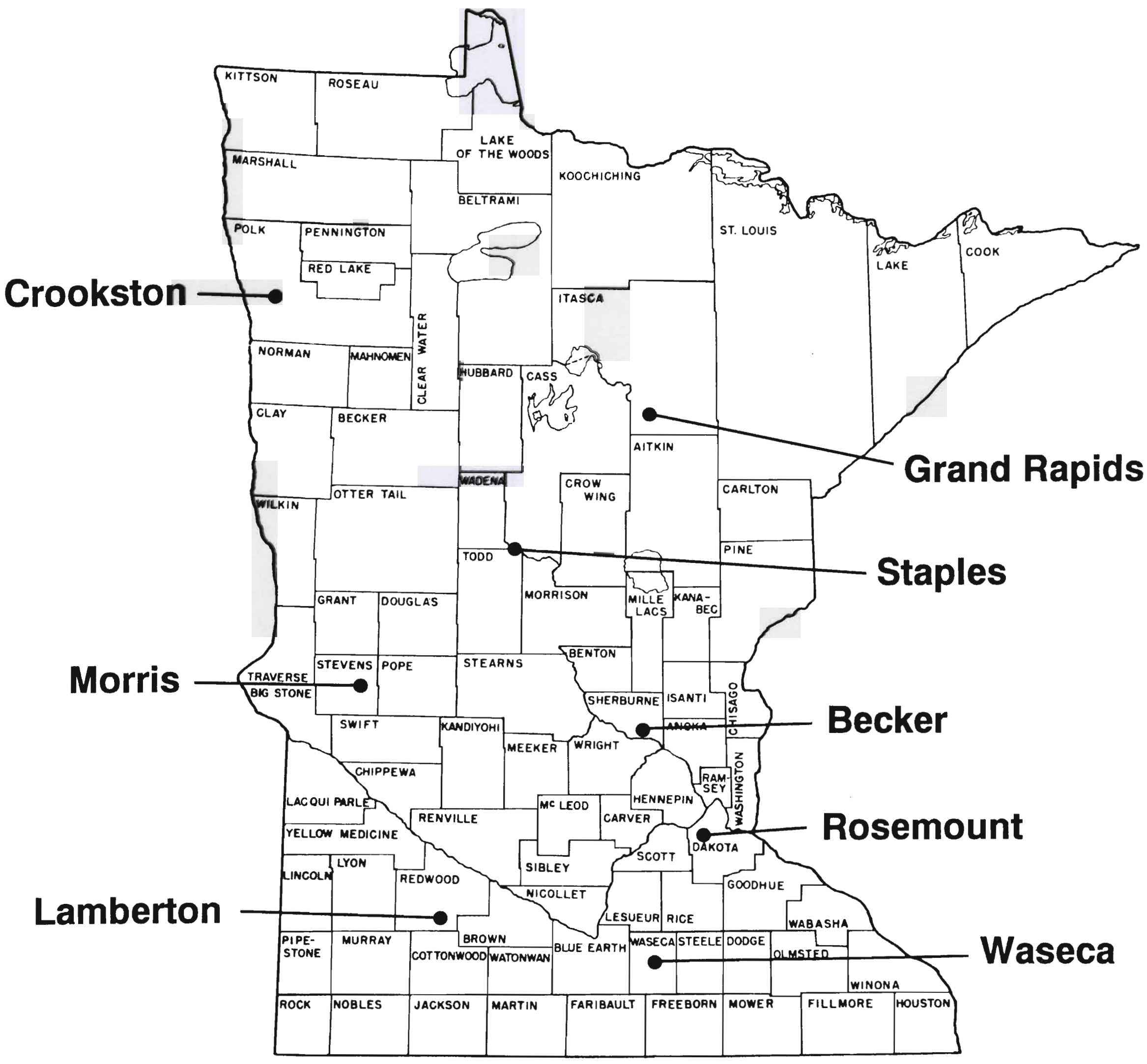
NOTE TO CATALOGERS AND LIBRARIANS

This is the second year of the soils "bluebook" being published as a newly numbered item within the Miscellaneous Publication series. Prior to the 1990 edition this publication was produced as number "2" annually revised. That was changed to gain consistency with numbering patterns for other annual reports of ongoing research published by the Minnesota Agricultural Experiment Station.

-- Series Editor

MINNESOTA AGRICULTURAL EXPERIMENT STATION
BRANCH STATIONS AND RESEARCH FARMS



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FALL 1990 SOIL MOISTURE

W. W. Nelson, S. Evans, G. W. Randall, J. Lamb, D. L. Ruschy,
D. G. Baker, State Climatology Office and the S.C.S. Personnel
of Mille Lacs, Sibley, Todd and Wabasha Counties.

The autumn 1990 soil moisture picture for the state is good for that part of the state south and east of a line running from Ortonville to Hibbing. Because there is normally only very small additions to the soil moisture by the over-winter precipitation, the present condition represents quite well the expected early spring 1991 situation.

In the northwestern counties of the state, essentially Polk County northward and in smaller areas in the north central part of Minnesota soil water is very low. Where the soil was fallow or in small grains the situation is not quite as critical as where a full season crop such as sugarbeets was grown. The region south of this area, essentially the central and southern part of the Red River Valley is a bit better, but is also well below average.

The soil moisture values shown in Fig. 1 represent the total plant available water in a 5-foot column of soil. Although there are but nine sites there are several hundred stations where the November precipitation data are available. As a result a general but by no means detailed map of soil moisture can be made.

The map, Fig. 1, shows three important items:

1. Soil moisture
   a. The location of the 9 soil moisture sites.
   b. The total plant available water content in the 5-foot column of soil.
   c. The percent of the total plant available capacity that is occupied by water.
   d. The crop that was grown in 1990.

2. Precipitation
   a. Lines of equal amounts (isolines) of November precipitation that can be added to the indicated soil moisture values which were measured in October.

3. Soil moisture shortage
   a. The area of extreme northwestern Minnesota where moisture supplies are believed to be most critically short is indicated by the dashed line.

The biweekly soil moisture values at Crookston, Lamberton, Morris and Waseca are shown in Fig. 2-5. The final sample at Lamberton is about 1 inch above average and at Waseca it is about average. The Crookston and Morris values are low. The Crookston soil moisture value would be much lower if the crop had been sugarbeets rather than small grain. The Morris value is a reflection of a relatively dry streak that is oriented NE to SW through the Morris area. Immediately to the north and, particularly to the south, the moisture status is better.

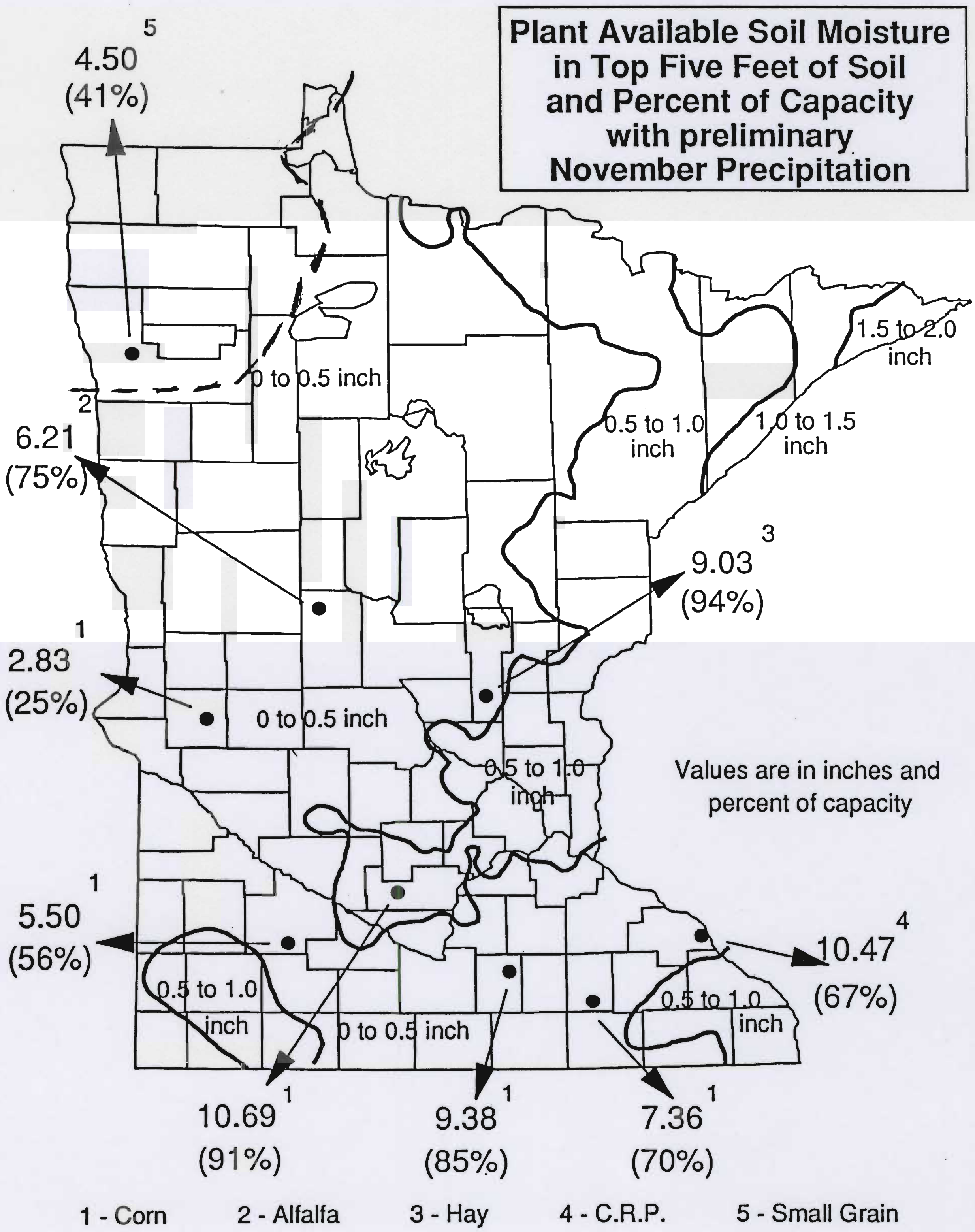


FIGURE 1. LATE AUTUMN 1990 SOIL MOISTURE

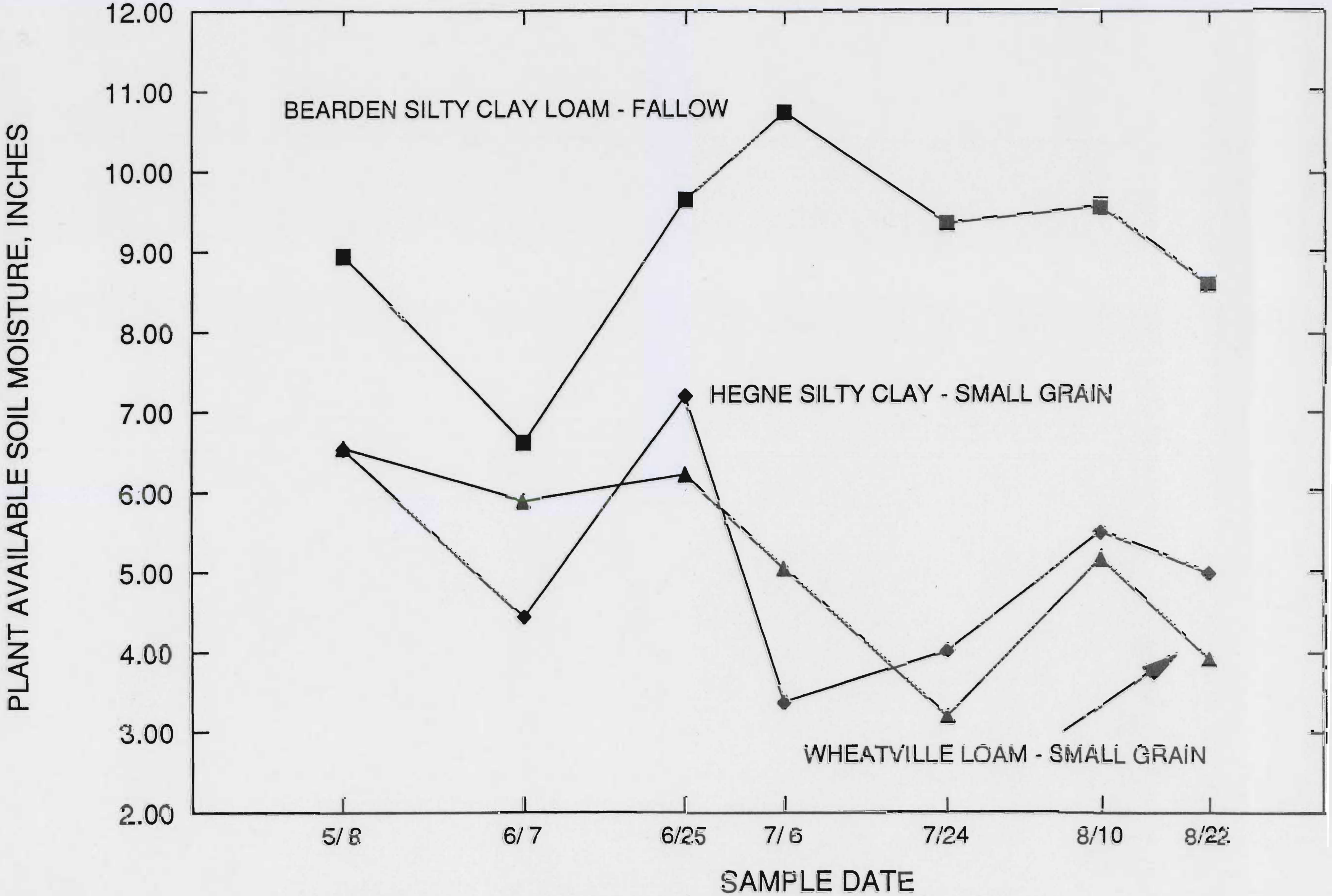


FIGURE 2. CROOKSTON 1990 SOIL MOISTURE DATA

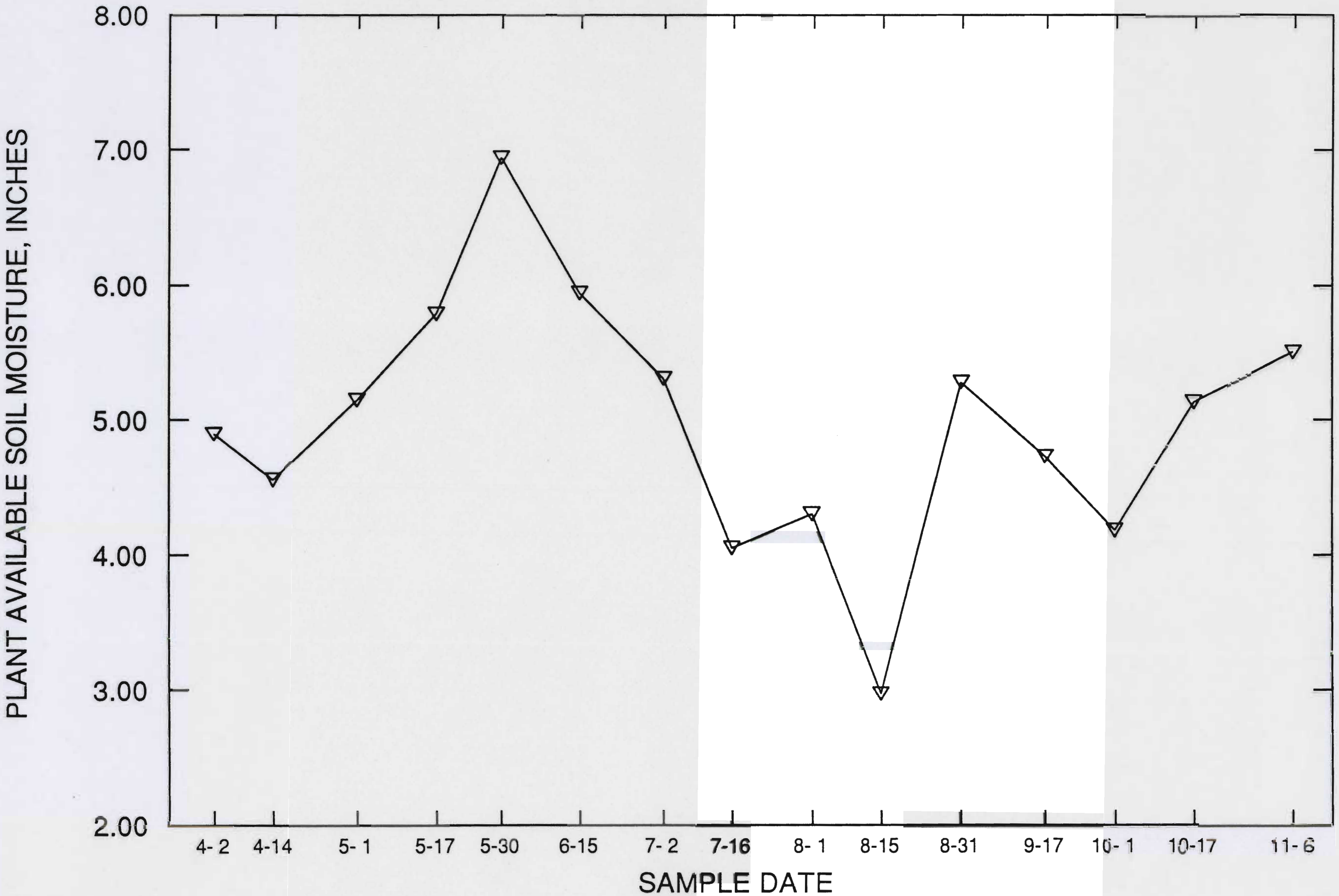


FIGURE 3. LAMBERTON 1990 SOIL MOISTURE DATA

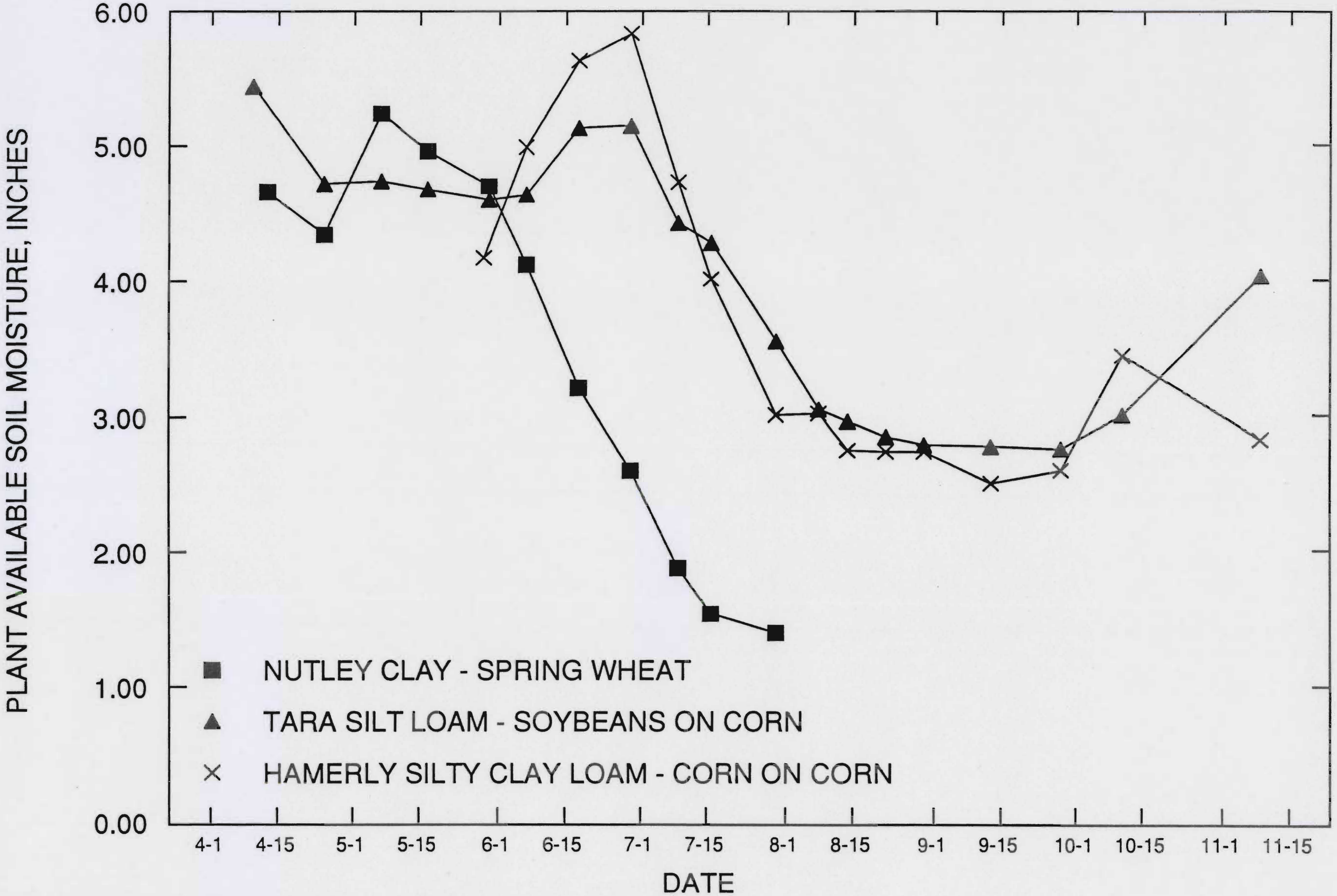


FIGURE 4. MORRIS 1990 SOIL MOISTURE DATA

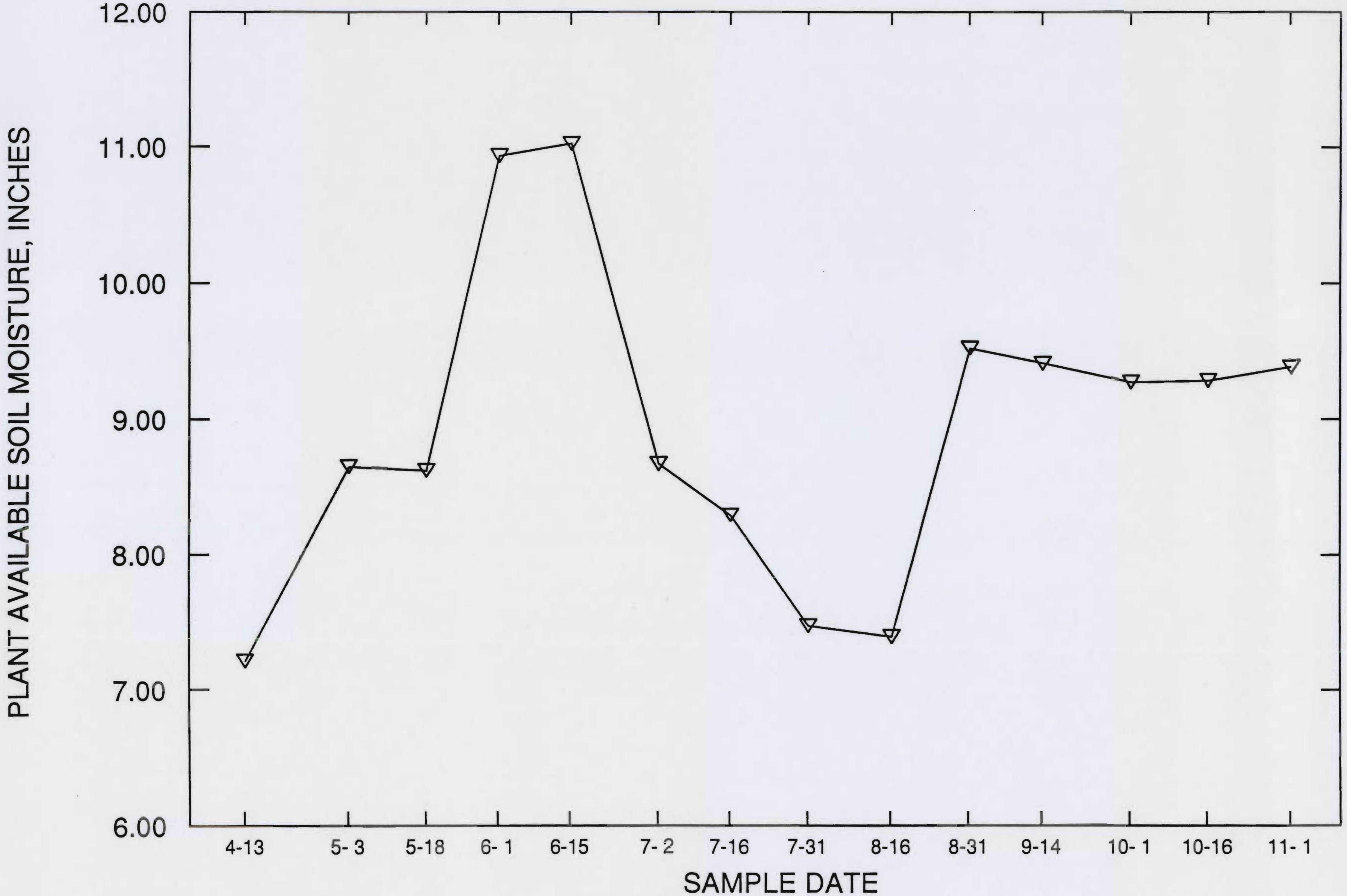


FIGURE 5. WASECA 1990 SOIL MOISTURE DATA

WATER YEAR CLIMATE SUMMARY
October 1989 - September 1990

Greg Spoden and James Zandlo, State Climatology Office,
and D. G. Baker

Despite the green lawns and the above average agricultural productivity observed in the 1989 growing season, the overall water picture at the onset of the 1989-1990 Water Year was grim. The relatively meager rainfall that fell during the growing season had been immediately swallowed up by thirsty vegetation. Very little surplus water was available to recharge lakes, rivers, wetlands, and shallow aquifers. Minnesota's drought was three years old with little improvement in sight. To aggravate matters, the Fall of 1989 provided less than normal precipitation during this critical recharge period. Not only were the large sinks of water such as lakes and wetlands in a deficient state, but soil moisture in the rooting zone was two to five inches below historical averages in many places. True recovery for most hydrologic systems can occur only after moisture in the soil is replenished.

The Winter of 1989-1990 began with a bitterly cold mid-December where temperatures consistently fell below -20 degrees Fahrenheit. Coupled with a lack of snow, the biting temperatures caused a thorough and deep freezing of the ground that prevented over-winter precipitation from entering the soil. Fortunately the temperature moderated for the remainder of the Winter, resulting in an exceptionally mild January and February. However, snowfall remained a rarity, with much of Minnesota displaying a brown landscape even in late January.

Late Winter and early Spring of 1990 began with a warm and soggy splash. For the first time in many months, heavier than normal precipitation doused the state. Many areas of Minnesota received double their normal March allotment of precipitation. The balmy breezes of March thawed soils two to three weeks ahead of schedule, allowing generous infiltration of the welcome rains. Warm temperatures also advanced lake ice-out by nearly 10 days.

The wet March was a harbinger of things to come. The Spring and early Summer continued at a pace that seemed destined to drown the drought. April and May finished at or above historical precipitation averages, and June produced a deluge of unusual magnitude. Several Minnesota communities waded through puddles resulting from eight to ten inch rainfall totals for the month of June. Excessive wetness was a problem for the first time in four years in southern Minnesota. Heavy rainfall continued into July in the southern half of the state, however areas of western, northwestern, and north central Minnesota were slighted by Mother Nature. By the second week of August, precipitation across the whole of Minnesota diminished abruptly, a pattern that continued to the end of the Water Year with one notable exception, the Cloquet Area flood. For the growing season of April through September, southern Minnesota, bolstered by a soggy June, finished much wetter than the historical average. By contrast, much of northwestern Minnesota once again came up short of normal.

Rainfall events of note included a large storm complex which drenched southeastern Minnesota in April; a succession of thunderstorms which dropped five to seven inches of rain on southwestern and central Minnesota in mid-June; a powerful storm that caused some flooding along a thin strip from the city of Faribault to Wabasha County in early July; and the grand finale, a group of heavy thunderstorms which pounded the Cloquet area in early September.

In summarizing the Water Year, Fig. 1 and 2, we find a contradictory pattern of above normal, even excessive, precipitation in southeastern section of the state, and below normal precipitation in the southwest, west, and north. A state of extreme drought persists in the northwest where no sustained relief has materialized for four years. Elsewhere in Minnesota, despite the wet early summer, the long term impacts of the three year (1987-1989) drought are still being felt. Soil moisture values are adequate to abundant in some areas, nonetheless the overall hydrologic situation is still in need of improvement.

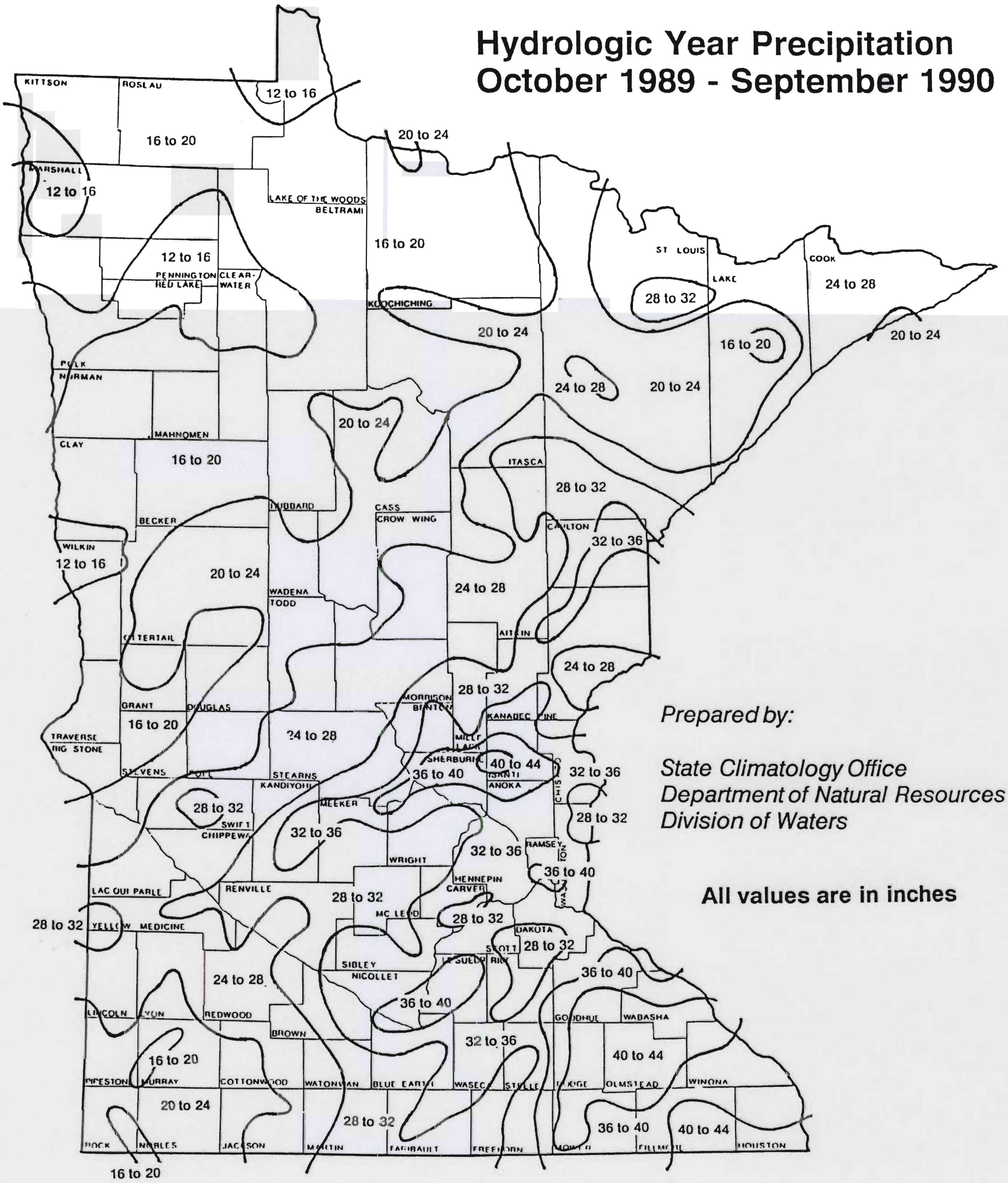
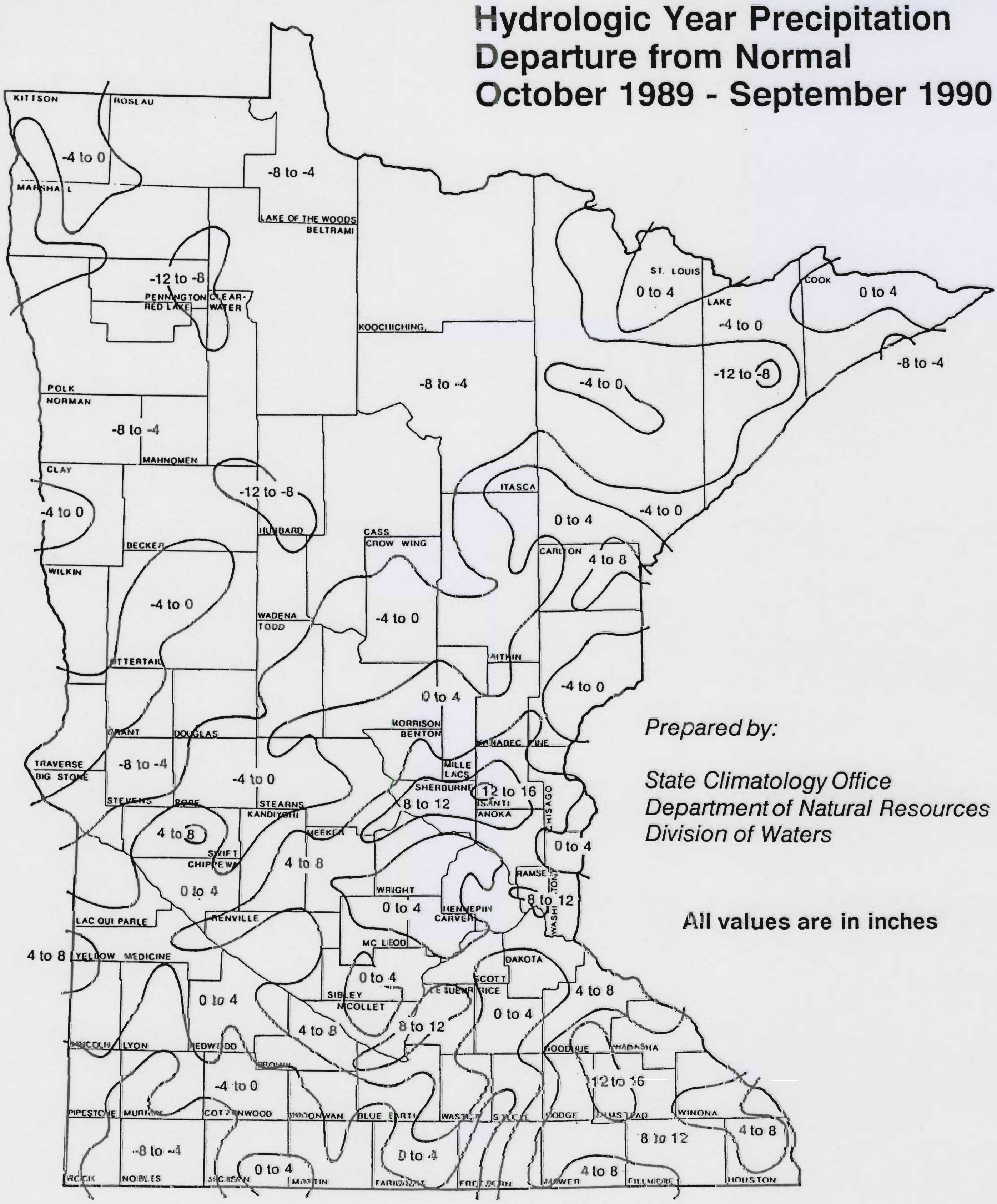


FIGURE 1. HYDROLOGIC YEAR PRECIPITATION

Hydrologic Year Precipitation Departure from Normal October 1989 - September 1990



Prepared by:

State Climatology Office
Department of Natural Resources
Division of Waters

All values are in inches

FIGURE 2. DEPARTURE FROM NORMAL

THE LOW TEMPERATURE EVENTS OF WINTER 1989-90

Donald G. Baker and David L. Ruschy

Several unusual meteorological events occurred during the 1989-90 winter that even now deserve our attention. The first was the outbreak of severe cold weather that lasted from 11 December, 1989, the first date when the minimum air temperature dropped below the long term average, until 25 December when the minimum was back to about average. The effects were much more severe than usual due to the lack of snow cover. A minimum air temperature of -26°F was observed at our climatological observatory on the St. Paul Campus on 21 December. This is not all that low for Minnesota, however, the resulting low soil temperatures, a minimum of 10°F at the 0.4 in and 18°F at the 8 in depth in the soil,point out the value of a good snow cover, which performs as a natural blanket or insulation for the soil.

A plot of the daily minimum soil temperatures under sod from 1 cm (0.4 in.) to 100 cm (40 in.) is shown in Fig. 1. It is evident that freezing temperatures in the soil reached a maximum depth of 97 cm (38 in.). The 60 cm (24 in) frozen layer is much deeper than usual for mid-December, although by late February or early March the mean depth of frozen soil at St. Paul over a 25-year period is about 100 cm (40 in.).

By late December, and for almost the remainder of the winter, the temperatures were unusually mild, except for two brief cold spells in mid-January and again in February (see Fig. 1). For example, a maximum air temperature of 59°F occurred on 12 February only to be followed by a minimum of 0°F on 14 February. This event may have been more serious than the December cold air outbreak, since the alfalfa dormancy probably was broken. What had started out as a record setting winter in terms of depth of soil freezing changed into a mild one. These wild temperature swings in both the air, and more particularly in the soil because of the lack of snow cover, exacted a toll upon the vegetation that is difficult to trace directly because the low temperature period occurred in the winter. The evidence was not apparent until spring. Forage specialists Don Barnes of the ARS, USDA, and Craig Sheaffer and Neal Martin, Agronomy Dept. U of M, estimated that these events damaged about 65% of the state's alfalfa acreage. These same specialists have stated that "most Minnesota alfalfa growers need greater levels of winterhardiness than growers in Wisconsin and Iowa". This is based on good climatology and we certainly agree; both states have milder winters in general and Wisconsin is more apt to have a better snow cover than Minnesota, particularly western Minnesota. The attached map of the state (Fig. 2) shows the areas of severe and moderate alfalfa damage (map courtesy of Barnes, Sheaffer, and Martin).

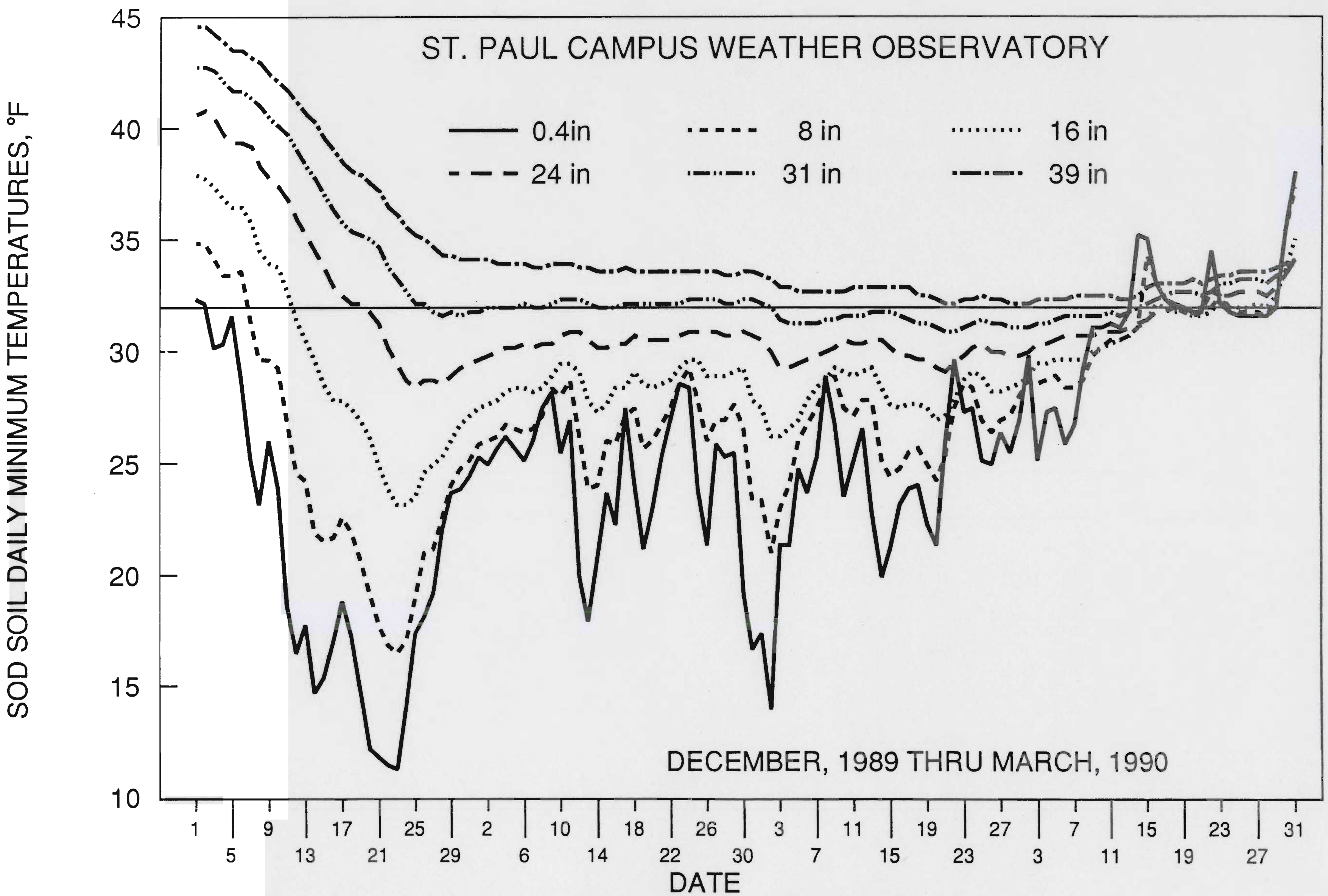
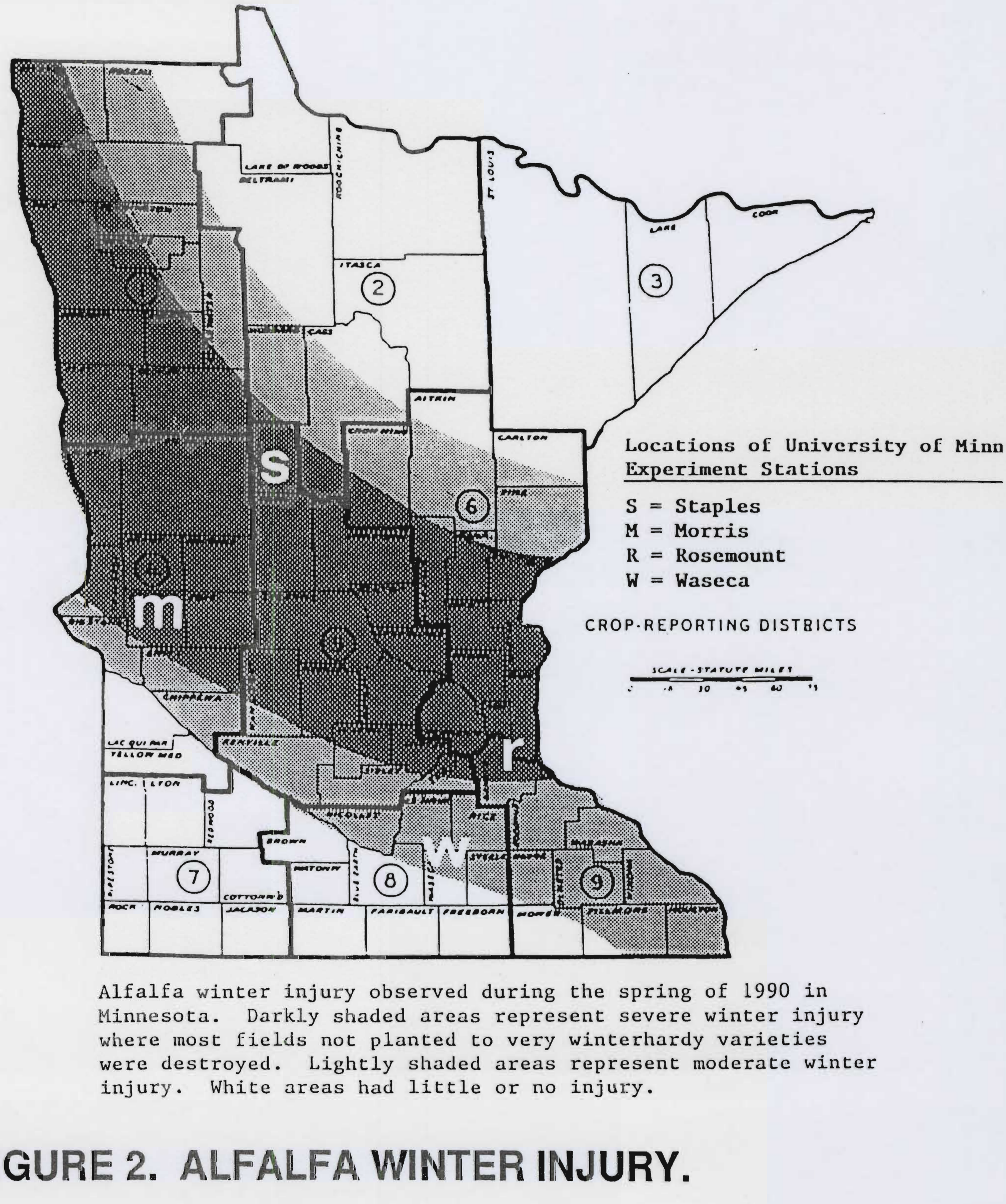


FIGURE 1. SOD SOIL DAILY MINIMUM TEMPERATURES.



Alfalfa winter injury observed during the spring of 1990 in Minnesota. Darkly shaded areas represent severe winter injury where most fields not planted to very winterhardy varieties were destroyed. Lightly shaded areas represent moderate winter injury. White areas had little or no injury.

FIGURE 2. ALFALFA WINTER INJURY.

DAILY PAN EVAPORATION ACROSS MINNESOTA

S. Evans, W. W. Nelson, G. W. Randall, D. G. Baker and D. L. Ruschy

Evaporation pan measurements can serve as useful indicators of the water consumed by a crop when properly applied. The problem in the use of such data arises, of course, when the soil has been depleted of water and the plants transpire at a greatly restricted rate while the evaporation losses from the pan continues at a rapid rate. Therefore, the application of these data should be limited to those times when the soil water content is at least 50% of field capacity. Under such conditions an alfalfa crop will consume about 70-75% of the pan loss and an annual crop such as corn varies from about 40% of pan evaporation loss at the beginning of the season to nearly 85% at silking and tasseling time.

That the total daily evaporation from the pan is relatively constant across the state is shown in Fig. 1. Evaporation is known to be a conservative meteorological quantity, that is, it is a quantity which shows relatively little change. However, a greater difference than observed in Fig. 1 was our expectation.

The variation in the daily evaporation values as indicated by the standard deviation is shown in Fig. 2. A gradual decrease with the progression of the season from the peak was found in the long-term record, 1961-1990, at Lamberton. Comparison of the standard deviation change with time shown in Fig. 2 with the coefficient of variation in Fig. 3 indicates that the greatest relative variation actually occurs at the beginning and end of the season. The greater variation in mid-season, shown with the standard deviation in Fig. 2, is due to the larger evaporation values rather than actual variation in them.

The seasonal (April 21 - October 10) totals of evaporation at the four stations from 1961 to 1990 are shown in Fig. 4. The most obvious features are the very high evaporation amounts in 1976 and 1988. Both years represent drought periods that are still well remembered. The 1976 drought was more or less centered in southwestern Minnesota and eastern South Dakota while the one in 1988 was nearly nationwide. The excessive evaporation occurring in 1976 and 1988 was due, of course, to the very dry surroundings and the advection of dry air across the pans.

The average season (April 21 - October 10) totals and the individual maximums and minimums are listed in Table 1.

Table 1. Seasonal averages and extremes of evaporation pan losses, April 21 - October 10, 1972-1990.

Station	Average	Maximum	Year	Minimum	Year
Lamberton(1)	40.90 in.	56.95	1976	33.46	1972
Morris	41.10	58.22	1976	33.95	1985
St. Paul	39.31	51.41	1988	33.46	1972
Waseca (2)	41.35	53.33	1988	36.03	1972

(1) Average 1961-1990 equals 42.24 in.
(2) Average 1964-1990 equals 40.67 in.

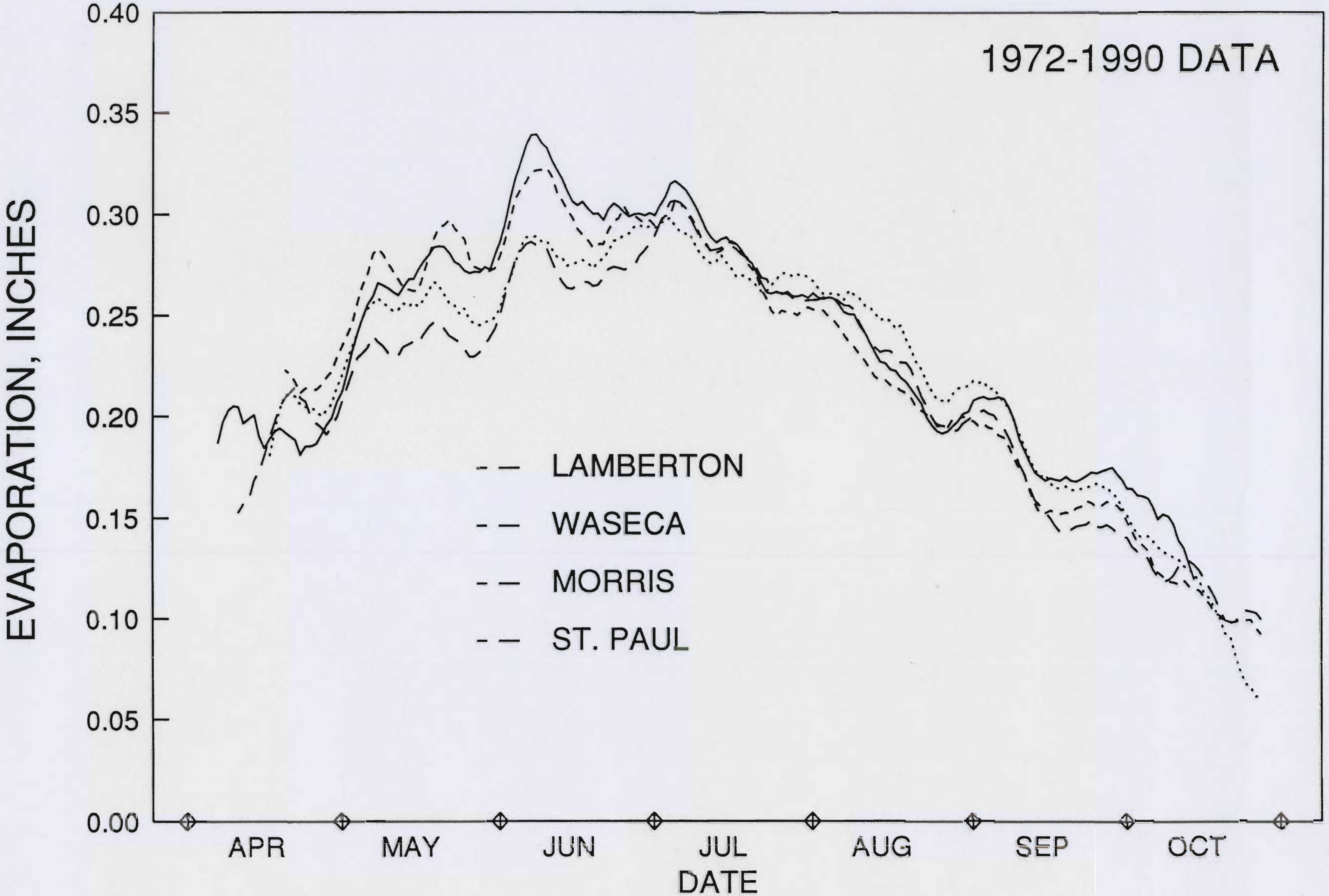


FIGURE 1. DAILY AVERAGE PAN EVAPORATION

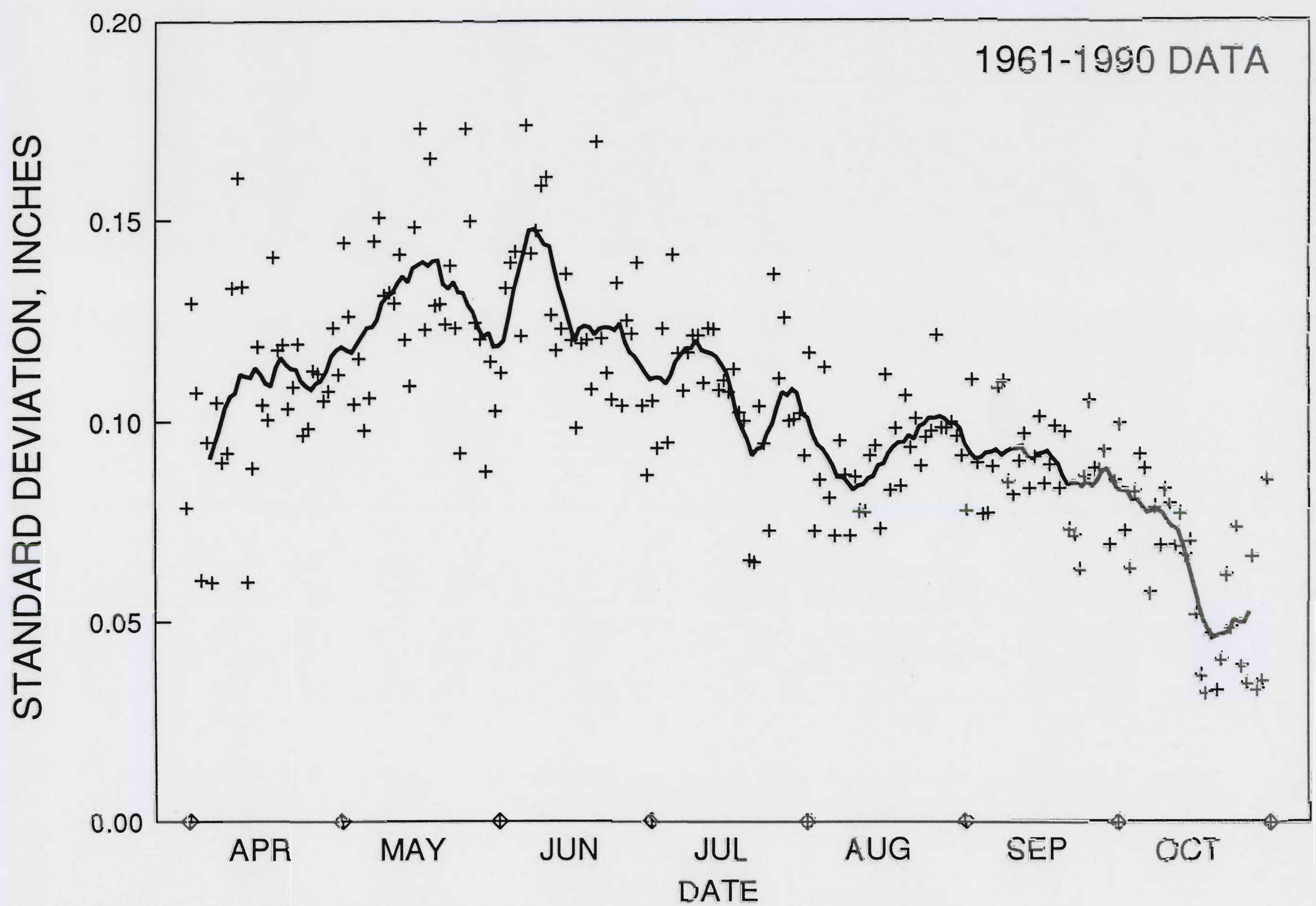


FIGURE 2. LAMBERTON DAILY PAN EVAPORATION

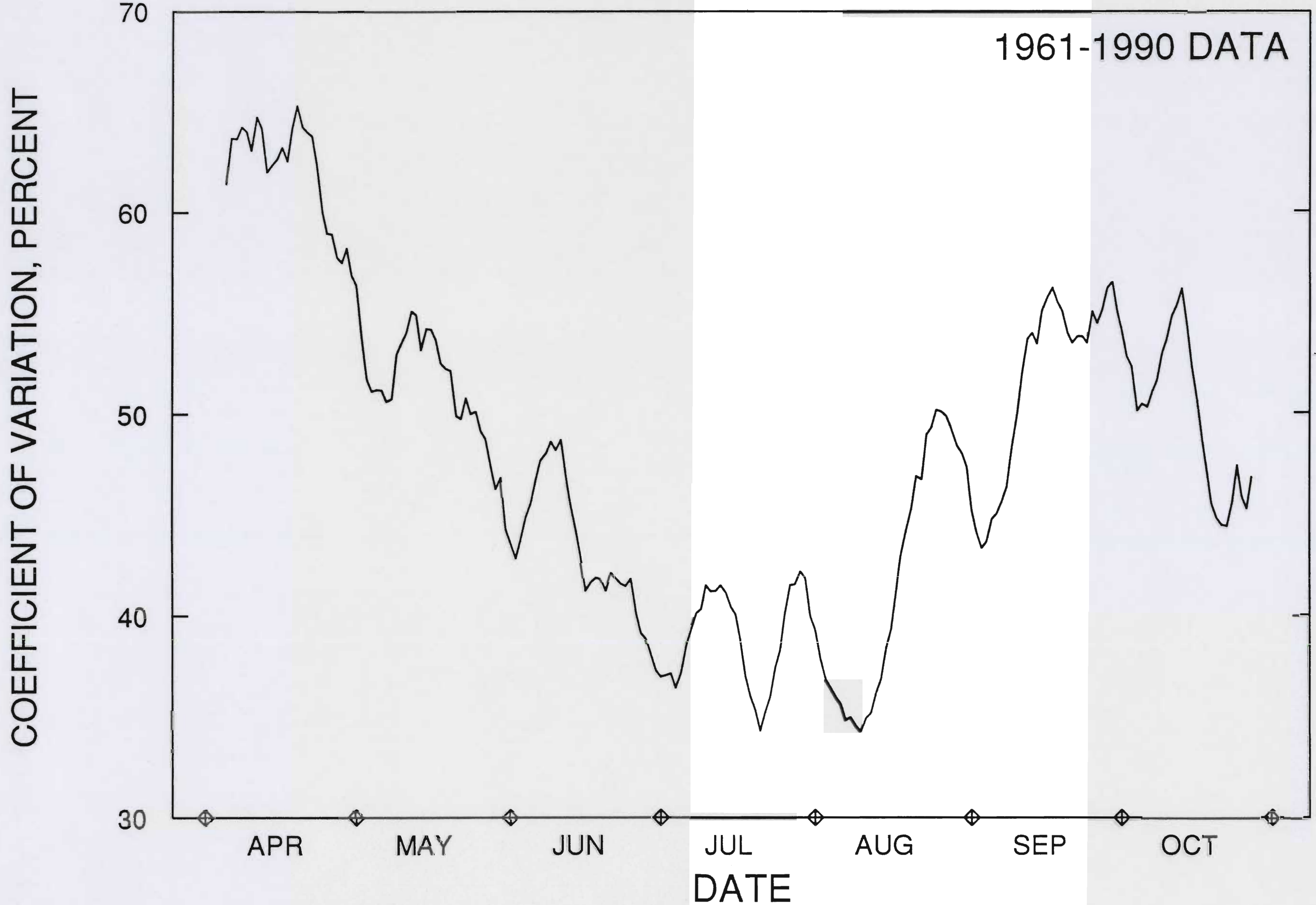


FIGURE 3. LAMBERTON DAILY PAN EVAPORATION

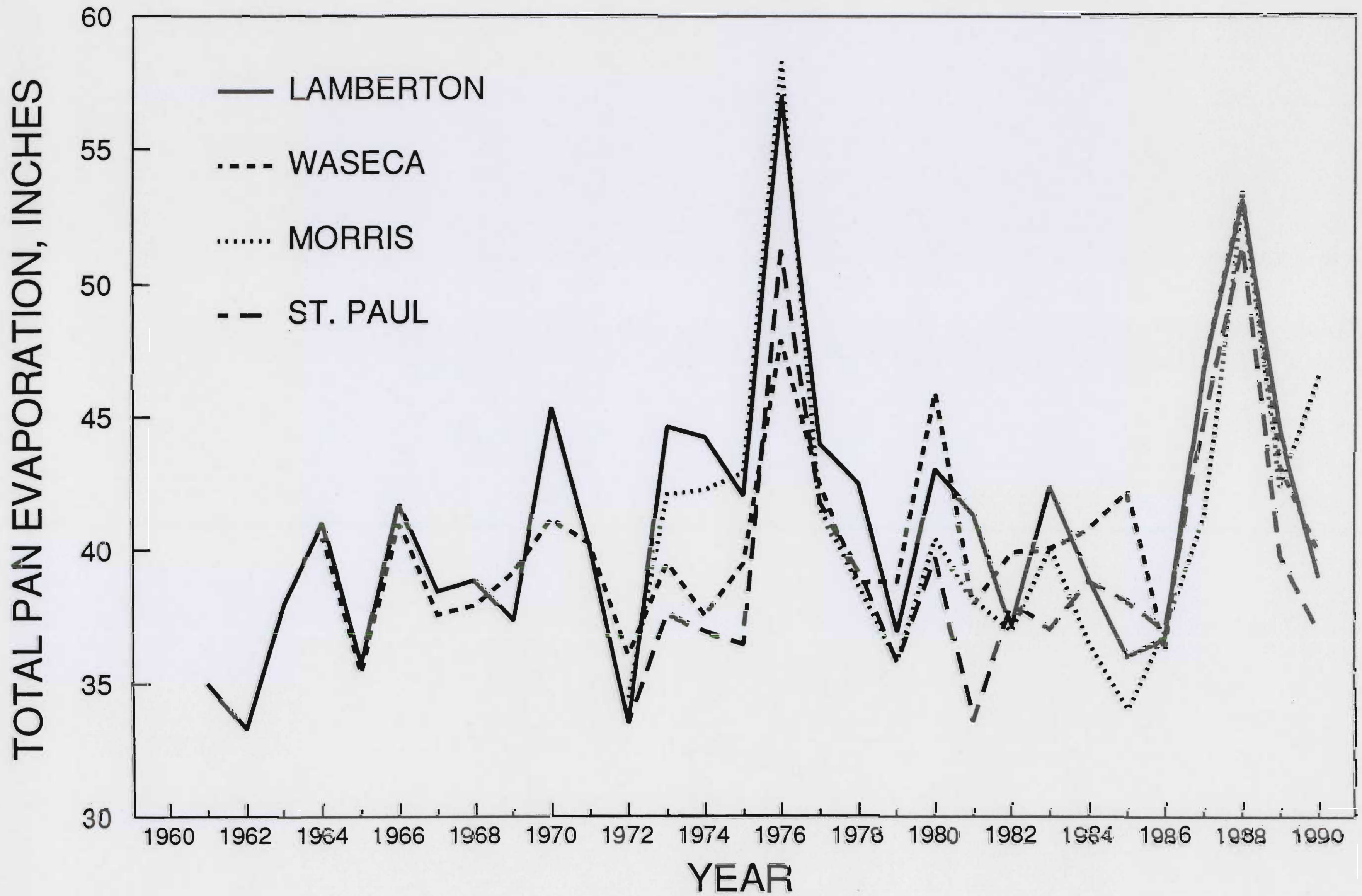


FIGURE 4. ANNUAL TOTAL PAN EVAPORATION

THE TEMPERATURE CHANGE ON DAYS FOLLOWING MEASURABLE PRECIPITATION

David L. Ruschy and Donald G. Baker

A question of some practical value for weather forecasters is this: following the passage of a front how many days is it before the really cold air arrives? For the horticulturist and gardener the question might be asked as: how much time in terms of covering sensitive vegetation do I have before covering the plants or otherwise protecting them. This is what we shall try to answer in this brief study.

In Minnesota the occurrence of precipitation is almost invariably associated with a frontal passage and a change in the air mass. Thus, a day with precipitation can also be taken to represent a day with a frontal passage. Of course, a front can pass without the occurrence of precipitation, but this is not frequent. It can also be argued that the great majority of the frontal passages counted this way are those of cold fronts. We chose this method of accounting for a frontal passage, that is, a day with precipitation, since a more suitable measure is not readily available to us.

The measure we used was the temperature of the days free of precipitation that followed a precipitation day. The precipitation day was defined as a day in which at least 0.01 inch was received. The number of days until the next precipitation day was counted and the maximum, minimum, and mean daily temperatures were recorded for each following day until the next precipitation day. The data used in this study are the 1891-1990 Minneapolis-St. Paul daily temperatures.

This 100 year record provides some extremely interesting results. For example, in Table 1 is listed both the total number of days on which measurable precipitation fell and the percent of possible days. The fewest precipitation days occurred in February and the greatest number in June. Spring, defined as March, April, and May, had the highest precent, 33.3%, with summer, June, July, and August, only fractionally lower. Winter had the lowest percentage of precipitation days, 27.1%.

The average decrease in temperature on the day following precipitation is shown in Table 2. It is interesting to note that the decrease was greater for the minimum temperature than for the maximum, and that it was much greater from November through March than the remainder of the year.

The January and July maximum, minimum, and mean temperature decrease and recovery following the precipitation day (and presumably the passage of a front and the introduction of a different air mass) are shown in Fig. 1. It is to be noted that the coldest mean daily temperature was on the first day following the precipitation and the return to higher temperatures began on the second day. It is obvious that the temperature change was greater in January than in July.

On the average the lowest maximum was found to occur on the first day following the precipitation day as shown in Table 3. However, the lowest minimum occurred on the second day in every month but February, March, April, and June. That the lowest temperature frequently occurred on the second day can be explained as follows. First, the coldest and least modified air introduced into the area by the fresh air mass is located near the center of this air mass rather than at its margins. A second reason is that some time is required for the clouds associated with the precipitation to move out of the region. As a result it is the second day that is commonly associated with the lowest minimum. The February, March, and April exceptions are believed to be due to the faster moving weather systems, common to the winter and early spring. For example, April is the month with the highest average wind speed.

Table 1. The number and percent frequency of days with at least 0.01 inch precipitation per month, season, and year, Minneapolis-St. Paul, 1891-1990.

Period	Days With Precipitation	Percent of Possible	Period	Days With Precipitation	Percent of Possible
January	855	27.6	July	938	30.3
February	727	26.0	August	953	30.7
March	926	29.9	September	943	31.4
April	988	22.9	October	833	26.9
May	1145	36.9	November	784	25.3
June	1156	38.5	December	853	27.5
Spring	3059	33.3	Autumn	2560	28.1
Summer	3047	33.1	Winter	2435	27.1
Annual	11,101	30.4			

Table 2. The mean decrease in the maximum, minimum, and average daily temperature on the day following one with at least 0.01 inch precipitation at Minneapolis-St. Paul, 1891-1989.

Month	Maximum	Minimum	Average	Month	Maximum	Minimum	Average
January	4.8°F	5.7°F	5.2°F	July	0.7°F	1.9°F	1.3°F
February	4.0	6.1	5.1	August	0.7	2.6	1.6
March	1.4	5.0	3.2	September	1.0	3.9	2.5
April	0.2	4.4	2.3	October	2.0	4.6	3.3
May	0.1	3.2	1.6	November	4.2	5.4	4.8
June	0.2	2.1	1.2	December	5.1	5.8	5.5

Table 3. The number of days after a day with at least 0.01 inch precipitation when the lowest temperature was recorded, MSP-WSO, 1891-1990.

Month	Maximum	Mean	Minimum	Month	Maximum	Mean	Minimum
January	1	1	2	July	1	1	2
February	1	1	1	August	1	1	2
March	1	1	1	September	1	1	2
April	1	1	1	October	1	1	2
May	1	1	2	November	1	1	2
June	1	1	1	December	1	1	2

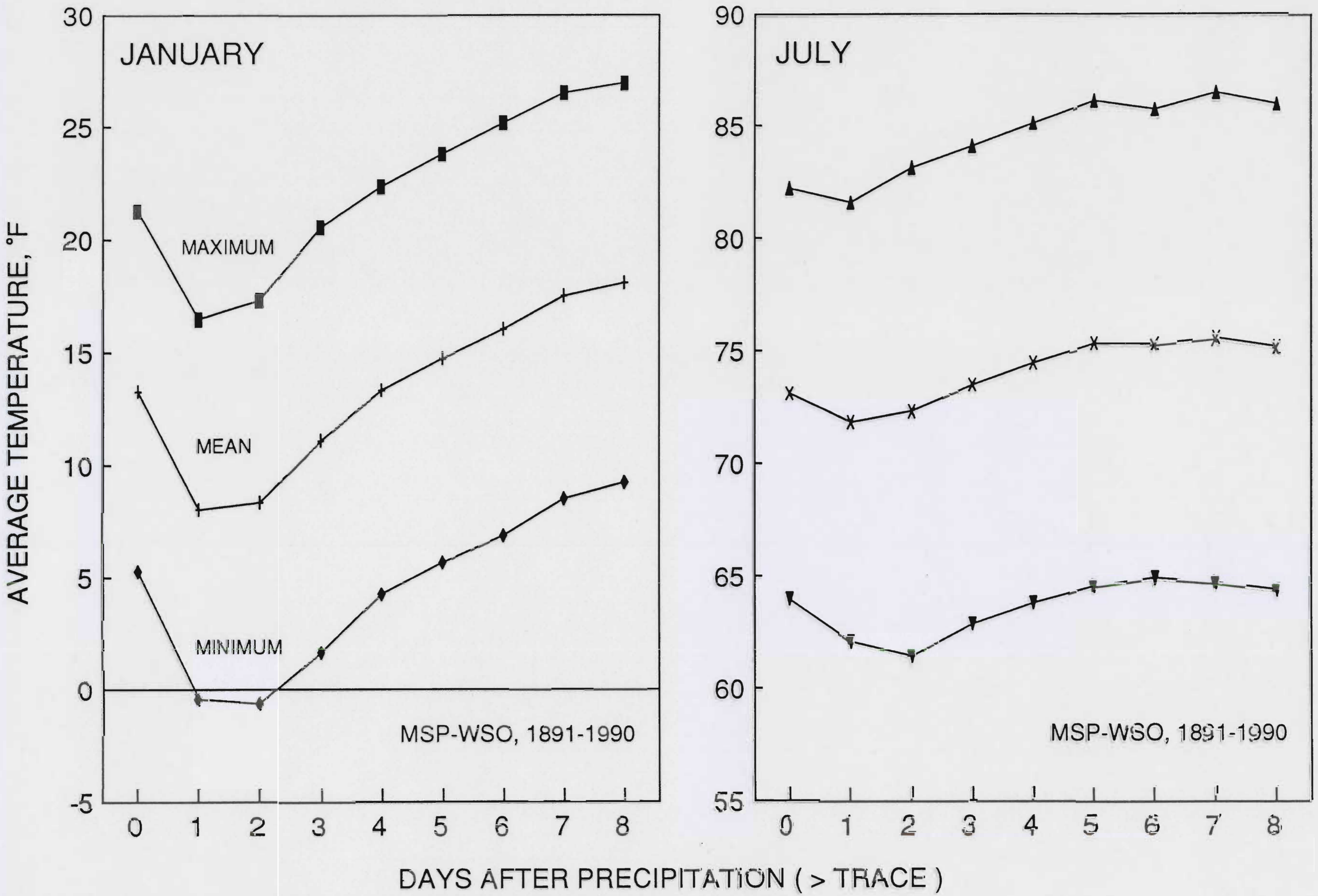


FIGURE 1. MEAN DAILY TEMPERATURES

THE CHANGE IN AIR AND DEEP (42 FEET) GROUND TEMPERATURES IN EASTERN MINNESOTA

Donald G. Baker and David L. Ruschy

In light of current concern over climate change high quality temperature records assume extra importance. As a result, the data from three Minnesota records are worthy of consideration. Although the duration of the records analyzed in this study are relatively short, their quality and source are such that they deserve our attention.

The data in this study were derived from two sources, all in or near St. Paul, Minnesota. The air temperatures are from the climatological observatory on the University of Minnesota St. Paul campus and from a National Weather Service Cooperative Network rural station (Farmington 3NW) 37 km south of the campus. This is termed the Eastern Minnesota record. At both stations the daily mean air temperatures were obtained from maximum and minimum thermometers housed in cotton region-type shelters. The deep ground temperatures (42 feet) were measured at the St. Paul campus and have been measured since 1963.

The mean annual temperatures of the three sets of data for the period 1963-1990 are shown in Fig. 1. The climatological observatory air temperature mean is 1.4°F warmer than the Eastern Minnesota mean, Table 1. This can be almost entirely ascribed to the 5 P.M. Central Standard Time observation time at the St. Paul observatory compared to the midnight observation at the Eastern Minnesota station. When the mean daily air temperatures are adjusted for the difference in the time of observation (midnight for the Eastern Minnesota record and 5 P.M. at St. Paul) the air temperature means for 1963-1990 period are nearly equal.

The difference between the deep ground and the Eastern Minnesota air temperatures, a nearly constant 3.0°F (Fig. 1 and Table 1), is a common difference between soil (ground) and air temperatures in continental climates. It is a demonstration of the fact that the atmosphere is warmed largely by the underlying (and warmer) surface rather than by the absorption of solar radiation.

Table 1. Means and linear trend slopes of the air and ground temperatures, 1963-1990

Temperature Source	Mean	Linear Trend Slope
Eastern Minnesota Air	43.9°F	0.063°F/year
Climatological Observatory Air	45.3	0.097
Climatological Observatory Ground	48.3	0.076

Temperature trends for the 1963-1990 period are in relatively close agreement as shown in Table 1. If continued over a century the increase for the Eastern Minnesota air temperatures would be 6.3°F while for the climatological observatory the air and the deep ground temperatures would be 9.7°F and 7.6°F, respectively. Of major interest is the appreciable rising trend in the deep ground temperatures, which are the least susceptible of the three to extraneous influences such as urban heating and industrialization.

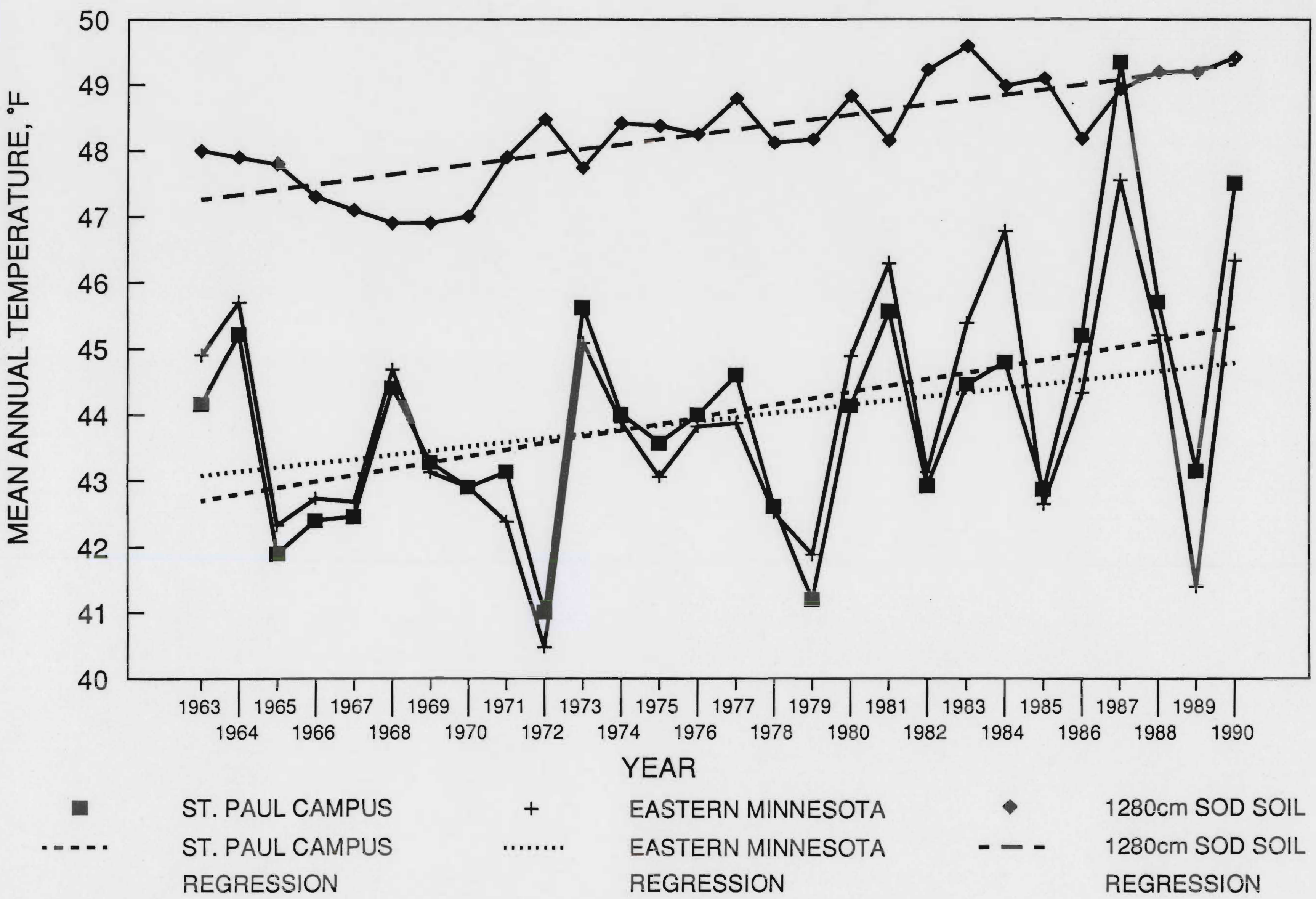


FIGURE 1. MEAN ANNUAL TEMPERATURE

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

Carl Rosen, Florian Lauer, Dave Birong, and Louise America[2]

ABSTRACT: The third year of a three year field experiment was conducted at the Sand Plain 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 (70, 140, 280 lb N/A) of nitrogen fertilizer were applied. Boron applications (4 lb B/A) did not reduce the incidence of hollow heart or brown center. At the late harvest date (Aug. 2), boron applications increased yield of 7-14 oz tubers, but decreased the yield of tubers less than 7 oz. Vine and tuber yield increased linearly with increasing nitrogen rate at both harvest dates. In previous years tuber yield was generally lower at the early harvest date with increasing nitrogen fertilizer. The reason for the early response this year was due to lower nitrogen availability caused by leaching rains that occurred in June. Incidence of hollow heart or brown center was greatest in the largest size tubers. Nitrogen fertilizer increased hollow heart incidence in Russet Burbank tubers greater than 7 oz., but had no effect on internal quality of Reddale. Nitrogen uptake by the potato plant increased with increasing rates of nitrogen application. At the early harvest (vines killed July 25), levels in the vine ranged from 18 - 66 lb N/A while at the late harvest (vines killed September 5) levels ranged from 4 - 26 lb N/A. Levels in the tubers at the early harvest ranged from 30 - 75 lb N/A while at the late harvest levels ranged from 62 - 139 lb N/A. Nitrate levels in potato petiole sap monitored by quick tests generally correlated well ($r^2 = 0.86$) with petiole nitrates determined by conventional laboratory procedures. This correlation was not as high as in previous years. Significant soil nitrate movement was detected at all nitrogen application rates due to leaching rains that occurred in June and July.

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.

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.

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

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 in 1988 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 19, 1990 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 22), and 35 or 105 lb N/A at hilling (June 7). Each plot consisted of four, 20 ft rows. The experimental design was a split plot with 4 replications. Nitrogen was the main plot and cultivar and boron were the subplots. Rainfall was supplemented with overhead irrigation to supply water needs. Monthly irrigation and rainfall through the season were as follows: April - 2.3" rainfall, no irrigation; May 3.9" rainfall, no irrigation; June - 9.2" rainfall, 0.8" irrigation; July - 6.9" rainfall, 3.9" irrigation; August - 7.0" rainfall, 3.2" 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 nitrate-N was determined in samples collected July 30 and September 6. 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'.

Nitrate-N in soil water was 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 25 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 tubers greater than 14 oz at the early harvest date and 7-14 oz tubers at the late harvest date (Table 1). Yield of tubers in the 4-7 oz at the late harvest date was lower with boron application. Boron may have reduced tuber initiation resulting in an increase in the larger tubers. Nitrogen rate had significant effects on tuber yield and size distribution. At both harvest dates yields of both cultivars increased linearly with nitrogen rate up to 280 lb N/A. These results are in contrast to previous years where early harvested potato yields decreased with nitrogen rate. Differences in N response between years are due to the high nitrate leaching losses in 1990 compared to 1989 (see discussion below). Nitrogen fertilizer dramatically increased vine yield of both cultivars at both harvest dates Tables 2 and 3). Vines remained greener later in the season with the highest nitrogen rate, although dieback was noticeable in all treatments. Boron application had no effect on vine yield.

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 Reddale. 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. For Russet Burbank at the late harvest date, nitrogen fertilizer increased the incidence of hollow heart in tubers greater than 7 oz.

Nutrient Concentrations and Uptake. Signs of nitrogen deficiency (general plant yellowing) were apparent at the 70 and 140 lb N/A rate toward the middle of July. Signs of nitrogen deficiency at the highest nitrogen rate were not apparent until early August. Concentrations of nitrogen, magnesium, and zinc in leaves sampled June 27 increased linearly with nitrogen application (Table 6). Concentrations of potassium and boron decreased with increasing nitrogen application rates. Boron treatment increased boron concentration in the leaf tissue, but had no effect on any of the other nutrients. Reddale leaves sampled June 27 had higher concentrations of phosphorus, iron, manganese, zinc, and boron, but lower concentrations of calcium and magnesium.

Concentrations of boron in tubers increased slightly with boron application at both harvest dates (Tables 7 and 8). Other nutrient concentrations in the tuber were not consistently affected by boron. Concentration of nitrogen in tubers sampled at both harvest dates increased with increasing nitrogen application. Tuber concentrations of copper, manganese, and zinc increased with nitrogen fertilizer at both harvests. Tuber calcium increased with increasing nitrogen at the early harvest date. Tuber phosphorus and potassium decreased with increasing nitrogen at the late harvest. Reddale tubers had higher concentrations of nitrogen, phosphorus, magnesium, zinc, copper, and boron, but lower concentrations of calcium and manganese 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, manganese, zinc, and boron, but less nitrogen and magnesium than Russet Burbank. At the later harvest, Reddale vines generally accumulated more nutrients 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. Boron application increased uptake of boron, but had no effect on the uptake of other nutrients.

Nutrient uptake by tubers is presented in Tables 9 and 10. Boron applications increased boron uptake at both the early and late harvest, but did not have any consistent effect on uptake of other nutrients. At both harvest dates, Reddale accumulated greater quantities of phosphorus, zinc, copper, and boron, but lower quantities of potassium, calcium, iron, and manganese compared to Russet Burbank. Uptake of all nutrients in the tuber increased with increasing nitrogen rate due to increases in dry matter accumulation. Boron applications increased the content of boron in the tuber, but had no effect on the uptake of other nutrients.

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. By the early harvest date (June 25), approximately 80% of the nitrogen had been taken up. During the month of August, the average uptake of nitrogen by Russet Burbank and Reddale was 12 lb N/A and 18 lb N/A, respectively. Most of the nitrogen within the plant was redistributed from vine to tuber during the month of August. At the early harvest date, there was still substantial amounts of N in the vine (62 lb N/A in the high nitrogen treatment). If the potato crop is killed early, there could be a significant contribution of nitrogen to the following crop.

Rainfall Distribution and Soil and Water Nitrate Levels Through the Growing Season. Several leaching events occurred during the 1990 growing season at Becker (Figure 1). Most notably was the rainfall occurring 60 days after planting. As expected, variability in the soil nitrate levels was high, particularly at the higher nitrogen rate (Table 12). There was little difference among soil nitrate levels due to nitrogen fertilizer treatments at either sampling date. Presumably, most of the nitrate had been leached by late July. The results of nitrate concentrations in soil water at the 2.5 and 4.5 foot depths also support the fact that most of the nitrate had leached by July (Figures 2, 3 and 4). Nitrate-N levels at the 2.5 foot depth peaked in June (about 60 days after planting) and then declined. This peak at the 2.5 foot depth was followed by a similar peak at the 4.5 foot depth and corresponded to the 4.5" inch rainfall occurring on June 18 and 19 (Figure 1). The only difference among the different nitrogen rates in nitrate movement was the time taken to achieve background concentrations. For the 70 and 140 lb N/A rates most nitrate had leached out or had been taken up by the potato plant at the 2.5' depth by 85 days after planting. In contrast, nitrate was still present at the 2.5' foot depth in the 280 lb N/A treatment for about 20 more days. At the 4.5' depth, nitrate-N concentrations correlated well with nitrogen rate. The higher the nitrogen rate the higher the nitrate-N concentration and the longer the peak lasted. By the end of the season, nitrate concentrations at all depths and nitrogen treatments were low indicating that significant movement of nitrate beyond the root zone had occurred.

Leaf and Petiole Total Nitrogen and Nitrate-N Concentrations. Nitrogen status of the plant every two weeks starting at hilling as measured by various procedures is presented in Table 13. All procedures used were able to detect differences in nitrogen status of the plant due to nitrogen fertilizer application. 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 ($r^2 = 0.86$) between the quick test and the conventional nitrate test. The equation relating the two tests is $y = 10.89x + 1035$, where x is the concentration of nitrate-N in the petiole sap (ug/ml) from the quick test and y is the predicted nitrate-N concentration (ug/g or ppm) based on the water extract from dried tissue. This correlation is not as good as those obtained in previous years, although the equation is similar (see 1990 and 1989 Bluebooks). 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.

In summary, based on three years of research, boron had no effect on internal tuber quality and had inconsistent effects on tuber yield. Nitrogen tended to increase tuber size which in turn increased the number of tubers having hollow heart. In nonleaching years, virtually all the nitrogen applied at the 70 and 140 lb N/A rate was taken up by the potato plant while significant N remained in the soil at the 280 lb N/A rate. In a leaching year (such as 1990), nitrogen movement beyond the root zone was detected in all nitrogen treatments. Tuber yield response to nitrogen was dependent on cultivar and rainfall.

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

			Harvest Date									
			August 3					September 12				
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	30.9	241.4	34.0	0.0	306.4	39.5	258.3	101.2	12.8	411.8
	0	140	32.2	276.1	58.0	0.0	366.2	26.7	286.8	173.1	17.5	504.1
	0	280	34.0	297.8	55.4	0.0	387.3	21.4	238.0	297.1	39.7	596.3
	4	70	29.4	259.9	33.2	0.0	322.5	35.1	244.6	114.6	0.0	394.3
	4	140	33.4	275.9	47.6	0.0	356.8	22.0	214.9	248.0	20.9	505.8
	4	280	35.3	275.0	52.6	0.0	362.9	19.8	244.3	289.7	30.6	584.4
Reddale	0	70	5.9	125.6	131.5	9.6	272.7	6.6	153.4	189.7	39.1	381.6
	0	140	12.1	135.2	175.5	28.5	351.3	9.0	117.5	282.5	94.1	503.2
	0	280	17.6	172.6	198.6	2.9	391.7	13.5	146.4	270.9	173.1	603.9
	4	70	8.6	128.8	155.0	16.6	308.9	4.5	113.6	255.1	27.5	400.7
	4	140	14.9	142.4	194.8	33.6	385.7	8.9	127.7	287.9	83.5	508.0
	4	280	11.5	144.1	203.7	22.9	382.2	10.9	118.6	283.4	181.6	594.5
Analysis of Variance												
Cultivar (C)												
	Russet B		32.5	271.0	46.8	0.0	350.3	27.4	247.8	204.0	20.3	499.4
	Reddale		11.7	141.5	176.5	19.0	348.8	8.9	129.5	261.6	98.6	498.7
Signif.			**	**	**	**	NS	**	**	**	**	NS
B rate (B)												
	0		22.1	208.1	108.9	6.8	345.9	19.5	200.1	219.1	61.5	500.2
	4		22.2	204.3	114.5	12.2	353.2	16.9	177.3	246.5	57.4	497.9
Signif.			NS	NS	NS	*	NS	*	*	*	NS	NS
N rate (N)												
	70		18.7	188.9	88.4	6.5	302.6	21.4	192.5	165.2	18.0	397.1
	140		23.1	207.4	119.0	15.5	365.0	16.7	186.7	247.9	54.0	505.3
	280		24.6	222.4	127.6	6.5	381.0	16.4	186.8	285.3	106.3	594.8
Signif.			*	*	*	NS	**	**	NS	*	**	NS
Linear			**	*	*	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 = 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 25).

Cultivar	B rate	N rate	F.W. 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	6.87	20.5	2.4	76.9	24.6	9.9	9.65	4.69	0.72	4.90	0.67
	0	140	10.44	34.9	3.6	108.3	36.9	20.2	17.80	5.37	0.71	4.05	0.99
	0	280	16.24	70.7	5.5	156.1	43.4	29.6	23.76	9.30	1.22	4.87	1.36
	4	70	7.50	24.2	2.5	81.8	25.7	11.4	12.48	4.58	0.80	4.97	1.07
	4	140	10.38	32.7	3.3	111.3	37.0	20.5	21.62	6.16	0.84	3.48	1.77
	4	280	16.44	66.1	5.2	158.9	42.2	28.1	21.45	9.17	1.15	4.59	1.84
Reddale	0	70	5.87	17.7	3.8	70.6	22.2	6.9	11.10	5.06	0.82	3.76	0.72
	0	140	10.05	27.3	4.4	103.9	31.1	11.4	11.03	6.05	0.73	3.36	1.02
	0	280	16.00	57.2	7.0	162.3	44.8	21.9	22.26	11.07	1.59	4.44	1.46
	4	70	7.43	21.9	4.2	85.9	24.8	8.3	16.61	6.28	1.07	4.58	1.32
	4	140	11.30	30.7	5.1	118.7	34.3	13.7	18.04	7.20	1.12	3.86	1.82
	4	280	15.52	56.2	6.8	158.7	47.4	23.2	21.38	11.49	1.24	5.59	2.26
Analysis of Variance													
Cultivar (C)													
Russet B			11.31	41.5	3.8	115.5	35.0	19.9	17.79	6.55	0.90	4.48	1.28
Reddale			11.03	35.2	5.2	116.7	34.1	14.2	16.74	7.86	1.09	4.27	1.43
Signif.			NS	**	**	NS	NS	**	NS	**	**	NS	**
B rate (B)													
	0		10.91	38.1	4.5	113.0	33.8	16.6	15.93	6.92	0.96	4.23	1.04
	4		11.43	38.6	4.5	119.2	35.2	17.5	18.60	7.48	1.03	4.51	1.68
Signif.			NS	NS	NS	NS	NS	NS	NS	*	NS	NS	**
N rate (N)													
	70		6.92	21.1	3.2	78.8	24.3	9.1	12.46	5.15	0.85	4.55	0.95
	140		10.54	31.4	4.1	110.5	34.8	16.4	17.12	6.19	0.85	3.68	1.40
	280		16.05	62.5	6.1	159.0	44.5	25.7	22.21	10.26	1.30	4.87	1.73
Signif.			**	**	**	**	**	**	NS	*	NS	NS	**
Linear			**	**	**	**	**	**	**	**	**	NS	**
Quad.			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	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 5).

Cultivar	B rate lb B/A	N rate lb N/A	F.W. Yield T/A	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
				Nutrient									
				------------- lb/A -------------					------------- oz/A -------------				
Russet B	0	70	0.88	3.5	0.4	9.9	10.3	3.9	6.39	1.18	0.32	0.16	0.26
	0	140	1.95	6.3	0.7	22.0	16.1	8.5	9.69	1.65	0.47	0.19	0.44
	0	280	4.96	13.2	1.0	36.6	17.2	12.0	8.72	2.14	0.45	0.17	0.55
	4	70	1.06	4.7	0.5	15.1	11.4	4.5	8.56	1.50	0.38	0.16	0.31
	4	140	1.81	6.8	0.7	18.9	19.7	9.4	12.85	2.50	0.43	0.33	0.58
	4	280	4.75	14.5	1.1	37.7	18.2	12.9	11.22	2.39	0.71	0.17	0.64
Reddale	0	70	1.04	6.7	1.2	18.2	13.3	4.4	10.07	2.80	0.98	0.40	0.32
	0	140	1.66	11.5	2.1	20.8	28.9	8.5	25.32	5.28	0.93	0.85	0.56
	0	280	2.73	18.1	2.4	31.2	26.6	11.1	25.30	6.53	1.00	0.57	0.63
	4	70	1.04	7.0	1.2	14.3	15.6	4.7	12.46	3.12	0.93	0.46	0.37
	4	140	1.70	11.5	2.0	24.7	27.3	8.5	24.17	5.45	1.24	0.85	0.62
	4	280	2.66	26.1	3.0	40.9	35.7	15.7	26.35	7.29	1.06	0.52	0.90
Analysis of Variance													
Cultivar (C)													
	Russet B		2.56	8.2	0.8	23.4	15.5	8.5	9.57	1.89	0.46	0.20	0.46
	Reddale		1.80	13.5	2.0	25.0	24.6	8.8	20.61	5.08	1.02	0.61	0.57
Signif.			**	**	**	NS	**	NS	**	**	**	**	*
B rate (B)													
	0		2.20	9.9	1.3	23.1	18.7	8.1	14.25	3.26	0.69	0.39	0.46
	4		2.17	11.8	1.4	25.3	21.3	9.3	15.93	3.71	0.79	0.41	0.57
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
N rate (N)													
	70		1.00	5.5	0.9	14.4	12.7	4.4	9.37	2.15	0.65	0.29	0.32
	140		1.78	9.0	1.4	21.6	23.0	8.7	18.01	3.72	0.77	0.55	0.55
	280		3.78	18.0	1.9	36.6	24.5	12.9	17.90	2.77	0.80	0.36	0.68
Signif.			**	**	**	*	NS	**	*	*	NS	NS	**
Linear			**	**	**	**	**	**	**	**	NS	NS	**
Quad.			NS	NS	NS	NS	**	NS	**	NS	NS	**	*
Interactions													
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			**	NS	**	NS	*	NS	**	**	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

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

B rate lb B/A	N rate lb N/A	August 3 4-7 oz	August 3 7-14 oz	August 3 > 14 oz	September 12 4-7 oz	September 12 7-14 oz	September 12 > 14 oz
		% Incidence					
0	70	2.0	18.5	43.3	4.0	22.5	54.0
0	140	0.0	30.5	88.5	3.0	27.0	78.7
0	280	0.0	15.3	12.5	3.0	16.0	59.0
4	70	2.0	10.0	63.8	3.0	27.8	79.3
4	140	1.0	18.0	63.3	1.0	35.0	69.0
4	280	7.0	14.3	81.5	5.0	13.5	68.0
B rate (B)							
	0	0.7	21.4	48.1	3.3	21.8	63.9
	4	3.3	14.1	69.5	3.0	25.4	72.1
Signif.		**	NS	NS	NS	NS	NS
N rate (N)							
	70	2.0	14.3	53.5	3.5	25.1	66.6
	140	0.5	24.3	75.9	2.0	31.0	73.9
	280	3.5	14.8	47.0	4.0	14.8	63.5
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= 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.

B rate lb B/A	N rate lb N/A	August 3 4-7 oz	August 3 7-14 oz	August 3 > 14 oz	September 12 4-7 oz	September 12 7-14 oz	September 12 > 14 oz
		% Incidence					
0	70	0.0	4.0	0.0	0.0	4.0	0.0
0	140	0.0	6.8	0.0	0.0	10.0	36.0
0	280	1.0	0.0	0.0	1.0	13.0	67.0
4	70	0.0	5.0	0.0	0.0	5.0	0.0
4	140	0.0	3.8	0.0	0.0	8.0	39.5
4	280	0.0	3.0	0.0	1.0	8.0	71.0
B rate (B)							
	0	0.3	3.6	0.0	0.3	9.0	34.3
	4	0.0	3.9	0.0	0.3	7.0	36.8
Signif.		NS	NS	--	NS	NS	NS
N rate (N)							
	70	0.0	4.5	0.0	0.0	4.5	0.0
	140	0.0	5.3	0.0	0.0	9.0	37.8
	280	0.5	1.5	0.0	1.0	10.5	69.0
Signif.		NS	NS	--	NS	NS	**
Linear		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 June 27 (74 days after planting).

			Nutrient									
Cultivar	B rate lb B/A	N rate lb N/A	N	P	K %	Ca	Mg	Fe	Mn	Zn ppm	Cu	B
Russet B	0	70	4.27	0.30	4.80	0.91	0.62	104	58	16	252	33
	0	140	4.95	0.32	4.44	0.88	0.69	94	55	14	54	26
	0	280	5.45	0.32	4.24	0.93	0.78	96	69	17	45	28
	4	70	4.15	0.31	5.41	0.90	0.62	129	71	14	159	62
	4	140	4.83	0.40	5.38	1.05	0.80	117	71	19	80	58
	4	280	5.39	0.33	4.10	0.92	0.79	94	73	17	47	42
Reddale	0	70	4.15	0.43	5.11	0.72	0.44	125	82	18	81	44
	0	140	4.32	0.41	4.51	0.73	0.46	115	73	19	45	36
	0	280	5.20	0.41	4.26	0.83	0.52	120	105	22	49	34
	4	70	4.14	0.45	5.01	0.67	0.44	135	94	20	157	65
	4	140	4.72	0.42	4.50	0.77	0.51	124	84	21	48	54
	4	280	5.51	0.42	3.81	0.84	0.53	113	91	22	24	50
Analysis of Variance												
Cultivar (C)												
	Russet B		4.84	0.33	4.73	0.94	0.73	105	66	16	103	41
	Reddale		4.67	0.42	4.54	0.76	0.48	122	88	20	67	47
Signif.			NS	**	NS	**	**	**	**	**	*	*
B rate (B)												
	0		4.72	0.36	4.56	0.83	0.58	109	74	17	87	34
	4		4.79	0.39	4.71	0.87	0.62	118	81	19	83	55
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		4.18	0.38	5.07	0.79	0.52	123	77	17	162	50
	140		4.70	0.39	4.75	0.87	0.63	113	71	18	58	44
	280		5.39	0.37	4.10	0.88	0.66	106	85	19	41	38
Signif.			**	NS	**	NS	**	NS	NS	*	**	**
Linear			**	NS	**	NS	**	*	NS	NS	**	**
Quad.			NS	NS	NS	NS	NS	NS	NS	NS	**	NS
Interactions												
C X B			NS	NS	**	NS	NS	NS	NS	NS	NS	NS
C X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	NS	NS	**	NS

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

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

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	0.52	0.22	1.85	268	869	90	10.7	6.9	2.9	4.9
	0	140	0.66	0.19	1.74	272	838	80	10.1	7.4	2.3	4.3
	0	280	0.86	0.20	1.91	388	940	88	11.7	10.2	3.6	5.4
	4	70	0.58	0.21	1.85	268	921	87	11.4	8.1	2.9	5.6
	4	140	0.63	0.19	1.75	283	845	93	10.7	7.8	2.3	5.4
	4	280	0.74	0.18	1.78	368	804	119	12.8	9.7	2.9	6.1
Reddale	0	70	0.62	0.29	2.08	153	937	74	7.7	9.3	4.0	6.7
	0	140	0.93	0.31	2.20	189	1180	75	9.0	11.6	4.3	7.8
	0	280	1.12	0.28	2.05	207	1007	88	9.7	14.0	4.9	6.8
	4	70	0.76	0.30	2.16	182	1009	76	8.7	10.7	4.2	7.6
	4	140	0.84	0.29	2.07	180	1044	78	8.6	11.4	4.2	7.2
	4	280	1.21	0.28	2.05	214	1049	87	9.8	13.3	4.5	7.7
Analysis of Variance												
Cultivar (C)												
	Russet B		0.66	0.20	1.81	308	870	93	11.2	8.3	2.8	5.3
	Reddale		0.92	0.29	2.10	188	1038	80	8.9	11.7	4.4	7.3
Signif.			**	**	**	**	**	**	**	**	**	**
B rate (B)												
	0		0.78	0.25	1.97	246	961	83	9.8	9.9	3.7	6.0
	4		0.80	0.24	1.94	249	946	90	10.3	10.2	0.9	6.6
Signif.			NS	NS	NS	NS	NS	*	NS	NS	NS	**
N rate (N)												
	70		0.62	0.25	1.98	218	934	82	9.6	8.8	3.5	6.2
	140		0.77	0.24	1.94	231	977	81	9.6	9.5	3.3	6.2
	280		0.98	0.24	1.95	294	950	96	11.0	11.8	4.0	6.5
Signif.			**	NS	NS	**	NS	NS	**	**	NS	NS
Linear			**	**	NS	**	NS	**	**	**	**	NS
Quad.			NS	NS	NS	NS	NS	NS	NS	NS	*	NS
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			NS	NS	NS	**	*	NS	NS	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 8. Nutrient concentrations in tubers as affected by N rate and boron - late harvest (Sept 12).

Cultivar lb B/A	B rate lb N/A	N rate	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			------- % ------			---------- ppm ----------						
Russet B	0	70	0.74	0.23	1.84	305	943	95	11.8	9.0	3.7	4.5
	0	140	0.87	0.22	1.80	301	1002	88	11.9	10.3	3.9	4.8
	0	280	0.90	0.20	1.63	294	876	87	11.9	11.0	4.2	4.2
	4	70	0.85	0.25	1.91	308	1005	99	12.7	10.0	3.7	5.0
	4	140	0.75	0.21	1.78	281	968	88	11.6	9.6	3.7	5.3
	4	280	1.13	0.20	1.71	309	995	95	13.1	12.4	4.8	5.4
Reddale	0	70	0.91	0.33	2.17	205	1141	66	9.6	13.3	5.9	7.1
	0	140	1.00	0.32	2.02	215	1121	71	9.5	13.5	5.3	6.3
	0	280	1.39	0.30	1.95	232	1171	86	11.9	17.4	7.1	7.2
	4	70	0.96	0.34	2.18	216	1175	80	10.5	13.8	5.8	7.7
	4	140	0.96	0.33	2.05	205	1204	73	9.9	14.5	6.5	7.5
	4	280	1.49	0.31	2.01	234	1236	92	12.3	17.1	6.8	7.8
<u>Analysis of Variance</u>												
<u>Cultivar</u> (C)												
	Russet B		0.87	0.22	1.78	300	965	92	12.2	10.4	4.0	4.9
	Reddale		1.12	0.32	2.06	218	1175	78	10.6	14.9	6.2	7.3
Signif.			**	**	**	**	**	**	**	**	**	**
<u>B rate</u> (B)												
	0		0.97	0.27	1.90	259	1042	82	11.1	12.4	5.0	5.7
	4		1.02	0.27	1.94	259	1097	88	11.7	12.9	5.2	6.4
Signif.			NS	NS	NS	NS	*	NS	NS	NS	NS	**
<u>N rate</u> (N)												
	70		0.87	0.29	2.00	259	1066	85	11.2	11.5	4.8	6.1
	140		0.90	0.27	1.90	251	1074	80	10.7	12.0	4.8	6.0
	280		1.23	0.25	1.80	267	1069	90	12.3	14.5	5.7	6.1
Signif.			**	**	**	NS	NS	NS	*	**	NS	NS
Linear			**	**	**	NS	NS	NS	*	**	**	NS
Quad.			*	NS	**	NS	NS	NS	NS	NS	NS	NS
<u>Interactions</u>												
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 9. Nutrient uptake by tubers as affected by nitrogen and boron - early harvest (August 3).

Cultivar	B rate	N rate	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			Nutrient									
	lb B/A	lb N/A	lbs/A					oz/A				
Russet B	0	70	33.3	14.2	118.8	1.7	5.6	9.3	1.10	0.71	0.30	0.51
	0	140	51.1	14.9	135.2	2.1	6.5	10.0	1.26	0.92	0.28	0.54
	0	280	64.5	14.8	142.7	2.9	7.0	10.6	1.41	1.22	0.43	0.65
	4	70	39.9	14.6	126.8	1.8	6.3	9.7	1.26	0.90	0.32	0.61
	4	140	47.2	14.0	131.3	2.1	6.3	11.2	1.29	0.94	0.28	0.64
	4	280	49.9	12.2	119.9	2.5	5.4	12.9	1.39	1.05	0.31	0.66
Reddale	0	70	29.5	13.5	97.8	0.7	4.4	5.6	0.59	0.70	0.30	0.50
	0	140	56.0	18.2	131.2	1.1	7.0	7.0	0.86	1.10	0.41	0.74
	0	280	68.1	16.9	124.5	1.3	6.1	8.6	0.95	1.36	0.47	0.66
	4	70	41.6	16.0	116.0	1.0	5.4	6.4	0.75	0.93	0.36	0.65
	4	140	52.8	18.1	130.0	1.1	6.6	7.8	0.86	1.15	0.43	0.72
	4	280	74.5	17.6	127.7	1.3	6.6	8.6	0.97	1.33	0.45	0.77
Analysis of Variance												
Cultivar (C)												
	Russet B		47.7	14.1	129.1	2.2	6.2	10.6	1.28	0.96	0.32	0.60
	Reddale		53.7	16.7	121.2	1.1	6.0	7.3	0.83	1.10	0.40	0.68
Signif.			NS	**	**	**	NS	**	**	**	**	**
B rate (B)												
	0		50.4	15.4	125.0	1.6	6.1	8.5	1.03	1.00	0.37	0.60
	4		51.0	15.4	125.3	1.6	6.1	9.4	1.09	1.05	0.36	0.68
Signif.			NS	NS	NS	NS	NS	*	NS	NS	NS	**
N rate (N)												
	70		36.1	14.5	114.8	1.3	5.4	7.8	0.93	0.81	0.32	0.57
	140		51.8	16.3	131.9	1.6	6.6	9.0	1.07	1.03	0.35	0.66
	280		64.2	15.4	128.7	2.0	6.3	10.2	1.18	1.24	0.42	0.69
Signif.			**	NS	*	**	NS	*	**	**	*	**
Linear			**	NS	**	**	*	**	**	**	**	**
Quad.			NS	**	**	NS	**	NS	NS	NS	NS	NS
Interactions												
C X B			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
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 12).

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	64.6	19.7	159.7	2.6	8.2	13.3	1.66	1.28	0.53	0.64
	0	140	93.1	23.2	193.0	3.2	10.8	15.0	2.05	1.78	0.67	0.83
	0	280	111.4	24.7	204.4	3.7	11.0	17.7	2.41	2.22	0.84	0.86
	4	70	69.3	20.0	156.4	2.5	8.2	13.3	1.70	1.33	0.50	0.66
	4	140	80.0	22.8	190.4	3.0	10.4	15.0	1.99	1.64	0.64	0.90
	4	280	139.2	25.2	211.0	3.8	12.2	18.7	2.58	2.46	0.96	1.06
Reddale	0	70	62.0	22.0	142.9	1.3	7.5	7.1	1.03	1.43	0.63	0.76
	0	140	85.5	27.2	172.1	1.8	9.5	9.6	1.29	1.84	0.72	0.86
	0	280	130.8	28.2	185.1	2.2	11.1	13.0	1.79	2.62	1.07	1.10
	4	70	63.5	22.3	145.1	1.4	7.8	8.6	1.13	1.49	0.63	0.82
	4	140	84.6	28.5	178.0	1.8	10.5	10.3	1.38	2.04	0.90	1.04
	4	280	138.6	29.2	187.2	2.2	11.5	13.9	1.85	2.56	1.03	1.16
Analysis of Variance												
Cultivar (C)												
	Russet B		92.9	22.6	185.8	3.1	10.1	15.5	2.07	1.78	0.69	0.82
	Reddale		94.1	26.3	168.4	1.8	9.7	10.4	1.41	2.00	0.83	0.96
Signif.			NS	**	**	**	NS	**	**	**	**	**
B rate (B)												
	0		91.2	24.2	176.2	2.5	9.7	12.6	1.71	1.86	0.74	0.84
	4		95.8	24.7	178.0	2.5	10.1	13.3	1.77	1.92	0.77	0.94
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		16.7	21.0	151.0	2.0	7.9	10.6	1.38	1.38	0.57	0.72
	140		16.7	25.4	183.4	2.5	10.3	12.5	1.68	1.82	0.73	0.91
	280		23.0	27.0	196.9	3.0	11.5	15.8	2.16	2.47	0.97	1.04
Signif.			**	*	*	**	**	**	**	**	**	*
Linear			**	**	**	**	**	**	**	**	**	**
Quad.			NS	**	**	*	**	NS	NS	NS	NS	*
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			NS	NS	NS	NS	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	Early Harvest			Late Harvest		
	lb N/A	Vines	Tubers	Total	Vines	Tubers	Total
		lb N/A					
Russet B	70	22.4	36.6	59.0	4.1	67.0	71.1
	140	33.8	49.2	83.0	6.6	86.5	93.1
	280	68.4	57.2	125.6	13.8	125.2	139.0
Reddale	70	19.8	35.5	55.3	6.8	62.7	69.5
	140	29.0	54.4	83.4	11.5	85.0	96.5
	280	56.7	71.3	128.0	22.1	134.7	156.8
Analysis of Variance							
Cultivar (C)							
	Russet B	41.5	47.7	89.2	8.2	92.9	101.1
	Reddale	35.2	53.7	88.9	13.5	94.1	107.6
Signif.		**	NS	NS	**	NS	NS
N rate (N)							
	70	21.1	36.1	57.2	5.5	64.8	70.3
	140	31.4	51.8	83.2	9.0	85.8	94.8
	280	62.5	64.2	126.7	18.0	130.0	148.0
Signif.		**	**	**	**	**	**
Linear		**	**	**	**	**	**
Quad.		*	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. Soil nitrate-N concentrations at the early (August 3) and late (Sept. 12) harvest.

N rate	Depth	Sampling Date: July 30		Sampling Date: Sept. 6	
lb/A	Ft.	In Row	Betwn Row	In Row	Betwn Row
		lb NO_3-N/half acre[1]			
70	0-1	4.1 ± 1.3	3.2 ± 2.5	6.7 ± 2.1	5.1 ± 1.4
	1-2	2.1 ± 2.0	1.1 ± 0.9	2.2 ± 0.6	1.6 ± 0.6
	2-3	0.9 ± 0.5	2.1 ± 5.4	1.8 ± 1.3	2.0 ± 2.1
	Total	7.0 ± 2.9	6.3 ± 7.8	10.5 ± 3.3	8.4 ± 2.5
Total lbs NO_3-N/A in field[2]		13.3 ± 8.1		18.9 ± 4.6	
140	0-1	3.8 ± 1.3	2.7 ± 1.4	7.4 ± 2.1	6.0 ± 1.9
	1-2	1.3 ± 0.7	0.8 ± 0.2	2.6 ± 1.2	1.5 ± 0.4
	2-3	1.0 ± 0.5	1.2 ± 2.1	1.5 ± 0.9	1.1 ± 0.3
	Total	6.0 ± 1.3	4.6 ± 2.4	11.2 ± 3.7	8.4 ± 1.9
Total lbs NO_3-N/A in field		10.6 ± 2.2		19.6 ± 4.9	
280	0-1	8.2 ± 8.2	5.9 ± 10.0	8.0 ± 3.0	7.6 ± 3.2
	1-2	2.3 ± 1.3	1.1 ± 0.4	2.6 ± 1.4	1.7 ± 0.6
	2-3	1.4 ± 0.7	0.9 ± 1.0	1.4 ± 0.6	1.1 ± 0.4
	Total	11.8 ± 8.3	7.7 ± 10.9	11.7 ± 4.2	10.1 ± 3.6
Total lbs NO_3-N/A in field		19.5 ± 19.0		21.8 ± 7.6	

[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.

Table 13. Comparison of nitrogen and nitrate-N concentration in leaves (leaflet + petiole), petioles, and petiole sap at six sampling dates.

Cultivar	N rate	June 7 (49 DAP[1])					June 15 (57 DAP)					June 27 (69 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	4.79	3.33	2778	12270	1616	5.10	2.84	2145	10151	-	4.21	1.81	620	769	48
	140	5.02	3.45	3477	15182	1610	5.48	3.18	4106	16178	-	4.89	2.52	2008	10199	673
	280	5.54	3.74	4449	19843	1981	5.72	3.45	5358	22350	-	5.42	3.09	4375	18589	828
Reddale	70	4.89	3.34	3331	15513	1523	4.94	2.88	2116	11916	-	4.14	1.40	372	1597	91
	140	5.04	3.64	4183	18976	1464	5.76	3.76	3774	17923	-	4.52	2.11	2129	8988	680
	280	5.45	3.90	5315	21288	1798	6.14	4.02	4633	20007	-	5.36	2.89	4127	20362	993
Analysis of Variance																
Cultivar (C)																
Russet B		5.12	3.51	3568	15765	1736	5.43	3.16	3870	16227	-	4.84	2.47	2334	9852	516
Reddale		5.13	3.63	4276	18593	1595	5.61	3.53	3508	16615	-	4.67	2.13	2209	10315	588
Signif.		NS	*	**	**	*	*	**	NS	NS	-	NS	**	NS	NS	NS
N rate (N)	70	4.84	3.34	3054	13891	1569	5.02	2.86	2131	11033	-	4.18	1.60	496	1183	70
	140	5.03	3.55	3830	17079	1537	5.62	3.43	3940	17051	-	4.70	2.32	2068	9593	677
	280	5.50	3.82	4882	20565	1889	5.93	3.74	4996	21178	-	5.39	2.99	4251	19476	911
Signif.		**	**	**	**	NS	**	**	**	**	-	**	**	**	**	**
Linear		**	**	**	**	**	**	**	**	**	-	**	**	**	**	**
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 13. Con't.

		Sampling Date														
		July 12 (84 DAP)					August 1 (104 DAP)					August 15 (118 DAP)				
Cultivar	N rate	Kjeldahl N		Water extrac-table NO_3-N		Quick test Sap NO_3-N	Kjeldahl N		Water extrac-table NO_3-N		Quick test Sap NO_3-N	Kjeldahl N		Water extrac-table 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	3.24	1.21	6	256	6	2.74	1.02	42	27	2	2.90	1.18	37	30	1
	140	3.61	1.36	15	412	9	2.99	1.11	49	145	1	2.86	1.16	77	40	2
	280	4.66	2.48	2679	11791	658	3.97	1.70	343	1993	40	3.58	1.45	97	515	16
Reddale	70	3.63	1.08	8	55	3	2.97	1.02	57	434	2	2.94	1.07	61	181	3
	140	3.49	1.11	46	433	37	2.82	0.94	52	32	2	2.68	0.95	58	49	2
	280	4.45	2.21	1679	7692	366	3.46	1.17	96	741	41	3.25	1.11	62	529	1
Analysis of Variance																
Cultivar (C)																
Russet B		3.84	1.69	900	4153	224	3.23	1.28	144	722	14	3.12	1.26	70	195	6
Reddale		3.86	1.47	577	2727	135	3.08	1.04	69	402	15	2.96	1.05	60	253	2
Signif.		NS	**	*	**	*	*	**	**	**	NS	*	**	NS	NS	NS
N rate (N)																
	70	3.44	1.15	7	156	5	2.85	1.02	50	230	2	2.92	1.13	49	105	2
	140	3.55	1.23	31	423	23	2.91	1.02	51	89	2	2.77	1.05	68	44	2
	280	4.55	2.35	2179	9741	512	3.72	1.44	219	1367	40	3.42	1.28	79	522	9
Signif.		**	**	**	**	**	**	**	*	**	*	**	*	NS	**	NS
Linear		**	**	**	**	**	**	**	**	**	**	**	**	NS	**	*
Quad.		*	**	**	**	**	**	**	*	**	NS	**	**	NS	NS	NS
Interaction																
C X N		NS	NS	**	**	**	**	**	**	**	NS	NS	NS	NS	NS	**

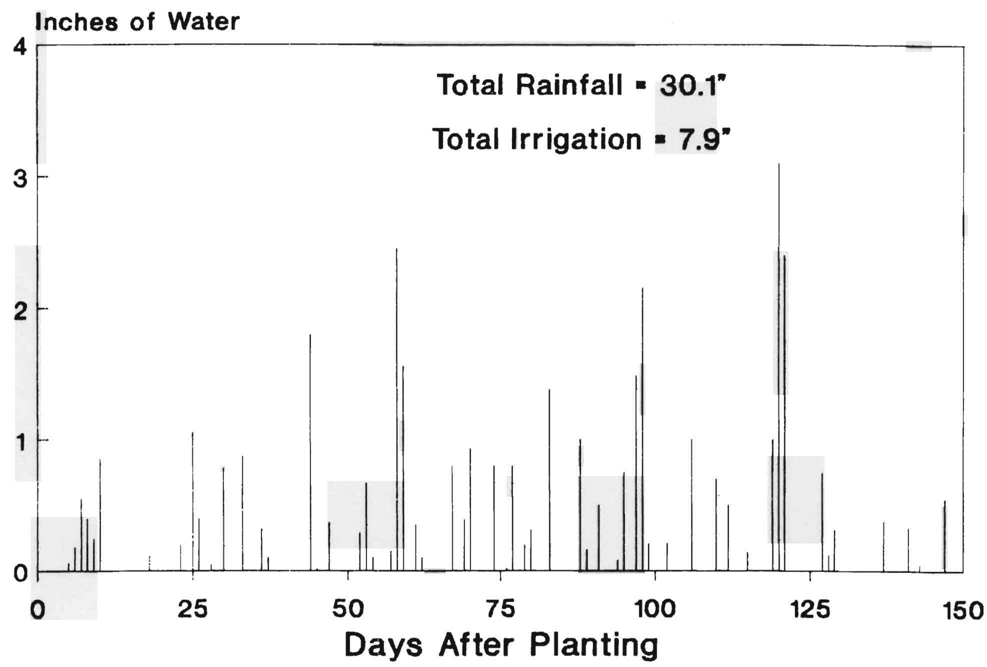

Figure 1. Rainfall and irrigation at Becker, MN during the 1990 growing season.

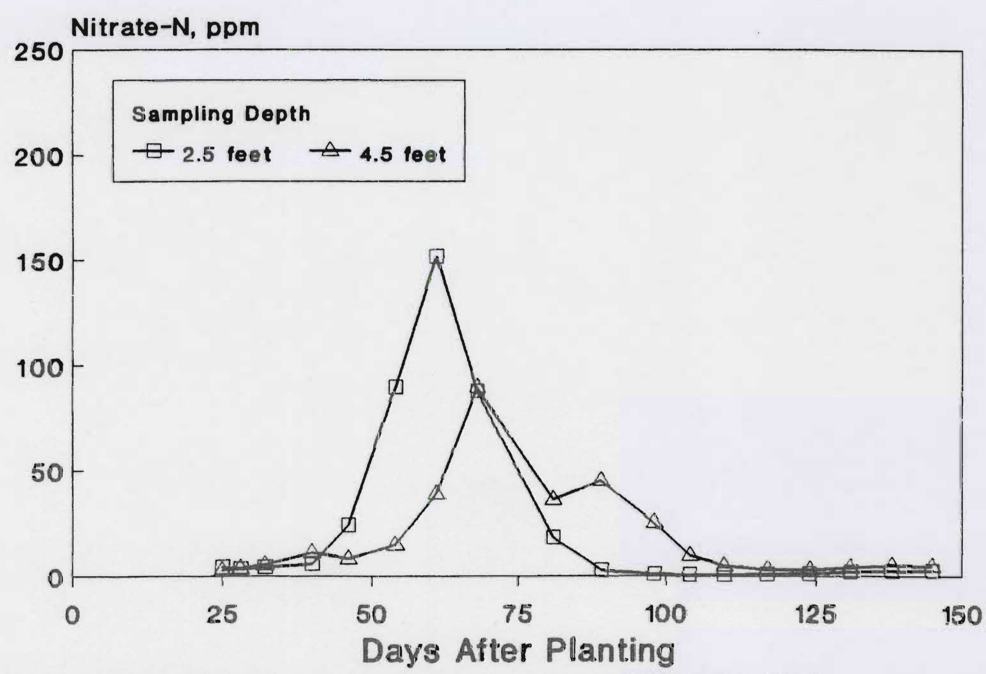

Figure 2. Nitrate-N concentrations in soil water at two depths during the 1990 growing season. Nitrogen application rate was 70 lb N/A.

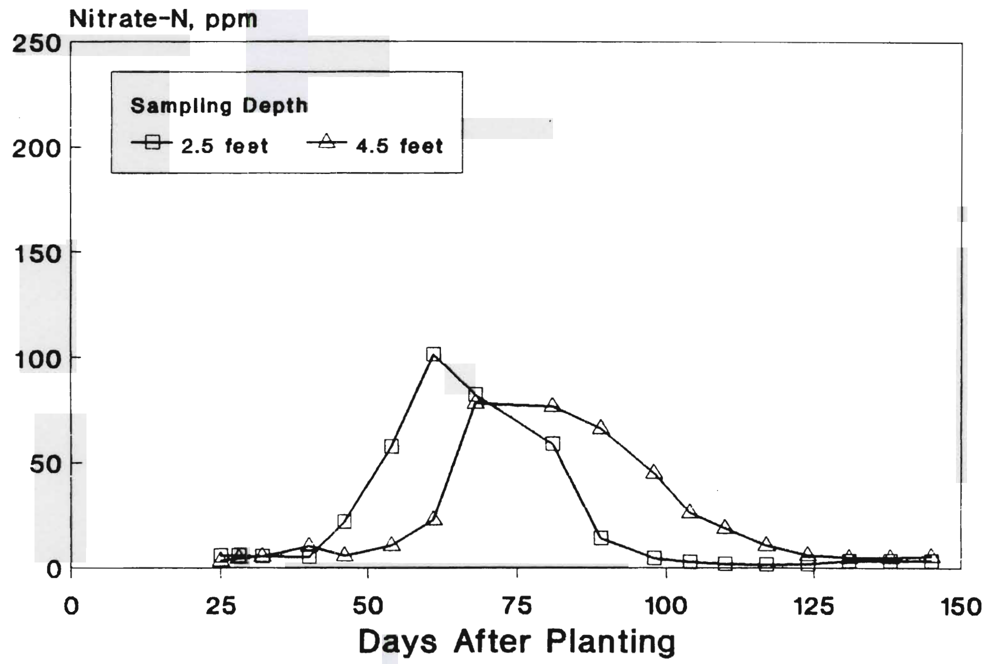

Figure 3. Nitrate-N concentrations in soil water at two depths during the 1990 growing season. Nitrogen application rate was 140 lb N/A.

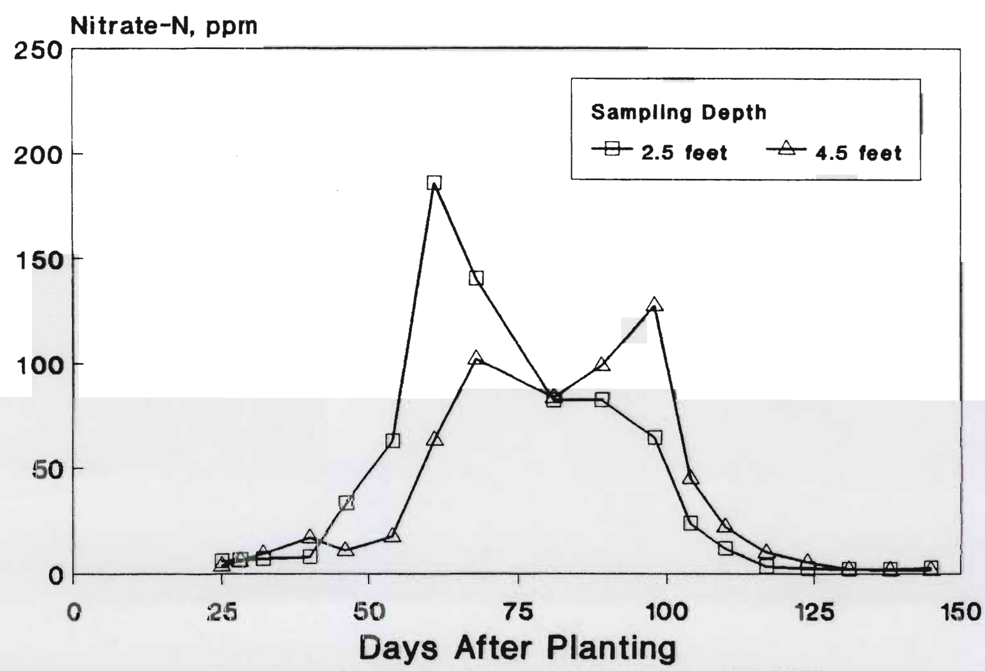

Figure 4. Nitrate-N concentrations in soil water at two depths during the 1990 growing season. Nitrogen application rate was 280 lb N/A.

PHOSPHORUS REQUIREMENTS FOR IRRIGATED POTATOES

Carl Rosen, Dave Birong, and Glenn Titrud

ABSTRACT: Response of irrigated potatoes to phosphate fertilizer on low and high P testing sites was evaluated. Phosphate fertilizer tended to increase tuber initiation and yield of 4-7 oz potatoes, but decrease the yield of 7-14 oz tubers. This effect was more pronounced on the low P site compared to the high P site. Total yield increased linearly with P fertilizer at the low P site, but was not affected by P fertilizer at the high P site.

Little research has been conducted that defines the phosphorus requirements of potato on high P testing soils. Many soils used for irrigated potato production are natively high in P or have been built up to high levels of P through continuous use of phosphate fertilizers. Currently, high rates of phosphate fertilizer are recommended on soils testing above 25 ppm. The objective of this study therefore, was to evaluate the response of irrigated potatoes to phosphate fertilizer on both high and low P testing soils.

PROCEDURES: Two sites at the Sand Plain Research Farm in Becker, Minn. were selected for this study. The soil at both sites are Hubbard loamy sands and were selected based on their Bray P1 extractable P concentrations - one a 'low' P site and the other a 'high' P site. Characteristics of each site were as follows:

	High P site	Low P site
Previous crop	Potato	Rye
Soil pH (1:1 - soil:water)	6.8	5.4
Bray P1	36 ppm	18 ppm
K - NH_4OAc	117 ppm	61 ppm

Prior to planting, 250 lb sul-po-mag in both sites, 100 lb K_2O in the high testing site and 200 lb K_2O in the low testing site were broadcast applied and incorporated. At planting, all plots received 70 lb N/A and 200 lb K_2O as a band application. Phosphate fertilizer (triple superphosphate, 0-46-0) treatments were as follows: 0, 50, 100, 150, 200, 250 lb P_2O_5/A. Phosphate fertilizer was applied as a band on either side of the row with a belt seed planter. Nitrogen was applied at the rate of 70 lb N/A at emergence (May 21), 70 lb N/A at hilling (June 6), and 30 lb N/A on July 25. Russet Burbank "A" size cut potatoes were planted on April 12, 1990 at a spacing of 36" between rows and 10" within the row. Each plot consisted of four 20' rows. The experimental design was a randomized complete block with four replications. Each site was irrigated according to the checkbook method for potatoes. Recently matured leaves (leaflets plus petioles) were sampled and dried for subsequent nutrient analysis. Whole plant samples (two plants per plot) were also collected on June 21 and separated into roots, vines, and tubers. Tubers were counted and plant parts were dried at 60C for two weeks and then weighed. The two middle rows of each plot were harvested on Sept. 18 and tubers were graded according to weight classes: <4 oz, 4-7 oz, 7-14 oz, and >14 oz.

RESULTS: Dry weight of vines, roots, and tubers sampled in June are presented in Tables 1 and 2. For the high P testing site, phosphate fertilizer did not significantly affect dry weight of the various plant parts although there was a trend toward increasing tuber weight with phosphate fertilizer application (Table 1). There was also a slight trend for increasing tuber number with phosphate fertilizer. For the low P testing site, phosphate fertilizer significantly increased vine and tuber dry weight as well as tuber number. From these early plant sample results, phosphate fertilizer appears to have some effect on tuber initiation. That is higher tuber numbers are correlated to an increase in phosphate fertilizer particularly when soil phosphorus is less than 20 ppm.

Elemental composition of the most recently matured leaf sampled in June is presented in Tables 3 and 4. Concentrations of leaf P generally increased with increasing phosphate fertilizer application. For the low testing P site, concentrations of leaf Ca and Mg also increased with phosphate fertilizer application which may be related to additions of these nutrients with the phosphate fertilizer. For the high P testing site leaf nutrient concentrations other than P were not affected by phosphate fertilizer.

Tuber yield and size distribution are presented in Tables 5 and 6. For the high P testing site, phosphate fertilizer did not affect total tuber yield, but did affect tuber size distribution. In general, phosphate fertilizer increased the yield of 4-7 oz tubers, but decreased the yield of 7-14 oz tubers. Similar results were also obtained in the low P testing site except that total yield also tended to increase with linearly with phosphate fertilizer. The increase in smaller sized tubers with P fertilization may be a reflection of the increase in tuber initiation observed in the June sampling. This study will be continued in future years to determine whether the trends observed are consistent over years.

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[1]We thank the R. D. Offutt Co. for providing funds to support this project.

[2]Ext. Soil Scientist and Jr. Scientist, respectively, Dept. of Soil Sci.; Director, Sand Plain Research Farm.

Table 1. Effect of phosphate fertilizer on dry matter of vines, roots, tubers and number of tubers sampled June 21. High initial soil test P and high pH plot.

Phosphate Treatment	Plant Part			
	vines	roots	tubers	# of tubers[1]
lbs P_2O_5/A	-------g dry weight[1] -------			
0 lbs/A	84.5	14.0	47.0	22
50 lbs/A	83.5	16.0	64.5	20
100 lbs/A	105.0	22.5	57.0	24
150 lbs/A	89.0	21.0	65.0	22
200 lbs/A	83.0	17.5	50.0	26
250 lbs/A	115.0	25.0	74.0	29
Pr>F	0.13	0.33	0.16	0.45
Lin P_2O_5	NS	NS	NS	NS
Quad P_2O_5	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	*	NS

NS = Nonsignificant, * = significant at 5%, ** = significant at 1%.
[1]Totals from two plants

Table 2. Effect of phosphate fertilizer on dry matter of vines, roots, tubers and number of tubers sampled June 21. Low initial soil test P and low pH plot.

Phosphate Treatment	Plant Part			
	vines	roots	tubers	# of tubers[1]
lbs P_2O_5/A	-------g dry weight[1] -------			
0 lbs/A	74.5	16.5	51.5	18
50 lbs/A	81.0	16.0	61.0	23
100 lbs/A	107.5	17.5	69.5	30
150 lbs/A	120.5	18.5	68.5	29
200 lbs/A	130.5	26.5	80.5	28
250 lbs/A	120.5	17.0	82.5	34
Pr>F	0.03	0.36	0.55	0.04
Lin P_2O_5	**	NS	++	**
Quad P_2O_5	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS

NS = Nonsignificant, ++ = significant at 10%, ** = significant at 1%.
[1]Totals from two plants

Table 3. Effects of phosphate fertilizer on nutrient concentration in leaf tissue (leaflets plus petioles). High initial soil test P and high pH. Leaves were sampled June 21, 1990.

Phosphate Treatment	Nutrient									
	NO3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
lbs P_2O_5/A	ppm	----------- % -----------				----------- ppm -----------				
0 lbs/A	2027	0.30	5.06	0.66	0.47	82	68	21	470	28
50 lbs/A	2314	0.32	5.15	0.65	0.49	89	67	21	512	28
100 lbs/A	2213	0.29	5.09	0.68	0.47	83	70	18	378	27
150 lbs/A	1666	0.33	4.72	0.66	0.48	84	61	21	546	28
200 lbs/A	1882	0.34	5.15	0.72	0.52	92	65	22	614	28
250 lbs/A	2214	0.36	5.18	0.72	0.48	87	68	20	468	27
Pr>F	0.44	0.18	0.23	0.90	0.60	0.21	0.83	0.23	0.26	0.94
Lin P_2O_5	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Quad P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 4. Effects of phosphate fertilizer on nutrient concentration in leaf tissue (leaflets plus petioles). Low initial soil test P and low pH. Leaves were sampled on June 21, 1990.

Phosphate Treatment	Nutrient									
	NO3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
lbs P_2O_5/A	ppm	%				ppm				
0 lbs/A	2012	0.26	4.82	0.52	0.34	97	113	17	175	20
50 lbs/A	2115	0.26	5.08	0.58	0.37	91	117	15	183	24
100 lbs/A	1706	0.24	4.64	0.54	0.35	78	128	15	144	22
150 lbs/A	1800	0.27	4.78	0.63	0.40	93	127	16	189	24
200 lbs/A	1866	0.26	4.88	0.61	0.39	93	115	14	148	24
250 lbs/A	1512	0.28	4.71	0.60	0.39	97	121	16	183	24
Pr>F	0.38	0.06	0.24	0.04	0.05	0.01	0.85	0.46	0.93	0.30
Lin P_2O_5	NS	NS	NS	**	**	NS	NS	NS	NS	NS
Quad P_2O_5	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 5. Effect of phosphate fertilizer on yield of Russet Burbank potatoes grown on the high initial soil test P and high pH plot.

Phosphate Treatment	Tuber Size				
lbs P_2O_5/A	<4oz	4-7oz	7-14oz	>14oz	Total
	cwt/A				
0 lbs/A	16.3	217.7	377.5	74.6	686.1
50 lbs/A	17.9	251.1	366.3	62.4	697.6
100 lbs/A	26.4	241.6	344.4	65.8	678.1
150 lbs/A	19.4	255.4	349.0	76.3	700.1
200 lbs/A	17.6	304.1	310.1	72.3	704.0
250 lbs/A	21.9	229.5	363.3	72.9	687.5
Pr>F	0.28	0.04	0.55	0.99	0.91
Lin P_2O_5	NS	NS	NS	NS	NS
Quad P_2O_5	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS

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

Table 6. Effect of phosphate fertilizer on yield of Russet Burbank potatos grown on the low initial soil test P and low pH plot.

Phosphate Treatment	Tuber Size				
lbs P_2O_5/A	<4oz	4-7oz	7-14oz	>14oz	Total
	cwt/A				
0 lbs/A	21.3	190.8	307.0	82.3	601.2
50 lbs/A	22.0	209.5	314.6	76.3	622.3
100 lbs/A	25.5	241.8	289.5	64.1	620.8
150 lbs/A	20.9	257.8	296.7	80.6	656.0
200 lbs/A	25.3	233.4	289.5	82.2	630.3
250 lbs/A	26.2	274.3	292.6	76.0	669.0
Pr>F	0.88	0.03	0.69	0.98	0.53
Lin P_2O_5	NS	**	NS	NS	++
Quad P_2O_5	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS

NS = Nonsignificant, ++ = significant at 10%, ** = significant at 1%.

INFLUENCE OF NITROGEN AND POTASSIUM FERTILIZATION ON THE YIELD AND NUTRIENT ACCUMULATION OF FOUR DIFFERENT CORN HYBRIDS-1990 [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 26th, 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 27th and two cultivations May 30,and June 13th. Nitrogen treatments were applied as anhydrous ammonia on June 14th (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 24th, August 14th, August 28th, 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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1. Funding provided by the University of Minnesota Agricultural Experiment Station and Dow Chemical Co.USA.
Appreciation is also expressed to DeKalb Seed Co., Holden Foundation Seed and Pioneer International for seed utilized in our experiment.
2. Professors, and Asst.Scientist, respectively, Dept. of Soil Science, Southern Experiment Station, and Dept of Soil Science University of Minnesota.

The irrigation program began on June 27th and continued through September 5th with a total of 9.15 inches being applied through an overhead solid set irrigation system. An additional 29.31 inches of water was obtained during the growing season as rainfall.

Waseca: The corn experiment at Waseca was similar to that established at Becker except only 40 treatments were evaluated. The experimental design was a split plot with four replications. Treatments included a factorial combination of four hybrids (Pioneer 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 1989. The four corn hybrids were planted on May 7th 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 8 and cultivation on June 21th. Nitrogen treatments were applied as anhydrous ammonia on July 2nd using procedures similar to that used at Becker. Rainfall accumulation over the growing season was 26.52 inches.

Plant and soil samples were taken four times (August 1st, August 29th, September 10th, and October 5th), 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: Maximum grain yields obtained in 1990 were 185 bu/A. This yield level is approximately 35 bu/A less than comparable treatments in 1989. The four hybrids tested produced significantly different yields, with DeKalb 485 having the highest yield, P-3737 the lowest yield, and P-3615 and LH74 X LH85 intermediate in yield. Although there was more precipitation during the 1990 growing season than in 1989 there was no yield advantage associated with fertilizer nitrogen application in excess of 160 lbs N/A. Significant hybrid interactions suggested that DeKalb 485 and LH74 X LH85 were the highest yielding at the low N rate, but D-485 was more responsive to the highest rate of N fertilization. Pioneer 3615 was the only hybrid to exhibit a positive yield response to potassium fertilization. All hybrids tended to have reduced yields when 200 lbs/A of potassium was applied. Nitrification inhibitor application increased yields at the high rates of potassium fertilization, minimizing the negative effect of the highest rate of potassium fertilizer.

Waseca: When no fertilizer N or K was applied the final corn grain yield of Pioneer 3475 was more than 20 bu/A higher than any of the other hybrids tested. The yield of Pioneer 3475 was increased with 80 lbs N/A but did not increase further with 160 lbs N/A. All other hybrids tested required 160 lbs N/A to obtain top yield. When fertilized, all hybrids attained similar yield levels except LH74 X LH82 which was lower than Pioneer 3475. Potassium fertilization had relatively little influence on overall yield, but added potassium did allow for higher yields when the N rate was increased from 80 to 160 lbs/A. Nitrification inhibitor application reduced grain 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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant Silking Stover		
#/A			#/A	T/A	% N	#/A
80	Pioneer 3615	---	---	3.03	1.62	98.7
80		NS	---	2.81	1.67	94.3
80		---	100	2.88	1.23	71.9
80		NS	100	3.28	1.63	107.1
80		---	200	2.78	1.04	58.0
80		NS	200	2.97	1.11	65.6
160		---	200	3.18	1.90	120.6
160		NS	200	3.20	1.78	114.3
240		---	---	2.83	1.66	94.4
240		NS	---	2.77	2.11	116.2
240		---	100	3.05	2.09	127.5
240		NS	100	3.44	1.84	126.6
240		---	200	2.79	1.98	111.4
240		NS	200	2.94	1.84	108.4
80	Pioneer 3737	---	---	3.12	1.44	89.7
80		NS	---	2.93	1.97	114.6
80		---	100	2.97	1.63	96.5
80		NS	100	3.15	1.84	115.4
80		---	200	3.14	1.62	101.8
80		NS	200	3.20	1.22	77.8
160		---	200	3.31	1.77	116.8
160		NS	200	3.21	2.07	132.9
240		---	---	3.16	2.28	144.8
240		NS	---	3.43	2.17	147.6
240		---	100	3.45	1.95	134.7
240		NS	100	3.13	1.74	109.2
240		---	200	2.88	1.70	96.7
240		NS	200	3.07	1.95	120.3
80	LH74 X LH85	---	---	2.97	1.40	83.5
80		NS	---	3.13	1.93	120.7
80		---	100	2.94	1.50	87.6
80		NS	100	3.27	1.51	99.1
80		---	200	3.26	1.53	99.9
80		NS	200	3.21	1.66	106.8
160		---	200	2.98	1.93	115.1
160		NS	200	3.16	1.77	112.2
240		---	---	3.08	1.93	119.0
240		NS	---	3.17	2.03	128.7
240		---	100	2.99	2.03	119.7
240		NS	100	3.05	1.99	121.4
240		---	200	2.99	1.75	105.2
240		NS	200	3.19	2.02	127.9
80	DeKalb 485	---	---	3.31	1.82	121.1
80		NS	---	3.51	1.61	112.6
80		---	100	3.41	1.56	107.1
80		NS	100	3.22	1.48	95.7
80		---	200	3.17	1.36	85.9
80		NS	200	3.54	1.68	118.7
160		---	200	3.34	1.94	130.0
160		NS	200	3.23	1.89	121.8
240		---	---	3.42	1.81	123.8
240		NS	---	3.26	1.99	130.1
240		---	100	3.26	2.04	133.1
240		NS	100	3.31	1.80	119.3
240		---	200	2.99	2.07	123.4
240		NS	200	3.31	2.16	142.9

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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	--------------T/A--------------			
80	Pioneer 3615	---	---	39.0	0.92	3.86	0.72	5.50
80		NS	---	41.1	0.97	3.44	0.75	5.16
80		---	100	31.3	0.74	3.92	0.64	5.29
80		NS	100	40.4	0.96	3.88	0.69	5.53
80		---	200	42.5	1.01	3.55	0.64	5.20
80		NS	200	35.3	0.84	3.58	0.63	5.05
160		---	200	42.0	0.99	3.87	0.81	5.67
160		NS	200	44.4	1.05	3.84	0.67	5.56
240		---	---	44.4	1.05	3.91	0.80	5.75
240		NS	---	37.7	0.89	3.34	0.79	5.02
240		---	100	40.7	0.96	3.91	0.72	5.59
240		NS	100	42.0	0.99	3.82	0.75	5.56
240		---	200	40.8	0.97	3.44	0.61	5.02
240		NS	200	41.6	0.98	3.72	0.68	5.38
80	Pioneer 3737	---	---	54.5	1.29	3.64	0.68	5.61
80		NS	---	48.8	1.15	3.69	0.67	5.51
80		---	100	46.4	1.10	3.49	0.56	5.14
80		NS	100	46.0	1.09	3.86	0.56	5.51
80		---	200	48.2	1.14	3.31	0.51	4.96
80		NS	200	48.8	1.15	3.44	0.54	5.13
160		---	200	53.3	1.26	3.55	0.58	5.40
160		NS	200	52.7	1.25	3.77	0.65	5.67
240		---	---	46.6	1.10	3.77	0.68	5.54
240		NS	---	49.4	1.17	3.54	0.69	5.40
240		---	100	58.6	1.39	4.21	0.71	6.31
240		NS	100	51.3	1.21	3.64	0.65	5.51
240		---	200	56.9	1.35	3.72	0.65	5.73
240		NS	200	59.4	1.40	3.65	0.70	5.75
80	LH74 X LH85	---	---	54.9	1.30	3.74	0.65	5.69
80		NS	---	49.3	1.17	3.30	0.71	5.18
80		---	100	55.0	1.30	3.90	0.73	5.92
80		NS	100	48.3	1.14	3.69	0.68	5.51
80		---	200	55.1	1.30	3.86	0.69	5.85
80		NS	200	53.8	1.27	3.84	0.73	5.84
160		---	200	46.7	1.11	3.42	0.70	5.23
160		NS	200	57.4	1.36	3.87	0.78	6.01
240		---	---	49.7	1.18	3.48	0.73	5.38
240		NS	---	61.6	1.46	3.70	0.77	5.93
240		---	100	54.0	1.28	3.92	0.71	5.91
240		NS	100	41.9	0.99	3.44	0.74	5.17
240		---	200	53.3	1.26	3.66	0.77	5.70
240		NS	200	57.3	1.36	3.60	0.73	5.69
80	DeKalb 485	---	---	48.1	1.14	3.92	0.66	5.72
80		NS	---	50.6	1.20	4.34	0.73	6.27
80		---	100	42.2	1.00	3.64	0.60	5.23
80		NS	100	42.7	1.01	3.85	0.66	5.51
80		---	200	41.6	0.98	4.33	0.62	5.93
80		NS	200	46.4	1.10	3.96	0.66	5.72
160		---	200	41.5	0.98	3.90	0.65	5.53
160		NS	200	44.0	1.04	4.02	0.73	5.79
240		---	---	53.8	1.27	3.75	0.72	5.74
240		NS	---	51.3	1.21	3.81	0.73	5.75
240		---	100	48.0	1.13	4.19	0.68	6.01
240		NS	100	47.3	1.12	4.05	0.67	5.84
240		---	200	46.5	1.10	4.14	0.72	5.95
240		NS	200	40.9	0.97	4.07	0.71	5.74

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 1990.

				N-Concentration			N-Removal			
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Cob	Stover	Grain	Cob	Total
#/A			#/A		%			#/A		
80	Pioneer 3615	---	---	0.73	1.83	1.01	56.2	33.7	14.6	104.4
80		NS	---	0.61	1.88	0.99	41.4	36.5	14.9	92.8
80		---	100	0.83	2.07	1.03	64.3	30.7	13.1	108.1
80		NS	100	0.93	1.88	1.06	72.2	35.8	14.7	122.7
80		---	200	0.74	1.76	0.85	52.8	35.3	11.1	99.2
80		NS	200	0.88	2.01	0.94	63.1	33.6	12.0	108.6
160		---	200	0.97	2.12	0.98	74.8	42.1	15.8	132.8
160		NS	200	0.88	1.99	0.88	67.6	41.8	12.1	121.5
240		---	---	0.91	1.98	1.02	71.3	41.5	16.2	129.0
240		NS	---	1.11	2.28	1.08	74.9	40.2	17.1	132.1
240		---	100	1.10	1.88	0.95	86.8	36.0	13.8	136.6
240		NS	100	0.91	2.11	0.88	70.2	42.0	13.1	125.2
240		---	200	1.07	1.69	1.01	73.6	32.6	12.4	118.6
240		NS	200	0.88	2.04	1.12	65.7	39.9	15.1	120.7
80	Pioneer 3737	---	---	0.68	1.88	0.83	49.3	48.1	11.3	108.6
80		NS	---	0.75	1.89	0.82	54.7	43.6	11.2	109.6
80		---	100	0.79	1.78	0.80	54.9	38.8	9.1	102.9
80		NS	100	0.78	1.86	0.83	59.9	40.6	9.3	109.8
80		---	200	0.57	1.64	0.75	37.4	37.6	7.7	82.7
80		NS	200	1.00	1.71	0.87	69.3	39.5	9.3	118.1
160		---	200	1.10	1.93	0.74	78.3	48.6	8.6	135.5
160		NS	200	0.92	1.98	0.79	69.2	49.4	10.2	128.7
240		---	---	1.15	2.14	0.82	85.9	46.9	11.1	144.0
240		NS	---	0.93	2.09	0.88	66.6	48.9	12.0	127.5
240		---	100	0.73	1.99	0.84	61.9	55.2	12.1	129.2
240		NS	100	0.93	1.80	0.84	67.8	43.1	10.9	121.7
240		---	200	0.98	1.94	0.96	72.6	52.2	12.6	137.4
240		NS	200	1.01	1.97	0.73	73.4	55.3	10.2	138.9
80	LH74 X LH85	---	---	0.83	1.60	0.79	62.3	41.5	10.3	114.1
80		NS	---	0.75	1.53	0.81	49.1	36.0	11.6	96.6
80		---	100	0.62	1.64	0.77	47.6	42.9	11.2	101.7
80		NS	100	0.74	1.64	0.87	54.9	37.6	11.8	104.3
80		---	200	0.80	1.52	0.74	61.7	39.5	10.3	111.5
80		NS	200	0.75	1.53	0.74	57.1	38.9	10.8	106.8
160		---	200	0.99	1.89	0.87	67.7	41.9	12.3	121.8
160		NS	200	0.92	1.82	0.82	71.2	49.3	12.8	133.3
240		---	---	1.01	1.86	0.90	70.0	43.7	13.0	126.7
240		NS	---	0.65	1.76	0.75	46.6	51.5	11.4	109.5
240		---	100	0.99	1.94	0.83	77.2	49.4	11.7	138.4
240		NS	100	1.08	1.69	0.81	74.5	34.0	11.8	120.4
240		---	200	1.00	1.89	0.78	73.6	47.6	12.0	133.2
240		NS	200	1.24	1.81	0.83	88.3	49.0	12.1	149.4
80	DeKalb 485	---	---	0.74	1.73	0.74	58.3	39.1	9.9	107.3
80		NS	---	0.90	1.76	0.79	78.0	41.3	11.5	130.9
80		---	100	0.91	1.64	0.80	66.2	32.6	9.6	108.3
80		NS	100	0.54	1.65	0.73	41.7	32.8	9.5	84.0
80		---	200	0.91	1.59	0.77	78.6	31.6	9.7	119.9
80		NS	200	0.95	1.78	0.74	74.0	38.9	9.9	122.8
160		---	200	1.00	2.07	0.75	77.9	40.6	9.7	128.3
160		NS	200	0.77	1.97	0.70	62.1	41.1	10.3	113.5
240		---	---	0.94	1.94	0.77	68.7	49.0	11.0	128.7
240		NS	---	0.85	1.90	0.77	63.8	45.9	11.3	120.9
240		---	100	0.93	1.85	0.77	77.5	41.8	10.4	129.7
240		NS	100	0.99	1.97	0.83	79.3	43.8	11.2	134.3
240		---	200	1.01	1.93	0.85	83.3	42.4	12.2	137.9
240		NS	200	1.00	2.05	0.83	81.3	39.6	11.7	132.6

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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	--------------T/A--------------			
80	Pioneer 3615	---	---	117.4	2.78	3.12	0.79	6.69
80		NS	---	104.2	2.47	2.96	0.82	6.25
80		---	100	104.1	2.46	3.11	0.83	6.41
80		NS	100	113.8	2.69	3.18	0.79	6.66
80		---	200	103.6	2.45	2.88	0.72	6.05
80		NS	200	99.6	2.36	2.89	0.68	5.93
160		---	200	118.3	2.80	3.14	0.82	6.76
160		NS	200	124.5	2.95	3.29	0.87	7.11
240		---	---	117.7	2.78	3.08	0.83	6.70
240		NS	---	123.6	2.92	3.30	0.94	7.17
240		---	100	116.8	2.76	3.24	0.86	6.86
240		NS	100	117.7	2.79	3.49	0.86	7.13
240		---	200	121.7	2.88	2.94	0.86	6.69
240		NS	200	115.6	2.73	3.26	0.90	6.90
80	Pioneer 3737	---	---	118.4	2.80	2.86	0.66	6.33
80		NS	---	107.6	2.55	3.12	0.68	6.35
80		---	100	124.0	2.93	2.88	0.73	6.54
80		NS	100	107.2	2.54	2.75	0.62	5.90
80		---	200	109.8	2.60	2.60	0.57	5.77
80		NS	200	113.1	2.68	2.94	0.61	6.22
160		---	200	144.7	3.42	3.25	0.79	7.47
160		NS	200	124.1	2.94	3.04	0.72	6.69
240		---	---	124.9	2.96	3.16	0.78	6.89
240		NS	---	127.2	3.01	3.11	0.83	6.95
240		---	100	140.4	3.32	3.29	0.80	7.41
240		NS	100	129.6	3.07	3.10	0.77	6.94
240		---	200	131.6	3.11	3.17	0.72	7.00
240		NS	200	130.5	3.09	3.12	0.74	6.94
80	LH74 X LH85	---	---	123.2	2.92	2.98	0.82	6.72
80		NS	---	127.0	3.01	2.93	0.85	6.79
80		---	100	116.6	2.76	3.01	0.78	6.55
80		NS	100	112.5	2.66	3.12	0.73	6.51
80		---	200	123.5	2.92	3.13	0.85	6.90
80		NS	200	129.1	3.05	3.25	0.80	7.10
160		---	200	120.8	2.86	2.91	0.79	6.56
160		NS	200	139.0	3.29	3.25	0.84	7.38
240		---	---	121.3	2.87	2.95	0.82	6.64
240		NS	---	149.2	3.53	3.11	0.95	7.58
240		---	100	124.1	2.94	2.93	0.86	6.72
240		NS	100	131.6	3.11	3.21	0.88	7.21
240		---	200	117.6	2.78	2.81	0.79	6.38
240		NS	200	129.2	3.06	3.26	0.88	7.19
80	DeKalb 485	---	---	121.7	2.88	3.55	0.83	7.25
80		NS	---	124.9	2.96	3.53	0.84	7.33
80		---	100	122.1	2.89	3.49	0.80	7.18
80		NS	100	129.0	3.05	3.65	0.84	7.54
80		---	200	114.2	2.70	3.35	0.73	6.78
80		NS	200	112.4	2.66	3.13	0.73	6.53
160		---	200	113.5	2.69	3.33	0.77	6.78
160		NS	200	122.7	2.90	3.36	0.80	7.07
240		---	---	127.3	3.01	3.47	0.80	7.28
240		NS	---	121.5	2.87	3.45	0.79	7.12
240		---	100	129.9	3.07	3.53	0.88	7.48
240		NS	100	125.3	2.97	3.39	0.82	7.17
240		---	200	136.3	3.23	3.71	0.92	7.86
240		NS	200	119.4	2.83	3.58	0.79	7.19

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 1990.

				N-Concentration			N-Removal			
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Cob	Stover	Grain	Cob	Total
#/A			#/A	-----------%----------			-----------------#/A-------------			
80	Pioneer 3615	---	---	0.82	1.27	0.51	51.3	70.6	8.0	129.8
80		NS	---	1.08	1.36	0.58	64.0	67.2	9.5	140.7
80		---	100	1.04	1.37	0.63	64.8	67.4	10.7	142.9
80		NS	100	0.97	1.54	0.63	61.6	82.6	9.9	154.2
80		---	200	0.76	1.41	0.50	44.3	69.4	7.2	120.9
80		NS	200	0.97	1.39	0.72	56.0	65.3	9.9	131.2
160		---	200	1.27	1.66	0.57	79.9	93.3	9.1	182.4
160		NS	200	1.11	1.47	0.51	73.0	86.5	8.9	168.4
240		---	---	1.40	1.55	0.53	86.0	86.3	8.8	181.2
240		NS	---	1.16	1.48	0.51	76.0	86.8	9.6	172.4
240		---	100	1.26	1.53	0.54	82.3	84.7	9.2	176.2
240		NS	100	1.37	1.69	0.52	95.3	94.1	9.0	198.4
240		---	200	1.13	1.56	0.56	66.2	90.0	9.5	165.7
240		NS	200	1.26	1.43	0.54	82.1	78.8	9.7	170.7
80	Pioneer 3737	---	---	0.93	1.37	0.45	53.1	76.4	5.9	135.4
80		NS	---	1.06	1.52	0.42	65.4	77.5	5.9	148.8
80		---	100	0.97	1.37	0.45	56.1	80.4	6.6	143.1
80		NS	100	1.08	1.46	0.45	59.5	74.2	5.6	139.3
80		---	200	0.80	1.33	0.38	41.6	68.8	4.4	114.8
80		NS	200	0.85	1.39	0.49	49.3	74.3	5.9	129.6
160		---	200	1.04	1.63	0.44	68.2	111.5	7.1	186.8
160		NS	200	1.20	1.60	0.53	72.2	93.7	7.7	173.6
240		---	---	1.53	1.73	0.48	96.8	102.4	7.4	206.5
240		NS	---	1.37	1.74	0.52	85.3	104.8	8.6	198.6
240		---	100	1.23	1.66	0.45	80.8	110.6	7.2	198.5
240		NS	100	1.13	1.70	0.43	70.3	103.4	6.5	180.2
240		---	200	1.32	1.67	0.51	83.5	104.2	7.2	194.9
240		NS	200	1.32	1.69	0.48	82.2	104.5	7.1	193.8
80	LH74 X LH85	---	---	1.01	1.35	0.51	60.6	78.8	8.2	147.7
80		NS	---	1.09	1.40	0.64	64.2	83.9	11.0	159.0
80		---	100	1.17	1.30	0.68	70.7	71.6	10.6	152.9
80		NS	100	1.03	1.27	0.48	63.9	67.6	6.9	138.3
80		---	200	0.99	1.32	0.62	61.8	77.3	10.7	149.8
80		NS	200	0.91	1.33	0.53	59.3	81.3	8.5	149.0
160		---	200	1.08	1.48	0.52	62.3	85.0	8.2	155.5
160		NS	200	1.18	1.37	0.48	76.8	90.3	7.9	175.1
240		---	---	1.23	1.55	0.56	72.6	88.7	9.2	170.6
240		NS	---	1.23	1.53	0.52	76.0	108.0	10.0	194.
240		---	100	1.27	1.48	0.44	74.2	87.2	7.6	168.9
240		NS	100	1.19	1.52	0.55	76.3	94.5	9.6	180.4
240		---	200	1.13	1.56	0.48	63.2	86.7	7.6	157.4
240		NS	200	1.19	1.54	0.52	77.4	94.2	9.2	180.8
80	DeKalb 485	---	---	1.06	1.24	0.46	75.2	71.3	7.5	153.9
80		NS	---	1.03	1.21	0.58	73.2	71.6	9.7	154.4
80		---	100	1.07	1.19	0.45	74.4	68.7	7.1	150.2
80		NS	100	1.15	1.23	0.48	84.7	75.0	8.2	167.9
80		---	200	0.84	1.20	0.46	56.1	64.7	6.7	127.6
80		NS	200	1.24	1.29	0.49	77.2	69.4	7.2	153.8
160		---	200	1.22	1.45	0.51	81.0	78.3	7.8	167.0
160		NS	200	1.23	1.35	0.45	82.9	77.8	7.2	167.9
240		---	---	1.36	1.54	0.43	94.5	92.9	6.9	194.2
240		NS	---	1.60	1.55	0.53	110.3	89.0	8.4	207.7
240		---	100	1.36	1.51	0.53	96.4	92.6	9.3	198.3
240		NS	100	1.39	1.49	0.49	94.1	88.0	8.0	190.2
240		---	200	1.40	1.53	0.48	103.7	98.8	8.8	211.3
240		NS	200	1.47	1.49	0.49	105.1	84.2	7.7	197.0

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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
#/A			#/A	Bu/A	----------T/A----------		
80	Pioneer 3615	---	---	147.7	3.49	3.80	7.29
80		NS	---	142.2	3.36	3.38	6.74
80		---	100	166.5	3.94	3.94	7.88
80		NS	100	159.0	3.76	3.60	7.36
80		---	200	143.1	3.39	3.65	7.03
80		NS	200	151.0	3.57	3.66	7.23
160		---	200	148.6	3.52	3.51	7.03
160		NS	200	169.4	4.01	3.73	7.74
240		---	---	155.7	3.68	3.43	7.12
240		NS	---	157.9	3.74	3.55	7.29
240		---	100	172.8	4.09	3.66	7.75
240		NS	100	185.3	4.38	4.24	8.63
240		---	200	159.7	3.78	3.63	7.41
240		NS	200	180.0	4.26	3.97	8.23
80	Pioneer 3737	---	---	154.1	3.65	3.36	7.01
80		NS	---	143.1	3.39	3.82	7.20
80		---	100	133.0	3.15	3.47	6.61
80		NS	100	141.4	3.35	3.45	6.80
80		---	200	121.2	2.87	3.33	6.20
80		NS	200	137.6	3.26	3.50	6.75
160		---	200	159.0	3.76	3.51	7.27
160		NS	200	152.3	3.60	3.65	7.25
240		---	---	158.1	3.74	3.71	7.45
240		NS	---	153.2	3.62	3.73	7.35
240		---	100	171.1	4.05	3.78	7.83
240		NS	100	162.0	3.83	3.65	7.48
240		---	200	157.1	3.72	3.47	7.19
240		NS	200	157.5	3.73	3.38	7.11
80	LH74 X LH85	---	---	159.8	3.78	4.11	7.89
80		NS	---	164.4	3.89	4.24	8.13
80		---	100	166.6	3.94	4.06	8.00
80		NS	100	152.4	3.61	3.66	7.27
80		---	200	149.4	3.53	3.73	7.27
80		NS	200	150.3	3.56	3.78	7.34
160		---	200	151.0	3.57	3.80	7.37
160		NS	200	172.7	4.09	4.07	8.16
240		---	---	162.3	3.84	3.82	7.66
240		NS	---	161.1	3.81	3.74	7.55
240		---	100	178.5	4.22	3.86	8.08
240		NS	100	166.8	3.95	4.31	8.26
240		---	200	157.3	3.72	3.73	7.45
240		NS	200	151.4	3.58	3.57	7.15
80	DeKalb 485	---	---	165.6	3.92	4.15	8.07
80		NS	---	175.9	4.16	3.91	8.07
80		---	100	151.9	3.59	3.86	7.46
80		NS	100	158.3	3.75	4.28	8.03
80		---	200	157.1	3.72	4.16	7.88
80		NS	200	160.3	3.79	4.05	7.85
160		---	200	173.3	4.10	4.19	8.29
160		NS	200	171.3	4.05	4.13	8.18
240		---	---	186.0	4.40	4.27	8.67
240		NS	---	155.2	3.67	3.97	7.65
240		---	100	174.4	4.13	3.95	8.08
240		NS	100	184.4	4.36	4.08	8.44
240		---	200	171.1	4.05	3.82	7.87
240		NS	200	167.0	3.95	4.16	8.11

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 1990.

				N-Concentration		N-Removal		
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Stover	Grain	Total
#/A			#/A	-------%--------		-----------#/A---------		
80	Pioneer 3615	---	---	0.57	1.20	43.1	84.0	106.6
80		NS	---	0.58	1.37	39.0	92.3	131.3
80		---	100	0.56	1.12	44.6	88.7	133.2
80		NS	100	0.61	1.35	43.9	101.0	144.9
80		---	200	0.55	1.27	40.2	85.6	125.8
80		NS	200	0.49	1.24	36.0	88.3	124.3
160		---	200	0.74	1.54	51.9	108.4	160.3
160		NS	200	0.66	1.52	49.1	121.4	170.4
240		---	---	0.60	1.26	41.6	93.3	134.8
240		NS	---	0.74	1.48	52.5	110.4	162.9
240		---	100	0.66	1.53	48.3	124.7	173.0
240		NS	100	0.71	1.49	60.0	130.5	190.5
240		---	200	0.68	1.47	49.1	111.4	160.5
240		NS	200	0.73	1.40	57.9	118.8	176.7
80	Pioneer 3737	---	---	0.59	1.45	39.5	105.7	145.2
80		NS	---	0.50	1.40	38.7	94.9	133.6
80		---	100	0.57	1.24	39.3	77.6	116.9
80		NS	100	0.60	1.28	40.9	85.3	126.3
80		---	200	0.58	1.44	38.8	81.7	120.5
80		NS	200	0.56	1.35	38.8	87.8	126.7
160		---	200	0.72	1.48	51.0	110.7	161.7
160		NS	200	0.77	1.55	56.3	111.8	168.1
240		---	---	0.77	1.59	57.3	118.6	175.9
240		NS	---	0.84	1.53	63.0	111.0	174.0
240		---	100	0.72	1.52	54.0	122.9	176.9
240		NS	100	0.76	1.53	54.9	117.2	172.1
240		---	200	0.66	1.57	45.3	116.5	161.8
240		NS	200	0.85	1.49	57.5	111.4	168.9
80	LH74 X LH85	---	---	0.64	1.19	52.7	89.8	142.5
80		NS	---	0.58	1.17	49.6	91.5	141.1
80		---	100	0.81	1.13	65.8	89.0	154.8
80		NS	100	0.64	1.24	47.0	89.0	136.1
80		---	200	0.55	1.24	41.2	87.6	128.8
80		NS	200	0.62	1.15	47.0	81.9	128.9
160		---	200	0.79	1.49	59.7	106.5	166.2
160		NS	200	0.77	1.34	62.8	109.7	172.5
240		---	---	0.76	1.33	58.3	102.4	160.7
240		NS	---	0.67	1.45	50.4	110.2	160.6
240		---	100	0.94	1.42	72.2	119.7	191.9
240		NS	100	0.86	1.32	74.9	104.0	178.9
240		---	200	0.74	1.44	55.5	107.3	162.8
240		NS	200	0.76	1.44	54.5	103.7	158.2
80	DeKalb 485	---	---	0.65	1.27	54.4	99.5	154.0
80		NS	---	0.67	1.23	52.7	102.8	155.5
80		---	100	0.73	1.38	57.0	98.4	155.4
80		NS	100	0.57	1.29	48.6	96.4	145.0
80		---	200	0.58	1.08	48.5	79.9	128.4
80		NS	200	0.58	1.31	46.7	99.4	146.1
160		---	200	0.66	1.26	55.0	103.8	158.9
160		NS	200	0.76	1.24	62.7	100.9	163.5
240		---	---	0.73	1.67	62.4	146.6	209.0
240		NS	---	0.73	1.33	57.8	97.0	154.8
240		---	100	0.80	1.33	63.5	110.1	173.6
240		NS	100	0.83	1.38	67.5	120.0	187.5
240		---	200	0.71	1.50	54.1	121.2	175.3
240		NS	200	0.73	1.37	60.9	108.1	169.0

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	2.97	1.60	96.3
Pioneer 3737	3.13	1.72	107.7
LH74 X LH85	3.13	1.77	111.1
DeKalb 485	3.26	1.84	120.4
P-Value	99	99	99
BLSD (.05)	0.15	0.07	1.5
N-Rate			
80	3.15	1.40	89.3
160	3.20	1.88	120.4
240	3.02	1.93	117.0
P-Value	98	99	99
BLSD (.05)	0.13	0.07	6.1
Inhibitor			
None	3.06	1.71	105.4
N-Serve	3.18	1.76	112.4
P-Value	97	83	99
Hybrid X N-Rate	78	99	99
Hybrid X Inhibitor	16	71	72
N-Rate X Inhibitor	77	68	93
Hybrid X N-Rate X Inh.	32	99	99
Split Plot without the 160# N-Rate			
K-Rate			
0	3.12	1.84	114.9
100	3.17	1.74	110.7
200	3.08	1.66	103.1
P-Value	30	99	94
BLSD(.05)		0.12	
Hybrid X N-Rate X Inhibitor			
Hybrid			
Pioneer 3615	2.96	1.61	98.3
Pioneer 3737	3.13	1.79	112.4
LH74 X LH85	3.10	1.77	109.9
DeKalb 485	3.30	1.78	117.8
P-Value	99	99	99
BLSD(.05)	0.11	0.08	6.1
N-Rate			
80	3.13	1.54	97.0
240	3.12	1.95	122.1
P-Value	21	99	99
Inhibitor			
None	3.07	1.71	105.6
N-Serve	3.17	1.78	113.6
P-Value	99	99	99
Hybrid X N-Rate	63	91	64
Hybrid X Inhibitor	19	73	72
N-Rate X Inhibitor	1	90	72
Hybrid X N-Rate X Inhibitor	2	22	6
Hybrid X N-Rate X Inhibitor X K-Rate			
Hybrid X K-Rate	93	99	99
N-Rate X K-Rate	90	99	51
Hybrid X N-Rate X K-Rate	50	99	99
Inhibitor X K-Rate	73	99	80
Hybrid X Inhibitor X K-Rate	84	91	98
N-Rate X Inhibitor X K-Rate	43	98	99
Hybrid X N-Rate X Inhibitor X K-Rate	78	99	99

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

200 # K-Rate only RCB (Hybrid X N-Rate X Inh.)	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
Hybrids	Bu/A	-------------T/A---------------			
Pioneer 3615	41.1	0.97	3.66	0.67	5.31
Pioneer 3737	53.2	1.25	3.57	0.60	5.44
LH74 X LH85	53.9	1.27	3.70	0.73	5.71
DeKalb 485	43.4	1.02	4.09	0.68	5.77
P-Value	99	99	99	99	99
BLSD (.05)	2.8	0.06	0.21	0.04	0.29
N-Rate					
80	46.4	1.09	3.73	0.62	5.46
160	47.7	1.12	3.78	0.69	5.60
240	49.5	1.17	3.75	0.69	5.61
P-Value	92	93	12	99	63
BLSD (.05)				0.03	
Inhibitor					
None	47.3	1.12	3.72	0.66	5.51
N-Serve	48.4	1.14	3.78	0.68	5.61
P-Value	68	68	49	80	66
Hybrid X N-Rate	91	92	76	96	93
Hybrid X Inhibitor	67	67	27	62	27
N-Rate X Inhibitor	76	76	56	2	65
Hybrid X N-Rate X Inh.	84	84	23	93	32
Split Plot without the 160# N-Rate					
K-Rate					
0	48.7	1.15	3.70	0.71	5.57
100	46.0	1.08	3.83	0.67	5.59
200	48.0	1.13	3.74	0.66	5.54
P-Value	54	54	29	72	3
BLSD(.05)					
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	39.7	0.94	3.69	0.70	5.33
Pioneer 3737	51.2	1.21	3.66	0.63	5.50
LH74 X LH85	52.8	1.25	3.67	0.71	5.64
DeKalb 485	46.6	1.10	4.00	0.67	5.78
P-Value	99	99	99	99	99
BLSD(.05)	2.2	0.05	0.13	0.03	0.19
N-Rate					
80	46.2	1.09	3.75	0.65	5.49
240	48.9	1.15	3.76	0.71	5.64
P-Value	99	99	30	99	95
Inhibitor					
None	48.0	1.13	3.80	0.67	5.61
N-Serve	47.1	1.11	3.71	0.69	5.52
P-Value	48	48	89	84	76
Hybrid X N-Rate	59	59	72	63	81
Hybrid X Inhibitor	8	8	41	14	27
N-Rate X Inhibitor	17	17	77	52	69
Hybrid X N-Rate X Inhibitor	82	82	79	25	67
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	96	96	93	95	77
N-Rate X K-Rate	55	55	71	40	74
Hybrid X N-Rate X K-Rate	96	96	84	79	86
Inhibitor X K-Rate	32	32	34	19	32
Hybrid X Inhibitor X K-Rate	94	94	91	15	86
N-Rate X Inhibitor X K-Rate	82	82	86	6	86
Hybrid X N-Rate X Inhibitor X K-Rate	87	87	49	26	56

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	0.90	1.93	0.96	66.2	37.5	13.0	116.8
Pioneer 3737	0.92	1.86	0.80	66.7	47.0	9.7	123.5
LH74 X LH85	0.94	1.86	0.79	69.9	44.3	11.6	126.0
DeKalb 485	0.93	1.90	0.77	76.1	39.0	10.6	125.8
P-Value	32	99	99	98	99	99	82
BLSD (.05)		0.12	0.06	7.8	3.2	1.1	
N-Rate							
80	0.82	1.69	0.80	61.7	36.8	10.0	108.7
160	0.94	1.97	0.81	71.0	44.3	11.4	126.9
240	1.02	1.91	0.88	76.4	44.3	12.2	133.6
P-Value	99	99	99	99	99	99	99
BLSD (.05)	0.06	0.09	0.05	5.7	2.7	1.0	7.4
Inhibitor							
None	0.92	1.83	0.83	69.3	41.0	11.2	121.5
N-Serve	0.93	1.88	0.83	70.1	43.0	11.3	124.5
P-Value	7	83	20	26	90	28	64
Hybrid X N-Rate	96	73	72	93	93	50	95
Hybrid X Inhibitor	85	60	22	84	2	2	68
N-Rate X Inhibitor	99	87	64	95	2	40	85
Hybrid X N-Rate X Inh.	99	39	94	93	70	95	76
Split Plot without the 160# N-Rate							
K-Rate							
0	0.84	1.87	0.86	62.3	42.9	12.3	117.6
100	0.86	1.83	0.85	66.0	39.8	11.4	117.3
200	0.92	1.80	0.84	69.1	40.8	11.1	121.1
P-Value	99	75	52	79	82	81	28
BLSD(.05)	0.02						
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3615	0.89	1.95	0.99	66.0	36.4	13.9	116.5
Pioneer 3737	0.85	1.89	0.83	62.8	45.8	10.5	119.2
LH74 X LH85	0.87	1.70	0.80	63.5	42.6	11.4	117.7
DeKalb 485	0.88	1.81	0.78	70.5	39.9	10.6	121.4
P-Value	29	99	99	99	99	99	53
BLSD(.05)		0.07	0.02	5.5	2.3	0.6	
N-Rate							
80	0.78	1.74	0.83	58.5	37.7	11.0	107.3
240	0.97	1.93	0.86	73.1	44.6	12.3	130.1
P-Value	99	99	49	99	99	99	99
Inhibitor							
None	0.87	1.82	0.85	66.3	41.2	11.5	119.0
N-Serve	0.88	1.85	0.85	65.3	41.1	11.8	118.3
P-Value	25	83	35	41	5	82	25
Hybrid X N-Rate	63	85	1	53	64	32	47
Hybrid X Inhibitor	71	99	35	66	89	53	52
N-Rate X Inhibitor	80	3	91	91	33	87	91
Hybrid X N-Rate X Inhibitor	58	95	88	77	47	31	65
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	81	81	62	99	51	99	98
N-Rate X K-Rate	2	71	99	73	33	95	45
Hybrid X N-Rate X K-Rate	99	71	99	99	96	75	98
Inhibitor X K-Rate	92	89	5	94	92	10	95
Hybrid X Inhibitor X K-Rate	99	10	92	96	82	17	68
N-Rate X Inhibitor X K-Rate	99	27	99	99	95	83	97
Hybrid X N-Rate 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	113.8	2.69	3.06	0.80	6.57
Pioneer 3737	125.6	2.97	3.01	0.69	6.68
LH74 X LH85	126.5	2.99	3.10	0.82	6.91
DeKalb 485	119.7	2.83	3.41	0.79	7.03
P-Value	99	99	99	99	96
BLSD (.05)	6.5	0.15	0.18	0.04	0.4
N-Rate					
80	113.7	2.67	3.02	0.71	6.40
160	125.9	2.97	3.19	0.80	6.97
240	125.2	2.96	3.23	0.82	7.01
P-Value	99	99	97	99	99
BLSD (.05)	5.4	0.12	0.17	0.03	0.29
Iinhibitor					
None	121.3	2.87	3.10	0.77	6.74
N-Serve	121.6	2.87	3.19	0.78	6.85
P-Value	10	10	83	18	59
Hybrid X N-Rate	97	97	90	97	97
Hybrid X Inhibitor	95	95	82	39	90
N-Rate X Inhibitor	46	46	13	15	6
Hybrid X N-Rate X Inh.	90	90	47	85	74
Split Plot without the 160# N-Rate					
K-Rate					
0	122.3	2.89	3.16	0.81	6.87
100	121.5	2.87	3.21	0.80	6.88
200	119.2	2.82	3.12	0.76	6.71
P-Value	37	37	62	88	59
BLSD(.05)					
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	112.9	2.67	3.12	0.82	6.61
Pioneer 3737	122.0	2.88	3.00	0.70	6.60
LH74 X LH85	125.4	3.05	3.05	0.83	6.85
DeKalb 485	123.6	2.92	3.48	0.81	7.22
P-Value	99	99	99	99	99
BLSD(.05)	4.1	0.09	0.11	0.02	0.21
N-Rate					
80	115.8	2.73	3.10	0.75	6.59
240	126.2	2.98	3.23	0.83	7.05
P-Value	99	99	99	99	99
Inhibitor					
None	121.1	2.86	3.13	0.79	6.79
N-Serve	120.8	2.85	3.20	0.79	6.85
P-Value	17	17	86	33	56
Hybrid X N-Rate	96	96	93	93	98
Hybrid X Inhibitor	99	99	72	60	96
N-Rate X Inhibitor	55	55	42	79	59
Hybrid X N-Rate X Inhibitor	96	96	88	98	92
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	83	83	53	66	31
N-Rate X K-Rate	35	35	53	85	61
Hybrid X N-Rate X K-Rate	88	88	74	94	89
Inhibitor X K-Rate	33	33	16	96	21
Hybrid X Inhibitor X K-Rate	88	88	35	35	59
N-Rate X Inhibitor X K-Rate	90	90	8	13	46
Hybrid X N-Rate X Inhibitor X K-Rate	7	7	5	8	3

Table 12. Continued from table 5. Dent Stage R5

	N-Concentration			N-Removal			
	Stover	Grain	Cob	Stover	Grain	Cob	Total
	---------%----------			-----------#/A-------------			
200 # K-Rate only RCB (Hybrid X N-Rate X Inh.)							
Hybrid							
Pioneer3615	1.48	1.08	0.56	66.9	80.5	9.0	156.5
Pioneer 3737	1.55	1.08	0.46	66.1	92.8	6.5	165.5
LH74 X LH85	1.43	1.07	0.52	66.8	85.7	8.6	161.2
DeKalb 485	1.38	1.23	0.47	84.3	78.8	7.5	170.5
P-Value	99	99	99	99	99	99	97
BLSD (.05)	0.05	0.05	0.04	4.8	5.6	0.8	10.9
N-Rate							
80	1.33	0.91	0.52	55.7	71.3	7.5	134.5
160	1.50	1.16	0.49	74.5	89.5	7.9	172.0
240	1.55	1.27	0.50	82.9	92.6	8.3	183.9
P-Value	99	99	45	99	99	84	99
BLSD (.05)	0.04	0.04		4.1	4.6		7.6
Inhibitor							
None	1.08	1.48	0.50	67.6	85.6	7.8	161.1
N-Serve	1.16	1.44	0.51	74.4	83.3	8.0	165.9
P-Value	99	92	63	99	72	45	82
Hybrid X N-Rate	99	98	78	99	99	95	99
Hybrid X Inhibitor	85	85	76	23	84	59	54
N-Rate X Inhibitor	92	98	89	59	73	35	76
Hybrid X N-Rate X Inh.	99	2	98	98	70	84	86
Split Plot without the 160# N-Rate							
K-Rate							
0	1.18	1.46	0.51	75.2	84.7	8.4	168.4
100	1.16	1.45	0.51	75.2	83.9	8.2	167.4
200	1.09	1.44	0.51	69.3	81.9	7.9	159.2
P-Value	91	26	5	88	37	83	78
BLSD(.05)							
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3615	1.10	1.46	0.56	69.1	78.6	9.2	157.0
Pioneer 3737	1.13	1.55	0.45	68.6	90.1	6.5	165.3
LH74 X LH85	1.11	1.42	0.54	68.3	84.9	9.0	162.4
DeKalb 485	1.24	1.37	0.48	87.0	80.5	7.9	175.5
P-Value	99	99	99	99	99	99	99
BLSD(.05)	0.04	0.03	0.02	3.6	3.5	0.5	6.5
N-Rate							
80	0.99	1.33	0.52	62.0	73.1	6.5	143.1
240	1.30	1.57	0.50	84.6	93.9	7.0	186.9
P-Value	99	99	93	99	99	95	99
Inhibitor							
None	1.12	1.43	0.50	71.2	82.9	8.0	162.1
N-Serve	1.17	1.46	0.52	75.3	84.1	8.3	167.9
P-Value	99	98	95	99	64	91	99
Hybrid X N-Rate	99	99	99	99	99	99	99
Hybrid X Inhibitor	99	69	72	76	85	20	49
N-Rate X Inhibitor	98	99	75	72	44	7	66
Hybrid X N-Rate X Inhibitor	87	33	99	96	94	99	98
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	94	99	62	96	90	52	83
N-Rate X K-Rate	99	19	49	91	6	56	83
Hybrid X N-Rate X K-Rate	86	54	64	81	33	91	62
Inhibitor X K-Rate	98	88	97	91	48	99	40
Hybrid X Inhibitor X K-Rate	47	94	71	5	96	46	52
N-Rate X Inhibitor X K-Rate	73	52	93	39	72	75	23
Hybrid X N-Rate X Inh. X K-Rate	99	34	99	99	1	98	64

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	158.6	3.75	3.69	7.44
Pioneer 3737	147.4	3.48	3.47	6.96
LH74 X LH85	155.3	3.67	3.78	7.45
DeKalb 485	166.6	3.94	4.08	8.03
P-Value	99	99	99	99
BLSD (.05)	6.4	0.15	0.13	0.25
N-Rate				
80	146.2	3.46	3.73	7.19
160	162.1	3.83	3.82	7.66
240	162.6	3.84	3.71	7.56
P-Value	99	99	78	99
BLSD (.05)	5.4	0.12		0.22
Inhibitor				
None	153.9	3.64	3.71	7.35
N-Serve	160.0	3.78	3.80	7.59
P-Value	99	99	92	99
Hybrid X N-Rate	94	94	72	91
Hybrid X Inhibitor	91	91	21	76
N-Rate X Inhibitor	40	40	32	26
Hybrid X N-Rate X Inh.	88	88	76	83
Split Plot without the 160# N-Rate				
K-Rate				
0	158.8	3.75	3.81	7.57
100	164.0	3.86	3.86	7.74
200	154.4	3.72	3.72	7.37
P-Value	84	84	58	78
BLSD(.05)				
Hybrid X N-Rate X Inhibitor				
Hybrid				
Pioneer 3615	160.0	3.78	3.70	7.49
Pioneer 3737	149.1	3.52	3.55	7.08
LH74 X LH85	160.0	3.78	3.88	7.67
DeKalb 485	167.2	3.95	4.05	8.01
P-Value	99	99	99	99
BLSD(.05)	4.6	0.10	0.11	0.19
N-Rate				
80	152.1	3.60	3.79	7.38
240	166.0	3.93	3.81	7.74
P-Value	99	99	37	99
Inhibitor				
None	159.1	3.76	3.78	7.54
N-Serve	159.0	3.76	3.82	7.58
P-Value	6	6	61	36
Hybrid X N-Rate	99	99	69	96
Hybrid X Inhibitor	68	68	4	34
N-Rate X Inhibitor	67	67	83	21
Hybrid X N-Rate X Inhibitor	96	96	99	99
Hybrid X N-Rate X Inhibitor X K-Rate				
Hybrid X K-Rate	99	99	97	99
N-Rate X K-Rate	99	99	87	99
Hybrid X N-Rate X K-Rate	49	49	70	14
Inhibitor X K-Rate	90	90	53	79
Hybrid X Inhibitor X K-Rate	84	84	83	78
N-Rate X Inhibitor X K-Rate	50	50	88	75
Hybrid X N-Rate X Inhibitor X K-Rate	79	79	85	47

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	0.63	1.40	47.3	105.6	153.0
Pioneer 3737	0.68	1.47	47.9	103.3	151.2
LH74 X LH85	0.70	1.34	53.4	99.4	152.8
DeKalb 485	0.67	1.29	54.6	102.2	156.8
P-Value	99	99	99	71	44
BLSD (.05)	0.04	0.05	3.3		
N-Rate					
80	0.56	1.25	42.1	86.5	128.6
160	0.73	1.42	56.0	109.1	165.1
240	0.73	1.45	54.3	112.3	166.6
P-Value	99	99	99	99	99
BLSD (.05)	0.03	0.04	2.7	4.9	6.1
Inhibitor					
None	0.66	1.39	49.1	101.7	150.9
N-Serve	0.68	1.36	52.5	103.6	156.1
P-Value	94	87	99	60	93
Hybrid X N-Rate	12	99	55	64	66
Hybrid X Inhibitor	93	67	51	52	31
N-Rate X Inhibitor	92	68	90	77	15
Hybrid X N-Rate X Inh.	94	99	79	78	45
Split Plot without the 160# N-Rate					
K-Rate					
0	0.66	1.37	50.8	103.1	153.9
100	0.70	1.34	55.1	104.6	159.8
200	0.64	1.35	48.2	99.4	147.6
P-Value	99	59	95	72	88
BLSD(.05)	0.01		4.9		
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.62	1.34	46.3	102.4	148.7
Pioneer 3737	0.66	1.44	47.3	102.5	149.8
LH74 X LH85	0.71	1.29	55.7	98.0	153.7
DeKalb 485	0.69	1.34	56.1	106.6	162.8
P-Value	99	99	99	99	99
BLSD(.05)	0.02	0.03	2.7	4.7	5.4
N-Rate					
80	0.59	1.26	45.5	90.7	136.3
240	0.74	1.45	57.2	114.0	171.2
P-Value	99	99	99	99	99
Inhibitor					
None	0.67	1.35	51.1	102.5	153.7
N-Serve	0.67	1.35	51.6	102.2	153.9
P-Value	13	19	41	20	8
Hybrid X N-Rate	96	34	85	76	90
Hybrid X Inhibitor	99	99	95	99	99
N-Rate X Inhibitor	99	99	99	99	15
Hybrid X N-Rate X Inhibitor	71	94	60	99	96
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	99	98	99	99	99
N-Rate X K-Rate	60	37	74	99	99
Hybrid X N-Rate X K-Rate	93	99	92	80	30
Inhibitor X K-Rate	93	75	79	73	77
Hybrid X Inhibitor X K-Rate	96	99	26	99	97
N-Rate X Inhibitor X K-Rate	5	30	67	11	45
Hybrid X N-Rate X Inhibitor X K-Rate	94	99	88	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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant Silking Stover		
#/A			#/A	T/A	% N	#/A
0	Pioneer 3615	---	---	2.46	0.94	46.4
0		---	100	2.69	1.03	55.1
80		---	---	2.81	1.39	78.0
80		NS	---	2.80	1.36	75.8
80		---	100	3.30	1.36	89.8
80		NS	100	2.96	1.31	77.6
160		---	---	3.01	1.44	86.6
160		NS	---	3.16	1.46	92.1
160		---	100	3.09	1.49	92.0
160		NS	100	3.08	1.41	86.4
0	Pioneer 3475	---	---	2.65	0.98	52.4
0		---	100	3.00	0.95	57.2
80		---	---	3.23	1.37	88.6
80		NS	---	3.11	1.31	81.7
80		---	100	3.73	1.38	103.3
80		NS	100	3.35	1.37	90.7
160		---	---	3.32	1.42	94.7
160		NS	---	3.52	1.51	106.1
160		---	100	3.48	1.39	97.1
160		NS	100	3.49	1.43	98.8
0	LH74 X LH51	---	---	2.69	0.90	48.4
0		---	100	2.39	0.91	43.7
80		---	---	3.33	1.54	102.5
80		NS	---	3.18	1.48	93.7
80		---	100	3.14	1.40	87.4
80		NS	100	3.15	1.41	88.0
160		---	---	3.05	1.86	112.7
160		NS	---	3.47	1.69	118.0
160		---	100	3.56	1.48	105.2
160		NS	100	3.32	1.52	100.8
0	LH74 X LH82	---	---	2.27	0.88	40.0
0		---	100	2.46	1.01	51.0
80		---	---	3.19	1.50	95.1
80		NS	---	2.83	1.48	83.2
80		---	100	3.11	1.48	91.9
80		NS	100	3.24	1.47	96.0
160		---	---	3.31	1.62	107.1
160		NS	---	2.75	1.63	89.9
160		---	100	3.40	1.62	110.3
160		NS	100	3.23	1.55	99.6

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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	-------------T/A---------------			
0	Pioneer 3615	---	---	74.8	1.77	3.46	0.58	5.81
0		---	100	69.8	1.65	3.44	0.56	5.64
80		---	---	93.5	2.21	3.59	0.71	6.51
80		NS	---	82.7	1.96	3.30	0.65	5.91
80		---	100	90.0	2.13	3.81	0.76	6.70
80		NS	100	81.7	1.93	3.69	0.73	6.36
160		---	---	99.7	2.36	3.73	0.83	6.93
160		NS	---	94.2	2.23	3.90	0.78	6.91
160		---	100	97.7	2.31	3.85	0.82	6.99
160		NS	100	94.1	2.23	3.96	0.78	6.96
0	Pioneer 3475	---	---	76.5	1.81	3.59	0.65	6.05
0		---	100	64.8	1.53	3.80	0.56	5.89
80		---	---	105.0	2.48	4.04	0.81	7.33
80		NS	---	96.6	2.29	4.26	0.80	7.34
80		---	100	95.7	2.26	4.83	0.80	7.89
80		NS	100	92.2	2.18	4.43	0.83	7.44
160		---	---	97.2	2.30	4.03	0.82	7.15
160		NS	---	108.9	2.58	4.51	0.88	7.97
160		---	100	97.1	2.30	4.81	0.79	7.90
160		NS	100	97.3	2.30	4.19	0.82	7.32
0	LH74 X LH51	---	---	56.8	1.34	3.93	0.50	5.77
0		---	100	52.6	1.24	3.98	0.47	5.70
80		---	---	81.5	1.93	4.54	0.64	7.11
80		NS	---	78.5	1.86	4.44	0.61	6.91
80		---	100	76.1	1.80	4.73	0.65	7.19
80		NS	100	67.8	1.60	4.71	0.62	6.93
160		---	---	83.3	1.97	4.70	0.68	7.35
160		NS	---	82.6	1.95	4.65	0.62	7.22
160		---	100	83.8	1.98	5.12	0.65	7.75
160		NS	100	80.4	1.90	5.21	0.68	7.80
0	LH74 X LH82	---	---	68.7	1.63	2.96	0.53	5.11
0		---	100	59.2	1.40	3.10	0.48	4.98
80		---	---	103.8	2.46	3.46	0.72	6.64
80		NS	---	103.6	2.45	3.55	0.75	6.75
80		---	100	105.2	2.49	3.96	0.77	7.23
80		NS	100	84.2	1.99	3.32	0.63	5.95
160		---	---	102.9	2.43	3.60	0.79	6.82
160		NS	---	107.3	2.54	3.33	0.80	6.67
160		---	100	106.5	2.52	4.02	0.76	7.31
160		NS	100	104.7	2.48	3.82	0.76	7.06

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 1990.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
#/A			#/A	-----------%----------			---------------#/A---------------			
0	Pioneer 3615	---	---	0.55	1.28	0.56	37.9	45.3	6.5	89.6
0		---	100	0.67	1.41	0.63	46.1	46.5	7.0	99.6
80		---	---	0.87	1.50	0.65	63.4	66.5	9.2	139.1
80		NS	---	0.94	1.61	0.54	62.0	62.9	6.9	131.7
80		---	100	0.90	1.60	0.73	68.5	68.7	11.1	148.3
80		NS	100	0.71	1.56	0.62	52.4	60.3	9.0	121.7
160		---	---	1.00	1.56	0.67	74.4	73.6	11.2	159.1
160		NS	---	0.96	1.58	0.64	75.0	70.4	10.0	155.5
160		---	100	1.09	1.78	0.60	84.5	82.5	9.9	176.9
160		NS	100	1.04	1.65	0.71	82.2	73.2	11.0	166.4
0	Pioneer 3475	---	---	0.58	1.29	0.59	41.3	46.9	7.7	95.8
0		---	100	0.55	1.30	0.59	42.3	40.0	6.5	88.8
80		---	---	0.81	1.55	0.58	65.4	77.0	9.4	151.8
80		NS	---	0.81	1.30	0.61	69.1	59.2	9.6	137.9
80		---	100	0.77	1.55	0.56	74.3	69.8	9.0	153.1
80		NS	100	0.84	1.50	0.68	75.0	65.4	11.2	151.6
160		---	---	0.88	1.52	0.67	70.6	69.6	11.0	151.2
160		NS	---	0.78	1.55	0.54	70.4	79.7	9.6	159.7
160		---	100	0.92	1.58	0.70	88.5	72.6	11.0	172.1
160		NS	100	0.92	1.59	0.77	78.2	73.1	12.7	164.0
0	LH74 X LH51	---	---	0.62	1.30	0.51	47.9	35.2	5.0	88.1
0		---	100	0.53	1.31	0.56	42.0	32.5	5.3	79.8
80		---	---	0.73	1.46	0.55	65.7	56.5	7.2	129.4
80		NS	---	0.80	1.46	0.54	71.1	54.4	6.6	132.1
80		---	100	0.73	1.50	0.53	68.8	53.2	7.0	129.0
80		NS	100	0.76	1.67	0.53	71.2	53.4	6.6	131.2
160		---	---	0.87	1.76	0.61	81.2	69.5	8.3	159.0
160		NS	---	0.98	1.76	0.54	91.1	68.8	6.6	166.6
160		---	100	1.14	1.70	0.58	117.1	67.5	7.5	192.2
160		NS	100	0.99	1.83	0.57	103.6	69.8	7.8	181.2
0	LH74 X LH82	---	---	0.57	1.15	0.58	33.3	37.1	6.1	76.5
0		---	100	0.54	1.43	0.65	33.4	40.2	6.0	79.6
80		---	---	0.92	1.45	0.53	63.6	71.2	7.6	142.3
80		NS	---	0.81	1.33	0.49	57.6	65.3	7.2	130.1
80		---	100	0.92	1.45	0.51	73.3	71.8	7.9	153.1
80		NS	100	0.92	1.43	0.50	61.2	57.0	6.3	124.5
160		---	---	1.09	1.71	0.54	78.8	83.0	8.4	170.2
160		NS	---	0.99	1.59	0.53	65.6	80.8	8.5	154.9
160		---	100	1.06	1.76	0.53	85.2	88.7	8.2	182.1
160		NS	100	1.00	1.63	0.55	76.2	80.3	8.4	164.9

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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	-------------T/A---------------			
0	Pioneer 3615	---	---	104.0	2.46	2.39	0.44	5.29
0		---	100	118.8	2.81	2.92	0.55	6.28
80		---	---	139.2	3.29	3.07	0.63	7.00
80		NS	---	139.3	3.29	2.82	0.61	6.72
80		---	100	163.5	3.87	3.29	0.75	7.91
80		NS	100	144.3	3.42	3.15	0.66	7.23
160		---	---	163.2	3.86	3.28	0.74	7.88
160		NS	---	148.1	3.50	3.04	0.68	7.22
160		---	100	169.9	4.02	3.55	0.82	8.40
160		NS	100	165.4	3.91	3.20	0.77	7.88
0	Pioneer 3475	---	---	122.3	2.89	3.09	0.63	6.62
0		---	100	111.8	2.65	3.34	0.53	6.51
80		---	---	155.4	3.68	3.53	0.71	7.92
80		NS	---	160.3	3.79	3.55	0.75	8.10
80		---	100	170.5	4.03	4.09	0.82	8.95
80		NS	100	150.3	3.56	3.68	0.76	8.00
160		---	---	160.9	3.81	3.85	0.77	8.42
160		NS	---	156.6	3.70	3.61	0.76	8.08
160		---	100	146.7	3.47	3.87	0.72	8.06
160		NS	100	152.8	3.62	3.85	0.72	8.19
0	LH74 X LH51	---	---	97.2	2.30	3.26	0.45	6.01
0		---	100	92.1	2.18	3.41	0.42	6.00
80		---	---	143.0	3.38	4.00	0.57	7.95
80		NS	---	130.2	3.08	3.96	0.57	7.61
80		---	100	132.5	3.13	3.94	0.56	7.63
80		NS	100	140.2	3.32	4.30	0.63	8.25
160		---	---	157.8	3.73	4.39	0.64	8.76
160		NS	---	155.2	3.67	4.39	0.64	8.70
160		---	100	148.0	3.50	4.45	0.57	8.51
160		NS	100	145.8	3.45	4.31	0.60	8.36
0	LH74 X LH82	---	---	105.2	2.49	2.61	0.48	5.58
0		---	100	84.8	2.01	2.53	0.44	4.98
80		---	---	151.0	3.57	3.13	0.65	7.36
80		NS	---	142.2	3.36	3.18	0.62	7.16
80		---	100	147.8	3.50	3.26	0.64	7.41
80		NS	100	140.3	3.32	3.12	0.62	7.06
160		---	---	155.1	3.67	3.32	0.71	7.70
160		NS	---	147.9	3.50	3.23	0.69	7.42
160		---	100	164.2	3.89	3.57	0.72	8.17
160		NS	100	153.5	3.63	3.39	0.67	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 1990.

				N-Concentration			N-Removal			
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Cob	Stover	Grain	Cob	Total
#/A			#/A	-----------%----------			---------------#/A--------------			
0	Pioneer 3615	---	---	0.49	1.20	0.49	23.2	59.2	4.3	86.7
0		---	100	0.51	1.12	0.47	29.7	62.6	5.1	97.4
80		---	---	0.61	1.20	0.46	37.6	78.9	5.7	122.3
80		NS	---	0.62	1.12	0.46	35.0	73.5	5.6	114.2
80		---	100	0.66	1.15	0.46	43.7	88.9	6.9	139.5
80		NS	100	0.52	1.21	0.49	32.6	82.9	6.5	122.0
160		---	---	0.69	1.33	0.49	45.5	102.6	7.2	155.3
160		NS	---	0.64	1.38	0.45	39.4	96.3	6.2	141.9
160		---	100	0.66	1.34	0.47	47.1	106.8	7.7	161.6
160		NS	100	0.66	1.40	0.47	42.1	109.8	7.2	159.1
0	Pioneer 3475	---	---	0.47	1.00	0.48	28.9	57.5	6.1	92.5
0		---	100	0.48	1.06	0.45	32.4	56.2	4.8	93.4
80		---	---	0.56	1.18	0.46	39.6	86.6	6.5	132.8
80		NS	---	0.54	1.13	0.45	38.5	85.2	6.8	130.5
80		---	100	0.66	1.19	0.46	54.2	96.2	7.5	158.0
80		NS	100	0.61	1.07	0.47	44.8	76.0	7.2	128.0
160		---	---	0.68	1.30	0.47	52.2	99.4	7.2	158.8
160		NS	---	0.62	1.27	0.45	44.4	94.1	6.8	145.3
160		---	100	0.77	1.28	0.46	59.9	89.1	6.6	155.6
160		NS	100	0.68	1.26	0.47	52.4	91.0	6.8	150.2
0	LH74 X LH51	---	---	0.43	1.02	0.45	27.7	47.1	4.1	78.9
0		---	100	0.39	1.01	0.48	26.8	43.7	4.0	74.6
80		---	---	0.64	1.23	0.43	51.2	83.1	4.8	139.1
80		NS	---	0.63	1.20	0.42	49.8	74.1	4.8	128.8
80		---	100	0.65	1.18	0.43	50.9	73.6	4.8	129.3
80		NS	100	0.72	1.20	0.44	62.1	79.8	5.5	147.4
160		---	---	0.83	1.28	0.44	73.5	95.5	5.5	174.5
160		NS	---	0.77	1.26	0.43	68.3	93.3	5.5	167.1
160		---	100	0.74	1.33	0.43	66.3	93.1	4.9	164.3
160		NS	100	0.74	1.33	0.45	63.9	91.8	5.4	161.2
0	LH74 X LH82	---	---	0.46	0.99	0.42	24.1	49.1	4.0	77.2
0		---	100	0.44	1.16	0.45	22.2	46.2	3.9	72.3
80		---	---	0.69	1.25	0.45	43.5	89.1	5.9	138.5
80		NS	---	0.69	1.19	0.45	44.1	79.8	5.6	129.5
80		---	100	0.68	1.16	0.49	44.5	81.1	6.3	132.0
80		NS	100	0.55	1.11	0.43	33.9	73.3	5.3	112.5
160		---	---	0.75	1.32	0.45	50.4	96.8	6.3	153.5
160		NS	---	0.74	1.36	0.45	47.5	95.1	6.1	148.8
160		---	100	0.83	1.39	0.42	59.4	107.4	6.0	172.9
160		NS	100	0.80	1.38	0.44	54.2	99.8	6.0	160.0

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 1990.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
#/A			#/A	Bu/A	----------T/A---------		
0	Pioneer 3615	---	---	118.2	2.80	3.15	5.94
0		---	100	126.3	2.99	3.35	6.33
80		---	---	146.6	3.47	3.11	6.58
80		NS	---	144.2	3.41	3.15	6.56
80		---	100	154.5	3.66	3.44	7.09
80		NS	100	143.3	3.39	3.22	6.61
160		---	---	158.6	3.75	3.07	6.82
160		NS	---	153.3	3.63	3.07	6.69
160		---	100	165.8	3.92	3.25	7.18
160		NS	100	156.1	3.69	3.28	6.97
0	Pioneer 3475	---	---	138.9	3.29	3.63	6.92
0		---	100	143.3	3.39	3.83	7.22
80		---	---	161.7	3.82	3.72	7.55
80		NS	---	149.6	3.54	3.71	7.24
80		---	100	164.1	3.88	3.82	7.70
80		NS	100	150.9	3.57	3.76	7.34
160		---	---	156.6	3.70	3.40	7.10
160		NS	---	156.6	3.70	3.67	7.38
160		---	100	164.6	3.89	3.96	7.85
160		NS	100	144.7	3.42	3.63	7.06
0	LH74 X LH51	---	---	114.9	2.72	3.36	6.08
0		---	100	114.3	2.71	3.44	6.15
80		---	---	150.7	3.57	3.69	7.26
80		NS	---	149.1	3.53	3.69	7.22
80		---	100	151.9	3.59	3.82	7.42
80		NS	100	138.3	3.27	3.62	6.89
160		---	---	153.9	3.64	3.68	7.32
160		NS	---	150.0	3.55	3.76	7.31
160		---	100	159.1	3.77	3.93	7.70
160		NS	100	166.8	3.95	4.04	7.99
0	LH74 X LH82	---	---	112.8	2.67	3.20	5.87
0		---	100	114.1	2.70	3.12	5.82
80		---	---	151.8	3.59	3.48	7.07
80		NS	---	145.1	3.43	3.49	6.92
80		---	100	143.4	3.39	3.21	6.60
80		NS	100	144.7	3.42	3.36	6.78
160		---	---	154.2	3.65	3.43	7.08
160		NS	---	148.1	3.50	3.63	7.13
160		---	100	161.8	3.83	3.83	7.66
160		NS	100	147.3	3.49	3.58	7.07

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 1990.

				N-Concentration		N-Removal		
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Stover	Grain	Total
#/A			#/A	------%-------		----------#/A----------		
0	Pioneer 3615	---	---	0.41	1.12	25.6	62.9	88.5
0		---	100	0.41	1.10	27.3	66.0	93.3
80		---	---	0.38	1.31	24.0	90.6	114.6
80		NS	---	0.38	1.22	23.7	83.1	106.8
80		---	100	0.40	1.35	27.3	98.9	126.1
80		NS	100	0.41	1.27	26.3	85.6	111.9
160		---	---	0.40	1.32	24.7	99.2	123.9
160		NS	---	0.43	1.44	26.2	104.8	131.0
160		---	100	0.44	1.37	28.7	107.6	136.3
160		NS	100	0.44	1.40	28.5	103.2	131.7
0	Pioneer 4757	---	---	0.41	1.07	30.0	70.6	100.5
0		---	100	0.40	1.12	30.4	76.4	106.7
80		---	---	0.41	1.15	30.6	88.3	119.0
80		NS	---	0.38	1.14	28.1	80.7	108.9
80		---	100	0.45	1.19	34.1	92.6	126.7
80		NS	100	0.40	1.32	30.0	93.9	123.9
160		---	---	0.45	1.28	30.4	94.9	125.3
160		NS	---	0.43	1.28	31.9	94.8	126.7
160		---	100	0.48	1.26	38.1	97.9	136.0
160		NS	100	0.48	1.28	34.7	87.6	122.3
0	LH74 X LH51	---	---	0.36	0.94	24.0	51.1	75.1
0		---	100	0.37	1.08	25.6	58.7	84.3
80		---	---	0.47	1.17	34.5	83.7	118.3
80		NS	---	0.41	1.11	30.5	78.5	109.1
80		---	100	0.39	1.28	29.8	92.4	122.2
80		NS	100	0.40	1.07	29.2	70.5	99.6
160		---	---	0.50	1.35	36.5	98.1	134.6
160		NS	---	0.45	1.35	34.0	95.6	129.6
160		---	100	0.46	1.32	36.5	99.3	135.8
160		NS	100	0.44	1.31	35.6	103.4	139.0
0	LH74 X LH82	---	---	0.42	1.06	26.8	56.2	83.0
0		---	100	0.45	1.20	28.0	64.5	92.4
80		---	---	0.48	1.21	33.4	86.6	120.0
80		NS	---	0.43	1.16	29.7	79.3	109.1
80		---	100	0.46	1.24	29.4	84.4	113.7
80		NS	100	0.47	1.09	31.5	74.9	106.4
160		---	---	0.49	1.33	33.5	97.2	130.7
160		NS	---	0.51	1.36	37.3	95.3	132.6
160		---	100	0.58	1.33	44.8	102.1	147.0
160		NS	100	0.51	1.46	36.2	102.1	138.3

Table 22. Waseca 1990	Whole Plant		
0 # K-Rate only RCB (Hybrid X N-Rate)	Tassling	Stover	N-Removal
Hybrids	% N	T/A	#/A
Pioneer 3615	1.26	2.75	70.3
Pioneer 3475	1.25	3.06	78.5
LH74 X LH51	1.43	3.02	87.6
LH74 X LH82	1.33	2.92	80.7
P-Value	99	94	99
BLSD (.05)	0.06		8.7
N-Rate			
0	0.96	2.51	46.8
80	1.45	3.14	91.0
160	1.58	3.17	100.2
P-Value	99	99	99
BLSD (.05)	0.06	0.18	6.7
Hybrid X N-Rate	99	88	93
100 # K-Rate only RCB			
Pioneer 3615	1.29	3.02	78.8
Pioneer 3475	1.23	3.40	85.8
LH74 X LH 51	1.26	3.02	78.7
LH74 X LH82	1.36	2.98	84.3
P-Value	94	99	75
BLSD (.05)		0.27	
N-Rate			
0	0.97	2.63	51.7
80	1.40	3.31	93.0
160	1.49	3.38	101.1
P-Value	99	99	99
BLSD (.05)	0.07	0.21	6.8
Hybrid X N-Rate	40	84	90
Split Plot without the 0 # N-Rate			
K-Rate			
0	1.50	3.12	94.1
100	1.44	3.28	94.6
P-Value	90	64	10
Hybrid X N-Rate X Inhibitor			
Hybrid			
Pioneer 3615	1.40	3.02	84.7
Pioneer 3475	1.39	3.40	95.1
LH74 X LH51	1.54	3.27	101.0
LH74 X LH82	1.54	3.13	96.6
P-Value	99	99	99
BLSD (.05)	0.05	0.15	5.3
N-Rate			
80	1.41	3.15	88.9
160	1.53	3.26	99.8
P-Value	99	99	99
Inhibitor			
None	1.48	3.25	96.3
N-Serve	1.46	3.16	92.3
P-Value	72	88	95
Hybrid X N-Rate	63	3	95
Hybrid X Inhibitor	27	54	44
N-Rate X Inhibitor	24	75	73
Hybrid X N-Rate X Inhibitor	33	73	84
Hybrid X N-Rate X Inhibtor X K-Rate			
Hybrid X K-Rate	99	38	99
N-Rate X K-Rate	88	38	81
Hybrid X N-Rate X K-Rate	70	86	45
Inhibitor X K-Rate	23	44	34
Hybrid X Inhibitor X K-Rate	64	91	76
N-Rate X Inhibitor X K-Rate	40	56	70
Hybrid X N-Rate X Inhibitor X K-Rate	29	59	13

Table 23 Waseca 1990

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	0.70	3.59	2.11	6.41	89.3
Pioneer 3475	0.75	3.88	2.19	6.84	92.8
LH74 X LH51	0.60	4.38	1.74	6.74	73.8
LH74 X LH82	0.68	3.33	2.17	6.19	91.8
P-Value	99	99	99	99	99
BLSD (.05)	0.04	0.28	0.14	0.47	6.3
N-Rate					
0	0.56	3.48	1.63	5.68	69.2
80	0.72	3.90	2.26	6.89	95.9
160	0.78	4.01	2.26	7.06	95.7
P-Value	99	96	99	99	99
BLSD (.05)	0.03	0.25	0.12	0.34	5.2
Hybrid X N-Rate	62	18	64	33	64
100 # K-Rate only RCB					
Hybrids					
Pioneer 3615	0.71	3.69	2.03	6.44	85.8
Pioneer 3475	0.71	4.48	2.03	7.22	85.8
LH74 X LH51	0.59	4.61	1.67	6.87	70.8
LH74 X LH82	0.67	3.69	2.13	6.50	90.3
P-Value	99	99	99	99	99
BLSD (.05)	0.05	0.29	0.17	0.50	7.4
N-Rate					
0	0.51	3.58	1.45	5.55	61.5
80	0.74	4.33	2.17	7.25	91.7
160	0.75	4.45	2.27	7.48	96.2
P-Value	99	99	99	99	99
BLSD (.05)	0.04	0.25	0.14	0.38	6.0
Hybrid X N-Rate	53	53	84	55	84
Split Plot without the 0 # N-Rate					
K-Rate					
0	0.74	3.97	2.24	6.96	95.0
100	0.74	4.27	2.15	7.17	90.5
P-Value	28	99	80	98	80
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.75	3.72	2.16	6.65	91.7
Pioneer 3475	0.81	4.38	2.33	7.54	98.7
LH74 X LH51	0.64	4.76	1.87	7.28	79.3
LH74 X LH82	0.74	3.63	2.42	6.80	102.2
P-Value	99	99	99	99	99
BLSD(.05)	0.02	0.16	0.10	0.25	4.3
N-Rate					
80	0.71	4.04	2.12	6.88	89.8
160	0.76	4.21	2.27	7.25	96.0
P-Value	99	99	99	99	99
Inhibitor					
None	0.75	4.17	2.24	7.17	94.9
N-Serve	0.73	4.08	2.15	6.96	91.0
P-Value	88	85	98	96	98
Hybrid X N-Rate	89	66	40	68	40
Hybrid X Inhibitor	86	43	47	35	47
N-Rate X Inhibitor	78	62	98	91	98
Hybrid X N-Rate X Inhibitor	16	18	25	3	25
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	77	21	19	2	19
N-Rate X K-Rate	84	47	84	12	84
Hybrid X N-Rate X K-Rate	45	72	24	70	24
Inhibitor X K-Rate	16	95	83	94	83
Hybrid X Inhibitor X K-Rate	81	96	55	86	55
N-Rate X Inhibitor X K-Rate	60	13	4	16	4
Hybrid X N-Rate X Inh. X K-Rate	73	62	55	75	55

Table 24. Waseca 1990	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	0.62	0.80	1.44	8.9	58.5	61.7	129.2
Pioneer 3475	0.61	0.75	1.45	9.3	59.1	64.5	132.9
LH74 X LH51	0.55	0.73	1.51	6.8	64.9	53.7	125.4
LH74 X LH82	0.54	0.85	1.43	7.3	58.5	63.7	129.6
P-Value	99	99	69	99	71	99	37
BLSD (.05)	0.05	0.06		0.8		5.4	
N-Rate							
0	0.55	0.57	1.25	6.3	40.0	41.1	87.5
80	0.57	0.83	1.49	8.3	64.5	67.8	140.6
160	0.62	0.95	1.63	9.7	76.2	73.9	159.9
P-Value	98	99	99	99	99	99	99
BLSD (.05)	0.04	0.05	0.06	0.7	6.0	4.3	9.0
Hybrid X N-Rate	84	98	99	40	37	99	89
100 # K-Rate only RCB							
Hybrid							
Pioneer 3615	0.65	0.88	1.59	9.3	66.3	65.8	141.5
Pioneer 3475	0.61	0.74	1.47	8.8	68.3	60.8	138.0
LH74 X LH51	0.55	0.79	1.50	6.6	75.9	51.0	133.6
LH74 X LH82	0.56	0.84	1.54	7.3	63.9	66.9	138.2
P-Value	98	99	92	99	99	99	40
BLSD (.05)	0.07	0.05		0.9	7.4	5.7	
N-Rate							
0	0.60	0.57	1.36	6.2	40.9	39.8	86.9
80	0.58	0.82	1.52	8.7	71.2	65.8	145.8
160	0.60	1.05	1.70	9.1	93.8	77.8	180.8
P-Value	32	99	99	99	99	99	99
BLSD (.05)		0.04	0.07	0.7	5.5	4.7	9.1
Hybrid X N-Rate	99	99	74	92	99	88	97
Split Plot ,without the 0 # N-Rate							
K-Rate							
0	0.57	0.88	1.54	8.5	70.3	69.2	148.1
100	0.60	0.91	1.61	9.0	78.7	69.2	157.0
P-Value	83	88	77	85	99	3	96
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3615	0.64	0.93	1.60	9.7	70.2	69.7	149.8
Pioneer 3475	0.84	0.84	1.51	10.4	73.9	70.8	155.1
LH74 X LH51	0.87	0.87	1.64	7.2	83.7	61.6	152.5
LH74 X LH82	0.96	0.52	1.54	7.8	70.1	74.7	152.7
P-Value	99	99	99	99	99	99	36
BLSD(.05)	0.03	0.03	0.05	0.4	4.9	3.8	
N-Rate							
80	0.57	0.82	1.49	8.2	66.4	63.2	137.9
160	0.60	0.98	1.66	9.3	82.6	75.1	167.2
P-Value	99	99	99	99	99	99	99
Inhibitor							
None	0.59	0.91	1.59	8.9	76.4	71.3	156.8
N-Serve	0.58	0.88	1.56	8.6	72.6	67.1	148.3
P-Value	64	95	80	94	96	99	99
Hybrid X N-Rate	43	99	99	42	99	95	99
Hybrid X Inhibitor	57	88	97	99	80	74	89
N-Rate X Inhibitor	41	82	1	81	37	95	56
Hybrid X N-Rate X Inhibitor	99	37	85	98	51	81	16
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	93	60	8	95	67	28	9
N-Rate X K-Rate	37	99	21	43	99	72	98
Hybrid X N-Rate X K-Rate	94	91	77	97	76	25	34
Inhibitor X K-Rate	99	69	58	99	95	53	85
Hybrid X Inhibitor X K-Rate	69	99	93	95	28	49	8
N-Rate X Inhibitor X K-Rate	87	6	74	95	15	62	34
Hybrid X N-Rate X Inhibitor X K-Rate	24	95	23	2	61	62	55

Table 25 Waseca 1990

Dent Stage R5	Dry Matter Production				Grain
0 # K-Rate only RCB	Cob	Stover	Grain	Total	Yields
Hybrid	-------------T/A-----------				Bu/A
Pioneer 3615	0.60	2.91	3.20	6.72	135.4
Pioneer 3475	0.70	3.48	3.46	7.65	146.2
LH74 X LH51	0.55	3.88	3.13	7.57	132.6
LH74 X LH82	0.61	3.02	3.24	6.87	137.0
P-Value	99	99	96	99	96
BLSD (.05)	0.03	0.22	0.25	0.38	10.9
N-Rate					
0	0.50	2.83	2.53	5.87	107.1
80	0.64	3.43	3.48	7.55	147.1
160	0.71	3.71	3.76	8.19	159.2
P-Value	99	99	99	99	99
BLSD (.05)	0.03	0.19	0.17	0.31	7.5
Hybrid X N-Rate	95	19	64	51	64
100 # K-Rate only RCB					
Hybrid					
Pioneer 3615	0.70	3.25	3.56	7.52	150.7
Pioneer 3475	0.69	3.76	3.38	7.83	143.0
LH74 X LH51	0.51	3.93	2.93	7.38	124.1
LH74 X LH82	0.60	3.12	3.12	6.85	132.2
P-Value	99	99	99	98	99
BLSD (.05)	0.04	0.34	0.29	0.68	12.5
N-Rate					
0	0.48	3.04	2.41	5.94	101.8
80	0.69	3.64	3.63	7.97	153.5
160	0.70	3.85	3.72	8.28	157.2
P-Value	99	99	99	99	99
BLSD (.05)	0.03	0.29	0.23	0.49	10.0
Hybrid X N-Rate	98	35	94	80	94
Split Plot without the 0 # N-Rate					
K-Rate					
0	0.67	3.52	3.55	7.75	150.3
100	0.68	3.68	3.60	7.98	152.2
P-Value	96	98	35	82	35
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.70	3.17	3.64	7.53	154.1
Pioneer 3475	0.75	3.75	3.70	8.21	156.7
LH74 X LH51	0.59	4.21	3.41	8.22	144.0
LH74 X LH82	0.66	3.27	3.55	7.49	150.2
P-Value	99	99	99	99	99
BLSD(.05)	0.02	0.16	0.17	0.32	7.5
N-Rate					
80	0.66	3.50	3.50	7.64	146.8
160	0.69	3.70	3.70	8.09	155.7
P-Value	99	99	99	99	99
Inhibitor					
None	0.68	3.66	3.65	8.00	154.3
N-Serve	0.67	3.54	3.50	7.72	148.2
P-Value	86	91	98	98	98
Hybrid X N-Rate	99	38	98	88	98
Hybrid X Inhibitor	94	54	30	53	30
N-Rate X Inhibitor	18	48	28	15	28
Hybrid X N-Rate X Inhibitor	2	11	9	12	9
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	99	21	94	78	94
N-Rate X K-Rate	97	39	48	57	48
Hybrid X N-Rate X K-Rate	82	25	54	51	54
Inhibitor X K-Rate	33	18	9	17	9
Hybrid X Inhibitor X K-Rate	65	11	36	28	36
N-Rate X Inhibitor X K-Rate	53	1	66	41	66
Hybrid X N-Rate X Inh. X K-Rate	57	57	82	72	57

Table 26. Waseca 1990	N-Concentration			N-Removal			
0 # K-Rate only RCB (Hybrid X N-Rate)	Cob	Stover	Grain	Cob	Stover	Grain	Total
Hybrids **Dent Stage R5**	----------%---------			------------#/A------------			
Pioneer 3615	0.47	0.59	1.24	5.7	35.4	80.2	121.4
Pioneer 3475	0.46	0.57	1.15	6.5	40.2	81.1	128.0
LH74 X LH51	0.43	0.63	1.17	4.8	50.7	75.2	130.8
LH74 X LH82	0.44	0.63	1.18	5.4	39.3	78.3	123.0
P-Value	99	88	96	99	99	61	66
BLSD (.05)	0.02		0.06	0.4	5.6		
N-Rate							
0	0.46	0.46	1.05	4.6	25.9	53.2	83.8
80	0.44	0.62	1.21	5.7	42.9	84.4	133.1
160	0.45	0.73	1.30	6.5	55.4	98.5	160.5
P-Value	54	99	99	99	99	99	99
BLSD (.05)		0.04	0.04	0.4	4.6	5.7	8.9
Hybrid X N-Rate	35	91	99	94	97	63	80
100 # K-Rate only RCB							
Hybrid							
Pioneer 3615	0.46	0.61	1.20	6.5	40.1	86.0	132.8
Pioneer 3475	0.45	0.63	1.17	6.2	48.8	80.5	135.6
LH74 X LH51	0.45	0.59	1.17	4.5	48.0	70.1	122.7
LH74 X LH82	0.45	0.65	1.23	5.4	42.0	78.2	125.7
P-Value	29	95	92	99	96	99	91
BLSD (.05)		0.04		0.4	6.1	6.8	
N-Rate							
0	0.46	0.45	1.08	4.4	27.7	52.1	84.4
80	0.46	0.66	1.16	6.3	48.3	84.9	139.6
160	0.44	0.75	1.33	6.3	58.1	99.0	163.5
P-Value	29	95	92	99	99	99	91
BLSD (.05)		0.03		0.4	4.5	5.4	
Hybrid X N-Rate	89	99	89	97	93	99	98
Split Plot without the 0 # N-Rate							
K-Rate							
0	0.44	0.67	1.24	6.0	47.5	88.6	142.5
100	0.45	0.68	1.24	6.2	50.7	90.0	147.0
P-Value	35	74	3	75	99	48	92
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3615	0.46	0.63	1.26	6.6	40.3	92.4	139.4
Pioneer 3475	0.46	0.64	1.21	6.9	48.2	89.6	144.8
LH74 X LH51	0.43	0.71	1.25	5.1	60.7	85.5	151.4
LH74 X LH82	0.44	0.71	1.26	5.9	47.1	90.3	143.4
P-Value	99	99	99	99	99	97	98
BLSD(.05)	0.01	0.03	0.03	0.2	3.4	5.1	8.2
N-Rate							
80	0.45	0.62	1.17	5.9	44.1	81.3	131.5
160	0.45	0.72	1.32	6.3	54.1	97.6	158.1
P-Value	7	99	99	99	99	99	99
Inhibitor							
None	0.45	0.69	1.25	6.2	51.2	91.7	149.2
N-Serve	0.45	0.65	1.24	6.0	47.0	87.2	140.0
P-Value	28	99	70	86	99	99	99
Hybrid X N-Rate	47	73	97	98	85	99	88
Hybrid X Inhibitor	17	63	83	93	77	32	62
N-Rate X Inhibitor	15	16	92	6	58	79	29
Hybrid X N-Rate X Inhibitor	89	70	31	55	45	21	30
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	15	98	53	98	91	96	70
N-Rate X K-Rate	66	44	96	98	12	40	12
Hybrid X N-Rate X K-Rate	15	99	78	37	98	88	96
Inhibitor X K-Rate	66	59	54	38	47	27	7
Hybrid X Inhibitor X K-Rate	66	83	61	48	75	55	71
N-Rate X Inhibitor X K-Rate	80	84	57	84	58	41	57
Hybrid X N-Rate X Inhibitor X K-Rate	43	66	40	25	48	86	76

Table 27 Waseca 1990

Physiological Maturity	Dry Matter Production				Grain
0 # K-Rate only RCB	Cob	Stover	Grain	Total	Yields
Hybrid	-----------T/a-----------				Bu/A
Pioneer 3615	---	3.10	3.33	6.54	141.1
Pioneer 3475	---	3.58	3.60	7.18	152.3
LH74 X LH51	---	3.57	3.31	6.88	139.8
LH74 X LH82	---	3.36	3.30	6.67	139.6
P-Value		99	99	99	99
BLSD (.05)		0.14	0.15	0.23	6.5
N-Rate					
0	---	3.33	2.86	6.20	121.2
80	---	3.50	3.61	7.11	152.6
160	---	3.39	3.68	7.08	155.8
P-Value		96	99	99	99
BLSD (.05)		0.14	0.12	0.19	5.2
Hybrid X N-Rate		94	95	99	95
100 # K-Rate only RCB					
Hybrid					
Pioneer 3615	---	3.34	3.52	6.86	148.8
Pioneer 3475	---	3.86	3.72	7.59	157.3
LH74 X LH51	---	3.73	3.35	7.08	141.8
LH74 X LH82	---	3.38	3.30	6.69	139.7
P-Value		99	99	99	99
BLSD (.05)		0.13	0.18	0.28	7.9
N-Rate					
0	---	3.43	2.94	6.37	124.4
80	---	3.57	3.63	7.20	153.4
160	---	3.74	3.85	7.59	162.8
P-Value		99	99	99	99
BLSD (.05)		0.12	0.15	0.23	6.3
Hybrid X N-Rate		99	84	99	84
Split Plot without the 0 # N-Rate					
K-Rate					
0	---	3.48	3.59	7.07	151.8
100	---	3.61	3.63	7.24	153.5
P-Value		98	37	85	37
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	---	3.19	3.61	6.81	152.7
Pioneer 3475	---	3.70	3.69	7.40	156.0
LH74 X LH51	---	3.78	3.60	7.38	152.4
LH74 X LH82	---	3.50	3.53	7.03	149.5
P-Value		99	96	99	96
BLSD(.05)		0.08	0.11	0.15	4.9
N-Rate					
80	---	3.51	3.53	7.05	149.3
160	---	3.57	3.69	7.26	156.0
P-Value		91	99	99	99
Inhibitor					
None	---	3.55	3.69	7.24	156.1
N-Serve	---	3.54	3.53	7.07	149.2
P-Value		28	99	99	99
Hybrid X N-Rate		99	97	99	97
Hybrid X Inhibitor		12	67	45	67
N-Rate X Inhibitor		55	24	46	24
Hybrid X N-Rate X Inhibitor		58	71	78	71
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate		88	36	74	36
N-Rate X K-Rate		99	90	99	90
Hybrid X N-Rate X K-Rate		76	85	81	85
Inhibitor X K-Rate		99	84	98	84
Hybrid X Inhibitor X K-Rate		37	41	49	41
N-Rate X Inhibitor X K-Rate		77	23	62	23
Hybrid X N-Rate X Inhibitor X K-Rate		98	93	99	93

Table 28. Waseca 1990	N-Concentration		N-Removal		
0 # K-Rate only RCB (Hybrid X N-Rate)	Stover	Grain	Stover	Grain	Total
Hybrids **Physiological Maturity**	------%---------		---------#/A--------		
Pioneer 3615	0.39	1.25	24.7	84.2	108.9
Pioneer 3475	0.42	1.16	30.3	84.6	114.9
LH74 X LH51	0.44	1.15	31.6	77.6	109.3
LH74 X LH82	0.46	1.20	331.2	79.9	111.2
P-Value	99	99	99	99	83
BLSD (.05)	0.02	0.05	2.3	5.1	
N-Rate					
0	0.39	1.04	26.5	60.1	86.7
80	0.43	1.21	30.6	87.3	117.9
160	0.45	1.32	31.2	97.3	128.6
P-Value	99	99	99	99	99
BLSD (.05)	0.02	0.04	2.0	3.7	4.5
Hybrid X N-Rate	99	98	99	98	99
100 # K-Rate only RCB					
Hybrid					
Pioneer 3615	0.41	1.27	27.7	90.8	118.5
Pioneer 3475	0.43	1.19	34.1	88.9	123.1
LH74 X LH51	0.40	1.22	30.6	83.4	114.0
LH74 X LH82	0.49	1.25	34.0	83.6	117.7
P-Value	99	96	99	95	82
BLSD (.05)	0.03	0.06	3.1	7.2	
N-Rate					
0	0.40	1.12	27.7	66.3	94.1
80	0.42	1.26	30.1	92.0	122.1
160	0.49	1.32	37.0	101.7	138.7
P-Value	99	99	99	99	99
BLSD (.05)	0.02	0.04	2.5	4.9	6.3
Hybrid X N-Rate	90	91	99	94	94
Split Plot without the 0 # N-Rate					
K-Rate					
0	0.43	1.26	30.5	90.6	121.2
100	0.44	1.28	32.5	93.5	126.0
P-Value	55	76	81	79	91
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3615	0.40	1.33	26.1	96.6	122.7
Pioneer 3475	0.43	1.23	32.2	91.3	123.5
LH74 X LH51	0.43	1.24	33.3	90.1	123.4
LH74 X LH82	0.49	1.27	34.4	90.2	124.7
P-Value	99	99	99	99	17
BLSD(.05)	0.01	0.03	1.4	3.4	
N-Rate					
80	0.41	1.20	29.4	85.2	114.7
160	0.46	1.34	33.5	98.9	132.5
P-Value	99	99	99	99	99
Inhibitor					
None	0.45	1.27	32.2	94.6	126.8
N-Serve	0.43	1.26	30.8	89.5	120.4
P-Value	99	30	99	99	99
Hybrid X N-Rate	67	99	99	99	99
Hybrid X Inhibitor	76	98	48	7	14
N-Rate X Inhibitor	27	99	44	99	99
Hybrid X N-Rate X Inhibitor	34	99	34	88	70
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	99	42	99	16	63
N-Rate X K-Rate	83	93	99	6	75
Hybrid X N-Rate X K-Rate	24	94	69	97	97
Inhibitor X K-Rate	23	68	74	83	89
Hybrid X Inhibitor X K-Rate	63	90	75	35	14
N-Rate X Inhibitor X K-Rate	99	47	99	17	61
Hybrid X N-Rate X Inhibitor X K-Rate	96	97	97	97	95

1990 WEATHER DATA
NORTHWEST EXPERIMENT STATION, CROOKSTON, MN

T.E. Cymbaluk[1]

The drought continues. Mother nature still has not cooperated with the amount of precipitation that is needed. Seven months in 1990 were below average in precipitation. 1990 received a total of 16.49 inches, four inches less than the 100 year average. The small grain season, (May 1 - July 31), received 6.98 inches of precipitation, 2.15 inches below normal. The sugarbeet season (May 1 - September 31), received 10.9 inches of precipitation, 3.29 inches less than the 100 year average. The months of May and July recieved less than 25 percent of their normal rain fall. In the last seven years, since 1984, there has been a deficit of 18.47 inches of precipitation when compared to the 100 year average. The last three years, since 1988, there has been a deficit of 11.91 inches of precipitation. The greatest amount of precipitation that occurred in a single day in 1990 was 2.33 inches on June 1.

Seven months in 1990 were below normal in regard to temperature. The average temperature for 1990 was 41.14°F, 1.66° higher than the 100 year average. January, Febuary, and March were well above the average temperature and December was well below the average temperature. The highest temperature in 1990 occurred on August 16 at 94°F. The coldest temperature was -38°F which occurred on December 25 and 26.

The last frost of the spring was on May 17, 1990 (30°F) which initiated a 127 day frost-free period ending on September 22 (25°F). The ground frost depth reached 37.5 inches on March 15. The ground frost started to thaw on March 30 and by April 25 the ground frost was gone.

Table 1. Weather summary for 1990 with 100-year averages precipitation and mean temperature.

Month	Precipitation 1990	Precipitation 1890-1989	Mean Temperature 1990	Mean Temperature 1890-1989
	------ inches ------		------- °F --------	
January	0.25	0.56	17.1	3.9
Febuary	0.31	0.56	14.5	8.5
March	1.96	0.84	28.5	23.0
April	1.75	1.51	41.4	41.7
May	0.71	2.60	54.5	54.8
June	5.79	2.71	64.8	64.4
July	0.48	3.03	68.1	69.7
August	3.01	2.93	69.0	67.4
September	0.91	2.13	58.7	57.3
October	0.53	1.47	42.3	45.1
November	0.07	0.78	28.1	26.7
December	0.72	0.58	6.7	11.2
Total	16.49	20.49	Mean 41.1	39.5

[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 1990.

Highest Maximum Temperature

Date	Old Record	New (1990)
	°F	
January 6	40 (1984)	40
January 10	44 (1958)	49
March 1	47 (1918)	47
March 9	50 (1902)	52
March 10	50 (1977)	55
March 11	53 (1902)	58
April 23	83 (1942)	89
September 24	83 (1930)	85
October 26	76 (1989)	76
October 31	69 (1950)	71
November 1	66 (1978)	68
December 8	45 (1939)	50
December 9	51 (1939)	56

Lowest Maximum Temperature

Date	Old Record	New (1990)
	°F	
April 11	63 (1951)	60
April 28	34 (1950)	33
December 21	-15 (1989)	-16
December 22	-10 (1945)	-11
December 29	-8 (1934)	-16

Lowest Minimum Temperature

Date	Old Record	New (1990)
	°F	
May 9	22 (1945)	22
October 11	19 (1893)	16
December 25	-35 (1933)	-38
December 26	-33 (1933)	-38

Highest Minimum Temperature

Date	Old Record	New (1990)
	°F	
January 22	21 (1983)	22
March 11	33 (1977)	39
April 23	52 (1957)	53
April 24	54 (1900)	59
October 31	45 (1948)	45
November 20	35 (1962)	44

Greatest amount of precipitation in a single day.

Date	Old Record	New (1990)
	inches	
June 1	2.01 (1969)	2.33

DIRECT COMPARISON OF DEEP NITRATE-N LEVELS AND OPTIMUM N FERTILIZER RATE

John A. Lamb[1]

Considerable information has been obtained on the optimum N rate to use on soil where soil nitrate-N tests are greater than 40 pounds per acre in the 2 to 4 foot depth. Most recommendations concur that 80-90 pounds N per acre are needed to ensure adequate early season growth. A direct, side-by-side comparison between a high subsoil nitrate-N and low subsoil nitrate-N soil has not been done. With the use of a deep fertilizer injector built at the Northwest Experiment Station, it was possible to duplicate a high nitrate condition within the same experimental site where the low nitrate condition occurs. This approach allows a direct and statistically sound method of measuring the differences in the N response of sugarbeet.

Materials and Methods:

A field trial was conducted on a Wheatville loam at the Northwest Experiment Station, Crookston, MN in 1990 with two deep fertilizer treatments of either 0 or 100 pounds N per acre injected to a depth of 30 inches in 12 inch increments in each row in October 1989. Surface broadcast treatments of 0, 40, 80, and 120 pounds N per acre were applied and incorporated at the same time. The initial 0-2 feet nitrate-N soil test was 60 lb. N per acre and 18 lb. N per acre at the 2 to 4 foot depth. Four replications with a randomized complete block design was used. KW 1745 was planted April 23, 1990 froze, and replanted May 11. The plots were overplanted and thinned back to 125 plants per 100 feet of row. Petiole samples for nitrate-N determination were taken July 24, August 21, and September 20. Sugarbeet tops were sampled at harvest with yield and total N content determined later. Root quality was determined at American Crystal Sugar Company's Quality lab in East Grand Forks, MN where the brei was sampled. Total N content of the brei was determined later.

Results and Discussion:

Root yield and recoverable sucrose per acre was not significantly effected by the either deep N or surface N applications, Table 1. The placement of N at 30 inches did reduce the sucrose concentration and recoverable sucrose per ton by 0.7 % and 15 pounds per ton, Table 1. The dry season influenced the lack of response to N fertilizer. Other than as a result of May and June precipitation there was very little growth and actually the yield level achieved was surprising.

[1] Associate Professor, Soil Science Dept., University of Minnesota, St. Paul, MN

Table 1. Root yield, sucrose concentration, recoverable sucrose per acre, and recoverable sucrose per ton for deep N application study, 1990 NWES.

Deep N lb/A	N Rate lb/A	Root Yield T/A%	Sucrose Conc. %	Recoverable Sucrose lb/A	Recoverable Sucrose lb/T
0	0	11.1	17.8	3550	322
0	40	12.5	16.7	3708	296
0	80	12.1	17.2	3674	303
0	120	13.1	17.1	3895	298
100	0	12.8	16.4	3681	289
100	40	13.4	17.1	4006	299
100	80	12.6	16.1	3523	281
100	120	13.2	16.5	3792	288
0		12.2	17.2	3707	305
100		13.0	16.5	3751	290
	0	11.9	17.1	3616	306
	40	13.0	16.9	3857	297
	80	12.3	16.6	3599	292
	120	13.1	16.8	3843	293
Statistic Analyses					
Deep N		NS	++	NS	++
N Rate		NS	NS	NS	NS
Linear		NS	NS	NS	NS
Quadratic		NS	NS	NS	NS
Deep N X N Rate		NS	NS	NS	NS
C.V. %		12.9	6.2	12.8	7.8

++ is significant at the 0.10 level.

The reduction in recoverable sucrose per ton can be attributed to the increase in amino-N concentration by the deep N treatment, Table 2. The use of surface N also significantly increased amino-N and tended to increase K concentrations, Table 2. Sodium (Na) was not effected by any treatment. Surface N application increased the loss to molasses 0.31 % which under the current quality payment system would directly effect the economic return. Deep N also increased the loss to molasses but only 0.10 %. In 1990 at NWES the optimum N application for both 0 and 100 pounds N per acre deep N treatments was 0 pounds N per acre. Hopefully in the future this study will be conduct under more optimum conditions in which more useful information can be obtained.

Table 2. Root Na, K, amino-N, and loss to molasses for deep N application study, 1990 NWES.

Deep N lb/A	N Rate lb/A	Na	K	amino N	loss to molasses %
		-----------	ppm	-----------	
0	0	413	2015	510	1.55
0	40	639	1925	598	1.74
0	80	503	2084	676	1.83
0	120	566	2160	770	2.00
100	0	574	1996	635	1.78
100	40	596	1997	743	1.93
100	80	561	2091	686	1.87
100	120	550	2042	755	1.94
0		531	2046	638	1.78
100		570	2031	705	1.88
	0	494	2005	572	1.66
	40	617	1961	670	1.83
	80	532	2087	681	1.85
	120	558	2101	763	1.97
Statistic Analyses					
Deep N		NS	NS	*	++
N Rate		NS	NS	**	**
Linear		NS	++	**	**
Quadratic		NS	NS	NS	NS
Deep N X N Rate		NS	NS	+	NS
C.V. %		31.3	7.3	12.1	8.9

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

PRIMARY TILLAGE EFFECTS ON SOIL SUSCEPTIBILITY TO EROSION AFTER SUGARBEET HARVEST

John A. Lamb[1/]

After sugarbeet harvest the soil is exposed to possible wind erosion. There are two strategies that can reduce susceptibility to erosion: residue and soil roughness management. Tillage affects both of these management strategies. Use of the correct tillage tool can increase the amount of residue left on the soil surface, (sugarbeet tops) by "unburying" the tops and at the same time leaving the surface in a rougher conditions. In fall 1989 a study was started with the objective to determine if there is an optimal primary tillage operation after sugarbeet production that will minimize soil erosion and not reduce crop production the following year.

Materials and Methods:

A study was conducted after sugarbeet harvest in 1989 on a Fargo silty clay soil at the Northwest Experiment Station. Five primary tillage treatments were implemented October 11, 1989 after sugarbeet harvest: 1) moldboard plow, 2) chisel plow (twisted shanks), 3) field cultivator, 4) disk, and 5) no tillage. Percent ground cover was measured October 17, 1989, April 18, 1990 (before fertilization), and April 25, 1990 (after planting). Dry aggregate distributions were only measured October 17, 1989, and April 19, 1990. Nitrogen fertilizer was applied according to soil test recomendations and incorporated with a multiweeder April 20, 1990. Marshall spring wheat was planted April 23, 1990 with a conventional double disk press wheel drill. Grain yields were taken August 1, 1990.

Results and Discussion:

There was a significant difference in ground cover as effected by primary tillage on all three measured dates, table 1. On the October date, after sugarbeet harvest, the soils which were treated with a field cultivator and light tandem disk had the most cover, 29 %, followed by chisel and no tillage, 20 and 21 %, and plowed soils having the least cover, 4 %. The amounts measured early spring before tillage had similar differences with small coverage reductions over the winter. After planting, April 25, 1990, the soils treated with a field cultivator, disk, and no tillage maintained 19 % coverage; chisel, 14 %, and plow, 3 %. This suggests that a shallow tillage operation such as with a field cultivator or disk will provide more wind protection than no tillage at all.

The geometric mean diameter (GMD) is a measurement of soil cloddiness. Aggregate (clods) with a size of 0.84 mm and greater are considered to be nonerodible. The greater the GMD is the less erodible a soil is. The data suggests that plowed soil has considerably greater GMD than the other treated soils on both dates measured. There is no significant difference occured between the soils treated with the other four primary tillages.

Grain yield is reported on a 13.5 % basis in table 1. There were no significances in yields from the different tillage treatments.

In the future it is planned to do similar studies on different soil textures.

Table 1. Ground cover, geometric mean diameter, grain yield, and grain protein as effected by primary tillage on a Fargo silty clay at NWES.

Primary Tillage	Ground Cover 10/17/89	Ground Cover 4/18/90	Ground Cover 4/25/90	Geometric Mean Diameter 10/17/89	Geometric Mean Diameter 4/19/90	Grain Yield	Grain Protein
	%			mm		bu/A	%
Plow	4	3	3	5.28	1.24	50.8	11.9
Chisel	20	16	14	2.88	1.00	54.3	11.0
Field Cult.	29	28	19	2.41	1.02	52.2	12.2
Disk	29	26	19	2.22	1.06	58.2	10.8
No Tillage	21	21	18	2.30	1.04	55.2	11.6
LSD 0.05	6.2	5.2	4.4	1.25	0.12	NS	1.1

[1/] Associate Professor, Soil Science Dept., University of Minnesota, St. Paul, MN

NITROGEN EFFECTS ON QUALITY OF SELECTED SUGARBEET VARIETIES

J.A. Lamb and L.J. Smith[1/]

During the recent drought years the amount of residual soil nitrate-N has risen and caused problems with maintaining sugarbeet quality. One possible management practice is to select a low impurity variety. Most varietal development occurs under more optimum soil N conditions. The objective of this study is to determine a low impurity variety will continue to be a low impurity variety at elevated soil nitrate-N levels and if that would be more cost effective management decision compared to average varieties under these conditions.

Three locations were used in 1990, Northwest Experiment Station (NWES), near Casselton, ND (CASS), and near Bird Island, MN (SOMN). The treatments were five varieties with the following characteristics, 1.) low Amino-N (LAN), 2.) low K, Na, and Amino-N (LKNAN), 3.) high K, Na, and Amino-N (NKNAN), 4.) small top growth (ST), and 5.) large top growth (LT), with two N levels (soil nitrate-N 0 - 2 ft + fertilizer), of 100 and 300 pounds per acre at NWES and CASS and 84 and 211 pounds per acre at SOMN. The study was a split plot design with four replications. Nitrogen levels were the main plots with varieties as the subplot. The subplot size was 14.7 ft (8 rows) wide and 35 ft long. The plots were planted May 3, May 4, and May 9, 1990 at NWES, Cass, and SOMN, respectively. Sugarbeet seed was overplanted and thinned to 125 plants per 100 feet of row. Petiole samples were taken three times during the period of July through harvest. Harvest occurred on September 20, September 27, and September 25, 1990 at NWES, CASS, and SOMN, respectively. At harvest the tops and roots were sampled for total N analyses along with root yield and quality. Quality was determined at the American Crystal Sugar Tare Lab in East Grand Forks, MN.

Results and Discussion:

Root yield and sucrose concentration are listed in table 1. Root yield over the three locations was increased 2.4 tons per acre when the N level was increased. The varieties root yields were different and the ranking from least to greatest was different at each location. Sucrose concentration was not affected at SOMN and NWES by the treatments. At CASS, there was an interaction between N level and variety. The varieties' sucrose concentration were effected differently by the addition of N. At the lower N level the LAN, HKNAN, and ST varities had the greatest sucrose. At the greater N level the LT variety had the greatest sucrose concentration.

Table 2 lists the means and statistics for recoverable sucrose per acre, recoverable sucrose per ton, and loss to molasses. Recoverable sucrose per acre and per ton and loss to molasses were inconsistant as to the response to change of N level by each variety over locations. On the average N increased recoverable sucrose per acre and loss to molasses with added N decreasing recoverable sucrose per ton.

Table 1. Root yield and sucrose concentration at NWES, CASS, and SOMN locations, 1990.

Variety	N Rate	Root Yield			Sucrose Conc.		
		NWES	CASS	SOMN	NWES	CASS	SOMN
	lb/A	------ T/A -----			------ % -------		
LKNAN	100	11.3	19.8	8.5	16.5	16.9	13.9
LAN	100	11.9	18.8	12.2	17.8	17.9	14.0
HKNAN	100	12.2	20.4	12.5	17.1	17.9	13.8
LT	100	10.9	18.9	13.4	17.4	17.3	14.0
ST	100	14.4	20.5	12.3	17.0	17.9	13.9
LKNAN	300	16.3	22.4	12.1	16.9	17.3	13.5
LAN	300	13.9	20.8	14.7	16.0	17.6	13.8
HKNAN	300	13.3	21.7	16.8	16.6	17.3	13.3
LT	300	13.6	21.1	14.2	16.6	18.2	13.4
ST	300	15.3	22.0	15.7	16.8	17.3	14.0
Statistical Analyses							
NLEVEL		*	NS	**	NS	NS	NS
VARIETY		**	**	*	NS	++	NS
NLEVEL X VARIETY		NS	NS	NS	++	*	NS

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

1/ Associate Professor, Soil Science Dept., University of Minnesota, St. Paul, MN and Superintendent, Northwest Experiment Station, University of Minnesota, Crookston, MN.

The root impurties: Na, K, and Amino-N, are listed in table 3. Sodium was affected by variety at all locations. At the CASS site the varietal differences were affected by N level. Potassium was not affected by treatments at the SOMN site. At NWES there was a significant difference in K caused by variety but no difference caused by N application. At the CASS location the K in the beet root changed differently depending on the variety. With the LT and LKNAN varieties K was reduced with the addition of N. Root K was increased with the addition of N for the LAN, HKNAN, and ST varieties.

Root Amino-N at NWES and SOMN increased with increasing N fertilization. At NWES the varieties had significantly different amino-N concentrations. At SOMN there were no differences in amino-N because of varieties. There was a significant interaction between N level and varieties at CASS for amino-N. The LT variety actually had a lower amino-N concentration when N was applied while the other varieties had greater amino-N.

Table 2. Recoverable sucrose per acre, recoverable sucrose per ton, and loss to molasses at NWES, CASS, and SOMN, 1990.

Variety	N Rate	Recoverable Sucrose						Loss to Molasses		
		NWES	CASS	SOMN	NWES	CASS	SOMN	NWES	CASS	SOMN
	lb/A	----- lb/A -----			----- lb/T -----			------ % -------		
LKNAN	100	3368	6029	2079	298	305	243	1.51	1.53	1.64
LAN	100	3808	6121	2958	321	326	242	1.59	1.48	1.74
HKNAN	100	3669	6625	2919	302	325	236	1.84	1.51	1.79
LT	100	3361	5786	3240	307	306	243	1.82	1.84	1.65
ST	100	4317	6628	2986	300	324	242	1.81	1.57	1.62
LKNAN	300	3877	6940	2776	292	310	231	1.81	1.59	1.77
LAN	300	3831	6584	3455	274	316	238	2.04	1.67	1.69
HKNAN	300	4735	6691	3712	291	309	233	2.17	1.74	1.92
LT	300	3889	6924	3240	287	328	225	2.08	1.59	1.92
ST	300	4490	6785	3784	293	309	241	1.93	1.67	1.78
Statistical Analyses										
NLEVEL		**	NS	**	NS	NS	NS	*	NS	NS
VARIETY		**	NS	*	NS	NS	NS	**	++	NS
NLEVEL X VARIETY		NS	*	NS	++	**	NS	NS	**	NS

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

Table 3. Root impurities at NWES, CASS, and SOMN, 1990.

Variety	N Rate	Na			K			Amino-N		
		NWES	CASS	SOMN	NWES	CASS	SOMN	NWES	CASS	SOMN
	lb/A	----- ppm ------			----- ppm ------			----- ppm ------		
LKNAN	100	385	225	499	1817	2179	2269	547	523	486
LAN	100	450	202	575	1906	2169	2331	561	496	516
HKNAN	100	550	174	653	1997	2323	2339	686	490	524
LT	100	600	358	607	1984	2370	2199	665	665	470
ST	100	429	195	490	2009	2140	2137	707	574	505
LKNAN	300	399	266	621	1913	2057	2184	742	586	564
LAN	300	574	240	679	2044	2228	2075	828	613	509
HKNAN	300	505	233	766	2245	2366	2288	894	630	596
LT	300	610	228	671	2048	2212	2374	840	561	612
ST	300	344	206	561	2038	2236	2142	822	626	605
Statistical Analyses										
NLEVEL		NS	NS	NS	NS	NS	NS	**	NS	++
VARIETY		**	**	*	++	**	NS	**	NS	NS
NLEVEL X VARIETY		NS	**	NS	NS	*	NS	NS	*	NS

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

In summary, one years results does not show any clear trend as to whether a variety that has lower impurities under normal soil nitrate-N conditions will preform similarly under high soil nitrate-N conditions.

I would like to thank Allan Cattanach and NDSU crew, and Stan Prokosch for their cooperation and help with the CASS and SOMN locations.

BRIGHT SUN ON SPRING WHEAT AND SUGARBEET

J. A. Lamb and T. E. Cymbaluk[1/]

Two studies were conducted in 1990 at the Northwest Experiment Station, Crookston, MN to evaluate the use of Bright Sun, a foliar topdress product on spring wheat and sugarbeet. Both studies were conducted on a Wheatville loam.

Spring Wheat

The treatments were a factorial combination of three soil N levels; 50, 100, and 150 pounds of soil nitrate-N 0 to 2 feet plus fertilizer N, and with and without Bright Sun. The fertilizer for the soil N treatments was applied as Urea (46 - 0 - 0) April 18, 1990 and incorporated with and multiweeder. The spring wheat variety, Marshall, was planted at a rate of 100 pounds of seed per acre on April 18, 1990. The experiment had four replications and was in a randomized complete block design. Population measurements were taken before tillering. The Bright Sun was applied at a rate of three gallons per acre with a total carrier, water, of 15 gallons per acre on June 14, 22, and July 10, 1990. The following measurements were taken at soft dough; forage yield, height, head number, heads per plant, and seeds per plant. The wheat was machine harvested August 1, 1990. At harvest grain yield (corrected to 13.5 % moisture), bushel weight, and grain protein (corrected to 13.5 % moisture) were determined.

Results and Discussion:

The growing season in 1990 was a continuation of the droughts of 1988 and 1989. The subsoil moisture was depleted at the start of the growing season and only seven inches of precipitation fell during the growing season which is 3.3 inches less than the 100 year average. The use of Bright Sun did not effect any of the parameters measured (Tables 1 and 2). The use of N fertilizer did increase plant height, heads per plant, seeds per plant, grain yield, grain protein, and forage yield. Soil N decreased bushel weight. Plant population was greatest at the 100 lb N/A rate with wheat treated with 50 the 150 lb N/A having less population.

Table 1. The effect of soil N level and Bright Sun on population, height, heads per acre, heads per plant, and seeds per plant at NWES in 1990.

Soil N lb/A	Bright Sun	Plant height in	Plant population plant/A	Heads per acre #/A	Heads per plant #/plant	Seeds per plant #/plant
50	No	24.0	927828	1989240	2.10	21.7
50	Yes	24.0	876427	2562780	2.35	22.3
100	No	25.3	956578	2904000	2.60	24.3
100	Yes	25.3	958320	2642640	2.85	23.1
150	No	26.0	899078	2417580	3.05	25.1
150	Yes	26.0	865973	2315940	3.10	24.2
	No	25.3	927828	2436940	2.58	23.7
	Yes	25.1	900240	2507120	2.77	23.2
50		24.0	902128	2276010	2.23	22.0
100		25.3	957449	2773320	2.73	23.7
150		26.3	882526	2366760	3.08	24.7
Statistical Analyses						
Soil N		**	++	NS	**	++
Bright Sun		NS	NS	NS	NS	NS
SN X BS		NS	NS	NS	NS	NS
C.V. %		5.0	6.8	20.6	16.9	9.8

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

[1/] Associate Professor of Soil Science Dept., University of Minnesota, St. Paul, MN and Junior Scientist, Northwest Experiment Station, University of Minnesota, Crookston, MN.

Table 2. The effect of soil N level and Bright Sun on grain yield, bushel weight, grain protein, and forage yield at NWES in 1990.

Soil N lb/A	Bright Sun	Grain Yield bu/A	Bushel Weight lb/bu	Grain Protein %	Forage Yield lb/A
50	No	23.8	62.1	10.3	3633
50	Yes	23.2	61.2	10.6	4035
100	No	28.3	58.3	12.5	4958
100	Yes	26.3	58.5	13.2	4173
150	No	25.1	56.5	13.5	5694
150	Yes	25.5	57.0	13.5	4681
	No	25.7	58.9	12.1	4762
	Yes	25.0	58.9	12.4	4296
50		23.5	61.6	10.5	3834
100		25.3	58.4	12.8	4565
150		27.3	56.7	13.5	5187
Statistical Analyses					
Soil N		*	**	**	**
Bright Sun		NS	NS	NS	NS
SN X BS		NS	NS	NS	NS
C.V. %		9.4	1.4	6.0	15.6

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

Sugarbeets:

Similar treatments were used in the sugarbeet trial as the spring wheat trial. The soil N levels were 60, 110, 160 lb N/A as soil nitrate-N, 0 to 2 feet plus fertilizer N applied as urea (46-0-0) on May 2, 1990. The sugarbeet variety KW 1745 was overplanted May 2, 1990 and thinned to a stand of 125 beets per 100 foot of 22 inch wide rows. As with the spring wheat, Bright Sun was applied at a rate of three gallons per acre with a total carrier, water, of 15 gallons per acre on June 22, July 13, and August 3, 1990. The roots were machine harvested September 20, 1990 and quality samples taken at that time. The quality parameters were determined in the American Crystal Sugar Company's Tare Lab in East Grand Forks, MN.

Results and Discussion:

Similar to the spring wheat, the application of Bright Sun did not effect any parameters measured in this trial. The soil N treatment increased root yield, recoverable sucrose per acre, sucrose loss per acre, root K concentration, and loss of molasses, (Tables 3 and 4).

Summary:

In 1990 at the Northwest Experiment Station, the application of Bright Sun did not effect the growth, yield, or quality of spring wheat or sugarbeet.

Table 3. The effect of soil N level and Bright Sun on root yield, sucrose, recoverable sucrose per acre, recoverable sucrose per ton processed, and sucrose loss per acre at NWES in 1990.

Soil N lb/A	Bright Sun	Root Yield T/A	Sucrose %	Recoverable Sucrose lb/A	Recoverable Sucrose lb/T	Sucrose Loss lb/A
60	No	13.4	17.1	4183	311	422
60	Yes	13.9	18.1	4579	330	433
110	No	14.3	18.0	4636	326	428
110	Yes	14.3	18.3	4779	333	479
160	No	16.2	17.8	5204	322	561
160	Yes	16.0	17.8	5137	322	553
	No	14.6	17.7	4674	320	488
	Yes	14.7	18.1	4831	328	488
60		13.7	17.6	4381	320	427
110		14.3	18.2	4707	330	480
160		16.1	17.8	5170	322	557
Statistical Analyses						
Soil N		*	NS	++	NS	**
Bright Sun		NS	NS	NS	NS	NS
SN X BS		NS	NS	NS	NS	NS
C.V. %		10.6	5.7	13.2	6.9	11.5

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

Table 4. The effect of soil N level and Bright Sun on impurity index, root Na, root K, root amino-N, and loss to molasses at NWES in 1990.

Soil N lb/A	Bright Sun	Impurity Index	Na ppm	K ppm	Amino-N ppm	Loss to Molasses %
60	No	619	343	1849	495	1.44
60	Yes	579	322	1850	493	1.42
110	No	633	361	1924	552	1.52
110	Yes	616	346	1847	572	1.54
160	No	648	346	1971	571	1.58
160	Yes	650	357	1965	568	1.57
	No	634	350	1915	539	1.52
	Yes	615	342	1887	544	1.51
60		599	333	1850	494	1.43
110		625	354	1886	562	1.54
160		649	352	1968	570	1.58
Statistical Analyses						
Soil N		NS	NS	*	NS	++
Bright Sun		NS	NS	NS	NS	NS
SN X BS		NS	NS	NS	NS	NS
C.V. %		13.0	27.6	4.2	14.3	8.7

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

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 1990, as in all previous years, excluding 1988, N-rate response was noted for corn but not for soybeans. In 1990, as in all previous years, excluding 1989, soybean yields showed no 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. 1990 was the final year of this study.)

Introduction: The soybean plant has the ability to produce its own nitrogen for plant growth and development via rhizobium bacteria activity. However, the symbiotic bacteria may not be able to provide adequate nitrogen for the soybean plant during the entire growing season. The residual nitrogen in the soil may act like starter fertilizer for the underdeveloped soybean plant. Also, the soil nitrogen may be used during soybean seed fill when the nodules become inactive. If nitrogen is below the zone of symbiotic activity (approximately 9-12 inches) it will not inhibit N fixation and may be used by the soybean plant later in the growing season while uptaking water at deeper depths. This study was initiated to examine the possible benefit of increased soybean yields from nitrogen leftover from the previous corn crop in a corn-soybean rotation.

Methods & Materials: The experiment was initiated in 1984 on a Normania loam. Each plot is 30 by 48 feet 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: 1990 and six year average corn and soybean yields are given in Table 2. Soil Nitrogen information is provided in Tables 3 and 4.

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 (see Table 2). Corn yields increased with increasing nitrogen rates until the 150 lbs/ac rate, then the yields began to decline (see Table 2). In the past, corn had a significant response to nitrogen each year. The six year average corn yields indicate only slightly increased yields after the 100 lbs/ac N rate (see Table 2). In 1990, there was not a significant effect on soybean yields from the residual nitrogen remaining from the corn plots. 1989 was the only year a significant non-linear relationship existed between the residual nitrogen rates applied to corn in 1988 (see the 1990 Bluebook for more information). Table 3 contains the soil nitrogen data from the fall of 1988 for the 0, 100, and 400 lbs/ac nitrogen rates at 1 foot increments down to 5 feet, and Table 4 contains soil nitrate data for the 0, 100, and 400 lbs/ac nitrogen rates at 1 foot increments down to 5 feet for 1984, 1985, and 1987 (not previously published in "Blue Books"). The total nitrogen in the soil is much greater under 400 lbs/ac N rate than the 0 and 100 lbs/ac N rate at all depths (Table 3 and 4). The soil nitrogen from the 100 lbs/ac N rate follows the 0 lbs/ac N rate very closely, except for the 0 to 1 foot increment following the 1988 drought (Table 3 and 4).

Summary: The results from this study indicate that excessive rates of nitrogen applied to corn in a corn-soybean rotation does not have a significant effect on ensuing soybean yields. The 400 lbs/ac of nitrogen rate resulted in much greater soil nitrogen values, whereas the 100 lbs/ac N rate had only slightly increased levels from the 0 lbs/ac N rate. The greatest amount of soil nitrogen occurred in the upper 2 feet of the profile.

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[1] Funding provided by the Agricultural Experiment Station.

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

Table 1. 1990 Corn and Soybean Management Information.

Item		Corn	Soybean
Soil Test (ppm)			
P_2O_5		40	30
K_2O		155	174
pH		6.1	5.9
1989 Fall Primary Tillage:		Soil Saver	Soil Saver
Secondary Tillage	Type:	Digger (Twice)	Disk (Twice)
	Date:	23 April	3 May
Seed	Hybrid/Variety:	Pioneer 3615	Hardin
	Rate:	27,700 ppa	150,000 seeds/ac
	Date:	25 April	4 May
Herbicide	Brand:	Eradicane-Bladex	Treflan-Sencor
	Rate:	2.5 & 1.5 #/ac	0.75 & 0.25 #/ac
	Date:	23 April	3 May
Cultivation	Date:	12 & 22 June	11 June & 6 July

Table 2. 1990 and Six Year (1985-90) Averages of Corn and Soybean Yields (Bu/Ac).

Nitrogen (lbs./ac.)	1990 Corn	1990 Soybeans	6 year Avg. Corn	6 year Avg. Soybeans
0	97.0	40.2	87.8	41.7
50	116.2	40.9	109.9	41.8
100	121.8	43.5	121.1	42.6
150	129.0	43.3	122.7	43.3
200	128.8	45.3	124.3	43.9
400	127.6	46.2	124.9	43.3

Table 3. Fall 1988 residual soil nitrogen (ppm) information.

Depth	0 lbs/ac			100 lbs/ac			400 lbs/ac		
(feet)	NH_4	NO_3	Total N	NH_4	NO_3	Total N	NH_4	NO_3	Total N
1	8.1	6.4	14.5	10.6	12.3	22.9	19.7	34.4	54.1
2	3.9	3.4	7.3	3.1	5.2	8.3	4.2	10.9	15.1
3	3.3	1.2	4.5	3.0	1.2	4.2	2.5	2.2	4.7
4	2.6	0.9	3.5	3.1	1.6	4.7	3.6	5.8	9.4
5	3.3	1.0	4.3	3.6	1.9	5.5	2.9	3.4	6.3

Table 4. 1984, 1985, and 1987 soil NO_3 (ppm) information for the 0, 100, and 400 lbs/ac N rates.

Depth	1984			1985			1987		
(feet)	0	100	400	0	100	400	0	100	400
1	1.7	3.2	10.1	2.6	2.6	27.2	2.3	5.1	43.8
2	0.8	1.4	17.6	2.1	2.8	23.3	0.5	0.9	2.7
3	1.4	2.3	8.1	1.5	2.8	13.7	0.5	2.4	3.2
4	3.5	3.8	4.2	1.7	2.2	12.1	0.9	1.4	3.2
5	4.8	4.2	4.6	2	2.3	7.7	1.4	1.5	3.8

THIRTY ONE 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 1990, there was little difference between the 80 and 160 pounds N/Ac treatments. The 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).

Introduction: The Continuous Corn Study is a nitrogen fertilization experiment involving various rates and application times of ammonium nitrate and urea. The experiment has been conducted since 1960 on a tiled Webster clay loam.

Methods: The fertilizer treatments have now been applied annually to the same plot area for 30 years. Each plot is 20 by 77.5 feet 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.

Results: The 1990 yields from this experiment are given in Table 1. The 30-year yield averages are provided in Table 2 (In 1976, no yields were obtained due to drought, thus only 30 years of data exist). The one-way analysis of variance (Table 3) indicates a significant treatment effect. The LSD for 1990 yield comparisons ($\alpha = 0.05$) is 15.1.

The results of 1990, like the results of 1989, did not completely follow the trend of the past where greatest yield response is to increasing N-rates with application time in the spring. 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 and 1990. The highest yielding treatments was 80 pounds of urea N/Ac fall incorporated (see Table 1). However, there was no significant difference in yields between either forms of N at the 80 and 160 lbs/ac rates, except for the significantly lower yielding fall incorporated 80 lbs/ac of ammonium nitrate treatment (see Table 1). This year and in the past, there has been a moderate response to delayed application time with the greatest response at the 40 lbs/ac N rate. The long term averages indicate that urea nitrogen treatments had approximately a 2 bu/ac yield advantage over ammonium nitrate, not including the side dressed ammonium nitrate rate of 160 lbs/ac. 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] Assistant Scientist and Superintendent - University of Minnesota, Southwest Experiment Station, respectively.

Table 1. 1990 Yields (Bu/Ac).

Application Time	Ammonium Nitrate 40#	Ammonium Nitrate 80#	Ammonium Nitrate 160#	Urea 40#	Urea 80#	Urea 160#
	---------------	---------------	Bu/Ac	---------------	---------------	---------------
Fall (Incorporated)	119	128	142	124	145	138
Fall Plowed Surface	123	---	---	120	---	---
Spring	133	135	---	124	137	---
Side Dress	123	140	139	130	135	---
Check 81				Grand Mean 124		

LSD ($\alpha = 0.05$) = 15 Bu/Ac

Table 2. 30 Year Average Yields (Bu/Ac).

Application Time	Ammonium Nitrate 40#	Ammonium Nitrate 80#	Ammonium Nitrate 160#	Urea 40#	Urea 80#	Urea 160#
	---------------	---------------	Bu/Ac	---------------	---------------	---------------
Fall (Incorporated)	85	105	112	88	104	113
Fall Plowed Surface	83	---	---	88	---	---
Spring	96	108	---	94	109	---
Side Dress	98	105	117	98	113	---
Check 67				Grand Mean 101		

Table 3. One-way analysis of variance.

Source	DF	Sum of Squares	Mean Square	P value
Block	3	1199.8	399.9	0.0204
Treatment	19	30808.0	1621.5	0.0000
Error	55	6212.2	113.0	

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

D.J. Fuchs, M. Lindstrom, and W.W. Nelson[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 1990, tillage and erosion levels had a significant effect on corn yields (alpha = 0.01). The effect of tillage on corn yields has not been consistent. The ridge tillage treatment had the highest yields in 1990. The effect of erosion level on corn yields has been constant 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", and 1989 results were presented in the 1990 "Bluebook".

Methods and Materials: Plots for this study were located in areas of a field which had been slightly, moderately, and severely 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: fall moldboard PLOW and RIDGE-tillage.

The field has been in continuous corn since the experiment started. Additional management information is given in Table 1. 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. Ridges were re-established during the 1990 growing season.

Summary of results: 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.

In 1990, there was a significant difference between moldboard plow and ridge tillage (see Table 2). The ridge tillage treatment averaged 135.2 bu/ac and the moldboard plow treatment averaged 123.5 bu/ac over all erosion levels. The severe erosion class had significantly lower yields than the moderate and slight erosion class (see Table 2). Least significant differences (LSD's) are provided.

In 1990, as in the past, erosion levels affected corn yields with greatest yields occurring on the least eroded areas. Primary tillage effects on yields have not been consistent. In 1990, ridge tillage had the highest yield. The ridge tillage plots were plowed in the fall of 1990, so actually the comparison between tillages is actually a cultivation technique comparison. Therefore two possible explanations for increased yields in the ridge area are: 1) the ridge cultivation on 6/21 provided better moisture conservation and soil environment which resulted in increased plant growth and yield and/or; 2) the moldboard plow and secondary tillage operations thoroughly mixed the soil liberating soil nutrients that were formerly unavailable to the plant for growth and development (recall that the ridge plots had lower K levels in the earleaves and showed visual symptoms of K deficiency).

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

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

[2] Assistant Scientist - U of MN, Southwest Experiment Station; Soil Scientist - USDA-ARS, Morris, MN 56267; Superintendent - U of MN, Southwest Experiment Station, respectively.

Table 1. 1990 Management Information.

Item	Type	Rate	Date
Secondary Tillage	disk	twice	4/20 & 4/21
Insecticide	Furadan	1.0 #/Ac	4/21
Seed	Pioneer 3615	27,700 p/Ac	" "
Herbicides	Eradicane	2.5 #/Ac	4/24
	Bladex	1.5 #/Ac	" "
Fertilizer	Starter	N = 14 #/Ac	4/21
		P_2O_5 = 41 #/Ac	" "
		K_2O = 15 #/Ac	" "
	Broadcast (Urea)	N = 125 #/Ac	4/19
Mechanical Weed Control	Cultivation	twice	6/1 & 6/21
Ridged[1]		once	6/21

1/ Both tillages received the 6/1 cultivation, and on 6/21 ridge plots were ridged and moldboard plow plots were cultivated.

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

Tillage[1]	Erosion Class[2]			Overall
	Slight	Moderate	Severe	Mean
Plow	131.8	132.4	106.3	123.5
Ridge	141.5	139.5	124.6	135.2
Overall Mean	136.6	136.0	115.4	129.3

1/ $LSD_{0.05}$ = 3.1 for comparing tillage treatments (averaged over all erosion classes).

2/ $LSD_{0.05}$ = 8.0 for comparing erosion classes (averaged over both tillage treatments).

Table 3. Analysis of Variance.

Randomized block with split plot restriction

Number of: Cases = 24 Blocks = 4
Tillage Levels = 2 Erosion Levels = 3

Source	DF	SS	MS	P-value
Block	3	7.7	2.6	0.7373
Tillage	1	819.0	819.0	0.0013 **
Whole Plot Error	3	17.3	5.8	
Erosion	2	2324.4	1162.2	0.0001 **
Interaction	2	135.8	67.9	0.3210
Sub-Plot Error	12	651.3	54.3	

** significant at alpha = 0.01

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

D.J. Fuchs, M. Lindstrom, and W.W. Nelson[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 1990, tillage had a significant effect on the 4 percent slopes only with the chisel plow treatment having the highest corn yields. No other treatments were significant excluding the row direction by slope position (top, middle or lower) treatment. In the past, slope position and/or planting direction also had significant effect on crop yields.

(The 1989 University of Minnesota "Blue Book" contains information for the years 1986, 1987 and 1988. The 1990 "Blue Book" contains information for 1989.)

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, and 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 4% slope had a significant tillage effect with greatest yields occurring on the chisel plow treatments (see Table 4B & 5). The effect of tillage treatments on yields have not been consistent (see previous "Blue Books"). 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. 1990 Management Information.

Item	Type	Rate	Date
Secondary Tillage[1]	Digger	2 passes	4/23
Seed	Pioneer 3615	27,700 seeds/ac	4/24
Herbicides	Lasso	3.0 lbs/ac	4/27
	Bladex	1.5 lbs/ac	4/27
Fertilizer	Urea-N	N = 130 lbs/ac	6/14
	Starter	N = 7 lbs/ac	4/24
		P_2O_5 = 20 lbs/ac	
		K_2O = 7 lbs/ac	
Cultivation			6/22

1/ No secondary tillage on ridge tillage plots.

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

[2] Assistant Scientist - U of MN, Southwest Experiment Station; Soil Scientist - USDA-ARS, Morris, MN 56267; Superintendent - U of MN, Southwest Experiment Station, respectively.

Table 2 (A-H). Corn Yields (bu/ac) on the 8 Percent Slope.

2A. Overall Average.

	Avg	s[3]
Overall	125.6	8.0

n (sample no.) = 54

2B. Tillage.

Tillage	Avg	s
Chisel	124.6	6.2
Moldboard	126.8	7.5
Ridge	125.5	10.0

n = 18

2C. Row Direction.

Row Direction	Avg	s
Up & Down	124.4	9.1
Contour	126.9	6.6

n = 27

2D. Slope Position.

Slope Position	Avg	s
Top	124.1	8.7
Mid	126.9	5.4
Bottom	125.8	9.5

n = 18

2E. Tillage - Row Direction Interaction.

Tillage	Row Dir.	Avg	s
Chisel	Up & Down	122.2	7.0
Chisel	Contour	127.0	4.5
Moldboard	Up & Down	125.9	10.1
Moldboard	Contour	127.6	4.5
Ridge	Up & Down	125.0	10.5
Ridge	Contour	126.0	10.1

n = 9

2F. Tillage - Slope Position Interaction.

Tillage	Slope Pos.	Avg	s
Chisel	Top	123.8	6.8
Chisel	Mid	126.2	5.7
Chisel	Bottom	123.8	6.9
Moldboard	Top	122.4	9.0
Moldboard	Mid	130.0	5.4
Moldboard	Bottom	127.9	6.8
Ridge	Top	126.2	11.1
Ridge	Mid	124.6	4.2
Ridge	Bottom	125.8	14.1

n = 6

[3] s = sample standard deviation

2G. Row Direction - Slope Position Interaction.

Row Dir.	Slope Pos.	Avg	s
Up & Down	Top	119.3	9.8
Up & Down	Mid	126.6	6.1
Up & Down	Bottom	127.2	9.6
Contour	Top	129.0	3.5
Contour	Mid	127.3	4.9
Contour	Bottom	124.4	9.7

n = 9

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

Till[4]	Row Dir.	Slope Pos.	Avg	s
CH	Up & Down	Top	120.0	8.3
CH	Up & Down	Mid	125.3	6.5
CH	Up & Down	Bottom	121.3	7.9
CH	Contour	Top	127.5	1.8
CH	Contour	Mid	127.1	6.0
CH	Contour	Bottom	126.2	6.3
MP	Up & Down	Top	117.3	11.1
MP	Up & Down	Mid	131.7	4.0
MP	Up & Down	Bottom	128.7	9.7
MP	Contour	Top	127.5	1.9
MP	Contour	Mid	128.4	7.0
MP	Contour	Bottom	127.0	4.3
RT	Up & Down	Top	120.5	13.7
RT	Up & Down	Mid	122.9	5.2
RT	Up & Down	Bottom	131.8	11.1
RT	Contour	Top	131.9	4.7
RT	Contour	Mid	126.3	3.1
RT	Contour	Bottom	119.9	16.4

n = 3

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	697.4	348.7	0.0614
Row Dir.	1	83.88	83.88	0.1951
Whole Plot Error	2	45.59	22.79	
Tillage	2	43.09	21.54	0.6848
Row*Tillage	2	35.74	17.87	0.7287
Sub-Plot Error	8	434.1	54.26	
Position	2	72.87	36.44	0.4960
Row*Position	2	379.3	189.6	0.0380 *
Tillage*Position	4	145.2	36.30	0.5870
Row*Till*Pos	4	227.8	56.94	0.3666
Sub-Sub Plot Err	24	1211.0	50.46	

* significant at alpha = 0.05

[4] Tillage codes: CH - chisel, RT = ridge tillage, MP = moldboard plow

Table 4 (A-D). Corn Yields (bu/ac) on the 4 Percent Slope.

4A. Overall Average.

	Avg	s
Overall	134.6	8.4

n = 12

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

Tillage	Avg	s
Chisel	140.8	6.8
Moldboard	132.9	8.2
Ridge	129.9	7.9

n = 4 $LSD_{0.05}$ = 6.8

4C. Row Direction.

Row Dir.	Avg	s
Up & Down	130.8	9.7
Contour	138.3	5.4

n = 6

4D. Tillage - Row Direction Interaction.

Till	Row Dir.	Avg	s
CH	Up & Down	138.8	11.0
CH	Contour	142.8	0.7
MP	Up & Down	127.8	9.9
MP	Contour	138.1	0.2
RT	Up & Down	125.9	7.6
RT	Contour	133.9	8.1

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	66.27	66.27	0.6867
Row Dir.	1	165.8	165.8	0.5523
Whole Plot Error	1	230.6	230.6	
Tillage	2	252.4	126.2	0.0254 *
Row*Tillage	2	20.10	10.05	0.4958
Sub-Plot Error	4	47.84	11.96	

* significant at alpha = 0.05

Table 6 (A-B). Corn Yields (bu/ac) on the 1 Percent Slope.

6A. Overall Average

	Avg	s
Overall	139.2	6.0

n = 6

6B. Tillage.

Tillage	Avg	s
Chisel	136.3	0.4
Moldboard	139.7	7.1
Ridge	141.6	9.9

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	92.04	92.04	0.2117
Tillage	2	29.42	14.71	0.6559
Whole Plot Error	2	56.08	28.04	

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1990

		Precipitation			Temperature			Soil Temperature (10 cm depth)	
Month	Period	1990	100-yr. av.	Dev. from av.	1990	100-yr. av.	Dev. from av.	1990	10 yr. av.
January	1-31	0.08	0.68	-0.60	22.4	8.0	+14.4	25.7	20.7
February	1-28	0.33	0.67	-0.34	18.3	12.8	+ 5.5	23.4	23.9
March	1-31	1.49	1.13	+ 0.36	31.3	26.7	+4.6	33.5	29.2
April	1-10	0.06	0.57	+0.51	36.2	38.0	- 1.8	37.4	
	11-20	0.16	0.64	-0.48	39.2	44.4	- 5.2	41.3	
	21-30	1.72	1.05	+0.67	56.3	48.3	+ 8.0	55.0	
Total or av.		1.94	2.26	-0.32	43.9	43.6	+ 0.3	44.6	41.4
May	1-10	0.07	0.77	-0.70	50.8	52.0	- 1.2	52.6	
	11-20	1.07	0.95	+0.12	51.0	55.8	- 4.8	55.2	
	21-31	0.50	1.25	-0.75	60.3	60.0	+ 0.3	62.8	
Total or av.		1.64	2.97	-1.33	54.2	56.1	- 1.9	57.1	57.1
June	1-10	0.90	1.29	-0.39	60.6	63.0	- 2.4	63.8	
	11-20	2.99	1.30	+1.69	68.4	66.3	+ 2.1	71.0	
	21-30	1.27	1.37	-0.10	70.4	68.1	+ 2.3	75.4	
Total or av.		5.16	3.96	+1.20	66.5	65.8	+ 0.7	70.1	69.3
July	1-10	0.05	1.44	-1.39	72.0	70.1	+ 1.9	81.8	
	11-20	1.00	1.06	-0.06	67.3	71.4	- 4.1	78.1	
	21-31	0.16	1.01	-0.85	67.5	71.4	- 3.9	75.1	
Total or av.		1.21	3.51	-2.30	68.9	70.9	- 2.0	78.2	76.7
August	1-10	0.02	1.04	-1.02	68.5	70.4	- 1.9	79.0	
	11-20	0.70	0.93	-0.23	66.6	69.0	- 2.4	75.5	
	21-31	0.92	1.04	-0.12	70.5	66.9	+ 3.6	73.4	
Total or av.		1.64	3.01	-1.37	68.6	68.7	- 0.1	75.9	73.9
September	1-30	2.15	2.20	-0.05	61.9	59.0	+ 2.9	64.9	61.5
October	1-31	1.60	1.74	-0.14	44.2	47.2	- 3.0	48.5	47.8
November	1-30	0.07	0.97	-0.90	33.3	29.7	+ 3.6	39.3	33.6
December	1-31	0.35	0.68	-0.33	12.6	15.2	- 2.6	26.3	23.4
April-Aug. Growing Season		11.59	15.71	-4.12	60.5	61.0	- 0.5	65.2	63.8
January-December Annual		17.66	23.78	-6.12	44.0	42.0	+ 2.0	46.7	46.7

CONTINUOUS CORN SILAGE[1]
MORRIS, 1990

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 25 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 25th 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 ($N+P_2O5+K_2O$) lbs./acre and the other half a rate of 148+96+96. Silage and shelled corn yield samples were collected.

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 previous years corn stalks were chopped on October 23, 1989. The fertilizer was then applied and disked in on October 23, 1989. The experimental area was moldboard plowed on October 24, 1989. The study was field cultivated two times on April 25, 1990 for seedbed preparation. The study was then seeded to Pioneer 3751 corn at 26,000 seeds/acre on May 4, 1990. Furadan 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 pre-emergence broadcast om May 4. Date of tasseling and silking was recorded. Silage yields were chopped from 3 10-foot rows on September 17 and grain yields were calculated from 2 45-foot rows harvested with a plot combine on October 2, 1990. Yields were also taken, as in past years, on an adjacent unfertilized (check) area where only the grain is removed.

Results and Discussion: Silage yields are given in Table 1. There were no significant differences in silage yields in 1990. The 25-year average shows no effect of silage versus grain but does show significant differences between high and low fertility treatments. Grain yields, including the grain yield from the unfertilized check area adjacent to the plots, are given in Table 2. The 1990 yields show no significant difference in grain yield between the high and low fertility treatments. The long-term 25 year average does show a significant grain yield advantage for high fertility over low fertility. This study will be continued in 1991.

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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	1990 Yield	1966-1990 Yield
	- - - - - - - - - dry matter, tons/acre	- - - - - - - -
Silage, low fertility	5.72	5.51
Silage, high fertility	5.12	5.98
Grain, low fertility	4.90	5.54
Grain, high fertility	5.01	5.84
Signif. Levels (%)		
Treatment	73	>99
Year	--	>99
Treatment x Year	--	99
LSD, treatment (.05)	NS	0.16

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

Treatment	1990 Yield	1966-1990 Yield
	- - - - - - - - - - - - bu/ac @ 15.5% M.	- - - - - - - -
Grain, low fertility	83.8	86.4
Grain, high fertility	77.4	90.6
Signif. Levels (%)		
Treatment	49	99
Year	--	>99
Treatment x Year	--	>99
LSD, treatment (.05)	NS	3.0
Grain, check (Bu/Ac)	44.0	46.7
Silage, check (D.M. Tons/Ac)	2.38	3.51

WINTER UREA APPLICATION ON HIGH pH SOILS[1]
MORRIS, 1990

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

ABSTRACT: A 3-year study designed to record the effects of winter application of urea nitrogen on high pH soils for corn production was completed in 1990. 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 nitrogen on frozen soil and/or on snow. Applying urea nitrogen on frozen soil appears to be as effective as spring applications, but applying urea nitrogen on snow appears to result in some yield loss, although there were no significant differences in yield due to time of application.

Objective: The nitrogen retention study was designed to record the effects of off-season applications of urea nitrogen 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 procedures for all years of the study were the same. Soil tests in the fall of 1989 were as follows: pH=7.8, $NaHCO_3$ P=21 lbs./acre, exch. K=200 lbs./acre, NO_3-N (0-24 inches) = 56 lbs./acre, and NO_3-N (24-48 inches) =93 lbs./acre. The experimental area for 1990 was moldboard plowed October 28, 1989 and the plots were staked out October 31, 1989. The frozen soil treatment (Trt. 2) was applied on November 16, 1989. The mid-winter treatment (Trt. 3) was applied March 16, 1990 with a snow cover depth of 6 inches. The spring treatment (Trt. 4) was applied April 25, 1990. All treatments had 120 lbs./acre nitrogen applied and urea (46-0-0) was the nitrogen source. The experimental area was field cultivated twice on April 25, immediately after Trt. 4 was applied. The plot area was seeded to Pioneer 3906 corn at 26,000 seeds/acre on May 4, 1990. Lasso 3.0 lbs./acre a.i. + Bladex 2.2 lbs./acre a.i. were broadcast pre-emergence after corn planting on May 7. The experiment was cultivated on June 14 and June 27, 1990. Tasseling and silking dates were recorded and a stand count was taken on August 16. Six plants and ears were harvested at the black layer stage of maturity for total nitrogen uptake analysis on September 17. Grain yield, moisture, and test weight were recorded at grain harvest on October 2, 1990. The plots were harvested with a plot combine, harvest area was four 65-foot rows.

Results and Discussion, 1990: Plant measurements are given in Table 1. No differences were found between treatments for tassel date, silking date, plant population, grain yield, or grain moisture. The lack of a significant yield response may have been due to the high NO_3-N in the 24-48 inch zone.

Results and Discussion, 1987, 1988 and-1990: Results from 1989 have been omitted from this report because high residual soil NO_3-N levels from the previous year resulted in a lack of nitrogen response when the check treatment was compared to the other treatments.

In 1987, 1988, and 1990 there were no significant differences in grain yield due to time of urea nitrogen application (Table 2). The spring treatment was the highest yielding in 1987 and 1990, and the frozen soil treatment was the highest yielding in 1988 and the 3-year average. The snow cover treatment yielded above the check treatment but lower than the other treatments in 1987, 1990, and the 3-year average. The snow cover treatment yielded above the spring treatment but below the frozen soil treatment in 1988. It appears that applying urea nitrogen on frozen soil is as good as a spring application and that an application of urea nitrogen on snow cover results in yield loss, possibly due to volatilization and/or runoff. The above mentioned differences in yield were small and not significant. High residual soil NO_3-N levels undoubtedly influenced this study in 1988, 1989, and 1990.

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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. Summary of plant measurements - 1990.

Treatment	Tassel Date from 7/1	Silk Date from 7/1	Plant Pop.	Grain Yield	Grain Moisture	Grain Test wt.
			1,000's/ac	bu/ac	%	lbs/bu
Check	28.0	30.8	26.5	106.6	19.7	53.3
Frozen Ground	28.0	31.0	26.9	111.6	20.2	52.5
Snow Cover	28.0	31.0	27.3	110.9	20.1	53.3
Spring	28.0	31.0	27.1	116.3	20.3	53.1
Signif. Levels:						
Treatment (%)	--	56	36	39	71	95
LSD (.05)	--	NS	NS	NS	NS	0.7
C.V. (%)	--	0.8	3.5	8.9	2.3	0.8

Table 2. Winter urea application study, Morris 1987-1988-1990, grain yield results.

Treatment	Grain Yield 1987	1988	1990	1987-90
	bu/ac			
Check	81.9	67.4	106.6	85.3
Frozen Ground	96.1	72.7	111.6	93.5
Snow Cover	89.2	64.4	110.9	88.2
Spring	100.0	61.8	116.3	92.7
Signif. Level:				
Treatment (%)	60	39	39	65
LSD (.05)	NS	NS	NS	NS
C.V. (%)	16.7	17.4	8.9	13.9

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

Morris, 1990

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 1988 a study was initiated at the West Central Experiment Station to study the effects of a one-time subsoiling and its interaction with various primary tillage systems on subsequent soil compaction, soil water recharge, 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 than non-subsoiled areas. There was a highly significant subsoiling by wheeltrack interaction on both variables. By the fall of 1989 the moisture differences disappeared, but the bulk density differences remained. It appeared that wheel traffic from secondary tillage, planting, cultivating, spraying, and harvesting equipment repacked the soil to its original density. There were no effects of tillage or subsoiling on corn grain yields in 1989. Soil moisture samples taken in both the spring and fall of 1990 showed that subsoiling had no effect on volumetric moisture content. In the spring of 1990 there were no effects from subsoiling on soil bulk density, but in the fall of 1990 there was a slight subsoiling by depth interaction effect on bulk density. However, most soil measurements were no longer affected by subsoiling. Penetrometer measurements show large effects of wheel traffic, but very small effects of subsoiling, regardless of tillage system. There were no effects of tillage or subsoiling on corn grain yields in 1990. Based on the results of 2 years of measurements, subsoiling did not increase yields and had no lasting effect on soil bulk density or water content.

OBJECTIVES: A 3-year study was initiated at the West Central Experiment Station to study the effects of (one time) subsoiling on subsequent crop growth, soil compaction, and soil moisture 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 is cropped to continuous corn. This report will discuss the 2nd year, 1990, results of the 3-year study.

TILLAGE, PLANTING, and HARVEST PROCEDURES: The experimental plot area was established the fall of 1988. The entire plot area was fertilized with a 150 lbs. P_2O_5/acre and 10 lbs./acre Zn broadcast 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, and the 1989 crop (1st year of the study) was corn harvested with a combine. The plot area was seeded with a 6-row planter. 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 16 inches deep, was used on the MSS, CSS, and NSS treatments. A paraplow, operating 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 the 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.

In the fall of 1989 the plots were treated as follows: (1) The MSS and MNS treatments were plowed using an onland hitch with 6 18-inch bottoms, (2) The CSS and CNS treatments were chiseled with a 15-foot pull type chisel plow, and (3) The NSS, NNS, DSS, and DNS treatments were not tilled.

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

[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.

Crop residue measurements were taken on April 10, 1990. On May 9, 1990 corn stalks were chopped on the NSS, NNS, DSS, and DNS treatments. On May 11 the MSS, MNS, CSS, CNS, DSS, and DNS treatments were all disked twice for seedbed preparation. All wheel traffic from tractors during the tillage operations was confined to the position to be used by the tractor pulling the corn planter. All subsequent wheel traffic was also be confined to corn planter tractor wheel tracks. The NSS and NNS treatments were not tilled. The plots were seeded to Pioneer 3788 corn at @ 18,000 seeds/acre on May 14, 1990 with a 6-row planter. Lorsban 15G @ 10 lbs./acre (1.5 lbs./acre a.i.) was applied at seeding. No starter fertilizer was used. Lasso + Bladex (4 + 2.2 lbs./acre /a.i.) was broadcast pre-emergence on May 15 and 16. Crop residue measurements after planting were taken on May 16. Anhydrous ammonia was applied at 120 lbs. N/acre on May 31. Two 10-foot rows in each plot were staked out on June 4, 1990 and heights of corn plants were measured on June 20, July 7, July 19, and August 3 to record any plant growth differences. Plots were cultivated on June 25. Atrazine + Crop Oil (1.5 lbs./acre a.i. + 1 gal./acre) was broadcast post-emergence on July 24. Tasseling and silking notes were recorded from July 29 through Aug 3. Plots were harvested for grain with a JD 3300 combine on October 5, 1990. A grain sample was retained. Bulk corn was harvested from the plots on October 8 and corn stalks were chopped on all treatments. The MSS and MNS treatments were plowed using an onland hitch with 6 18-inch bottoms on October 24 and the CSS and CNS treatments were chiseled with a 15-foot pull type chisel plow on October 23. Post-tillage crop residue measurements were taken on November 6, 1990.

SOIL SAMPLING PROCEDURES: Two 2-foot soil cores were taken from each plot in wheel track and non-wheel track areas after corn planting on May 18 and 21. 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. Plots were sampled to a depth of 2 feet in 0-6, 6-12, 12-18, 18-24 inch increments. The soil samples were weighed, dried at 105°C, and weighed back for bulk density and soil moisture determination. Penetrometer readings were taken on May 21. After grain harvest in the fall of 1990, but before any fall tillage, two 2-foot soil cores in 0-6, 6-12, 12-18, and 18-24 inch increments were again taken in wheel track and non-wheel track areas of each plot for bulk density and soil moisture determination. At the same time one 2- to 5-foot soil core in 24-36, 36-48, and 48-60 inch increments was taken in the wheel track and non-wheel track areas of each plot for soil moisture determination. Sampling took place on October 9 and 10, and penetrometer readings were taken on October 10, 1990.

MEASUREMENTS AND DISCUSSION: Growing conditions were somewhat poor in 1990 with adequate moisture available through June but then very dry conditions in July, August, and September. Summaries of residue and plant measurements are given in Table 1. Subsoiling did not affect residue cover in pre-plant or post-plant measurements. There was a significant subsoiling by tillage interaction on residue measurements made prior to corn planting, but there was no interaction on post-plant residue measurements (Tables 1 and 2). Tillage systems did significantly affect residue cover. Date of tasseling, date of silking, grain moisture at harvest, and bushel weight were significantly influenced by tillage. The moldboard treatment tasseled earlier, silked earlier (except for the chisel treatment), had lower grain moisture, and a heavier test weight than the other treatments. Grain yield was not influenced by tillage, subsoiling, or their interaction.

The height of corn plants measured at 2-week intervals beginning 37 days after planting is given in Table 3. Corn plant height was significantly influenced by tillage at all measuring dates and also significantly influenced by subsoiling on August 3. There were no subsoiling by tillage interactions. The moldboard plow treatment had significantly taller plants than the spring disk and no-till treatments at all dates and taller plants than the chisel treatment at all dates, significantly so on July 6 and July 19.

An overall statistical analysis of the volumetric soil moisture taken in the study is given in Table 4. In the spring of 1990 a significant tillage by depth interaction shows that soil moisture content was greater in the spring disk and no-till treatments than in the moldboard plow and chisel plow treatments at the 0-6 inch depth and possibly at the 6-12 inch depth (Table 5). The wheel traffic by depth interaction was significant in both the spring and fall of 1990 showing a difference in the upper 12 inches but no or very little difference occurring below the 12-inch depth (Table 6). In both the spring and fall, the wheel track areas had greater soil moisture content in the upper 12 inches than the non-wheel track areas. There was no increase in soil moisture content below 12 inches in the wheel track areas in the spring and only a slight increase in the 12-18 and 18-24 inch depths in the fall. Subsoiling did not significantly affect any soil moisture measurement.

An overall statistical analysis of bulk densities taken in the study is given in Table 7. There was a significant tillage by depth interaction on bulk densities in the fall of 1990 (Table 8). The moldboard plow treatment had a lower bulk density than spring disk and no-till treatments at all soil depths. The chisel plow treatment had the same bulk density as moldboard plow and a lower bulk density than spring disk and no-till at 6-12, 12-18, and 18-24 inch soil depths. At the 0-6 inch depth, chisel plow had the same bulk density as spring disk and no-till and a higher bulk density than moldboard plow. The tillage by depth interaction was not significant in 1989. In the spring of 1990 the significance level was 90% whereas in the fall of 1990 the significance level was 96%, perhaps indicating a difference in bulk densities associated with maturing tillage systems. There was a subsoiling by depth interaction effect on bulk densities, shown in Table 9, that occurred in the fall of 1990, but most of the effects came from depth. The subsoiled areas had slightly lower bulk densities than the non-subsoiled areas (varying from 0.01 g/cm^3 to 0.04 g/cm^3). There was no subsoiling by depth interaction in the spring of 1990. There were significant wheeltrack by depth interactions on bulk density in the spring and fall of 1990 (Table 10). In the spring and fall, wheel traffic increased the bulk density in the 0-6 and 6-12 inch depths while having little or no effect in the 12-18 and 18-24 inch depths.

Penetrometer resistance measurements taken in the spring after planting and in the fall after harvest are shown in figure 1. Primary differences observed are related mostly to wheel track (WT) and non-wheel (NWT) interrows. Subsoiling (SS),no subsoiling (NS) or paraplow in the case of the disc tillage have essentially disappeared for this second crop year. Differences in penetrometer resistance measurements observed between the spring and fall sampling may be attributed to soil moisture content at time of sampling. Statistical analysis of penetrometer resistance data has not been completed at this point.

In conclusion, results from the 2nd year of a 3-year study show a one-time subsoiling had no effect on grain yield and most other agronomic characteristics in 4 primary tillage systems. The subsoiling effects on soil bulk density remaining 2 years after treatment are very small. In 1989 the effects were highly significant, but in 1990 the effects were significant at the 86% level in the spring sampling and at the 63% level in the fall sampling. It appears that a combination of factors such as subsidence after the subsoiling operation and wheel traffic have reduced the subsoiling effects on bulk density. The volumetric water content was again highly affected by subsoiling in 1989, whereas in 1990 these effects were not significant. Based on the results of 2 years of measurements, subsoiling did not increase yields and had no lasting effect on soil bulk density or water content.

Table 1. Summary of plant measurements due to tillage and subsoiling, 1990.

			Tassel	Silk		Grain	
			Date	Date	Harvest	Yield	Test
Treatment	4/10	5/16	from 7/1	from 7/1	Moisture	15.5% M.	Weight
	- - % cover - -				(%)	(bu/ac)	(lbs/bu)
Moldboard	7.5	12.3	29.1	31.4	18.1	99.4	54.8
Chisel	53.5	41.3	30.0	32.3	19.6	92.7	53.8
Spr. Disk	88.3	65.5	30.9	33.1	20.4	108.5	52.3
No-Till	92.8	81.3	30.8	33.5	21.0	111.5	52.6
Main plots:							
Signif. Level (%)	>99	>99	>99	>99	>99	88	>99
LSD (.05)	4.3	5.0	0.5	0.9	1.3	NS	0.6
C.V. (%)	2.3	13.7	0.8	1.0	7.0	6.7	3.0
Subsoiled	60.9	49.6	30.2	32.5	19.8	102.3	53.2
Not subsoiled	60.1	50.5	30.2	32.6	19.8	103.8	53.5
Sub-plots:							
Signif. Level (%)	85	28	--	71	15	44	34
Interaction:							
Signif. Level (%)	95	14	69	83	63	38	60

Table 2. Effect of tillage treatments on residue cover in 1990.

Trt.	Before Planting 4/10	After Planting 5/16
MNS	8.0	11.5
MSS	7.0	13.0
CNS	52.0	41.0
CSS	55.0	41.5
DNS	87.5	67.5
DSS	89.0	63.5
NNS	93.0	82.0
NSS	92.5	80.5

Table 3. Corn plant heights measured at 2-week intervals, 1990.

Treatment	Date: June 20	July 6	July 19	August 3
	inches			
Moldboard	41.1	113.6	183.5	242.6
Chisel	36.8	101.1	168.1	231.5
Spring Disk	34.1	92.9	156.1	217.0
No-Till	32.5	87.9	147.5	207.0
Main Plots:				
Signif. Level (%)	97	>99	>99	>99
LSD (.05)	6.0	9.7	9.5	11.5
C.V. (%)	5.5	6.0	4.2	3.1
Subsoiled	36.7	100.3	166.2	228.1
Not subsoiled	35.6	97.4	161.4	221.0
Sub-Plots:				
Signif. Level (%)	87	80	92	99
Interaction:				
Signif. Level (%)	51	51	67	80

Table 4. Statistical analysis of soil volumetric moisture content.

Variable	Spring 1990	Fall 1990
	Pr > F	
Tillage (T)	.4267	.2688
using Rep * T as an error term		
Subsoiling (SS)	.6624	.8001
T * SS	.6722	.5034
using Rep * T as an error term		
Wheel Traffic (Wt)	.0025	.0001
T * Wt	.6050	.2841
SS * Wt	.1271	.3672
T * SS * Wt	.8515	.6818
Using Rep * T * SS * Wt as an error term		
Depth	.0001	.0001
T * D	.0001	.5156
SS * D	.4076	.2889
Wt * D	.0001	.0001
T * SS * D	.8174	.8875
T * Wt * D	.3371	.8138
SS * Wt * D	.2317	.6367
T * SS * Wt * D	.3517	.4969
C.V. (%)	10.6	9.1

Table 5. Effects of tillage and depth on volumetric water content, Spring, 1990.

Trt.	Depth (inches) 0-6	6-12	12-18	18-24	Mean
			-% v/v		
Moldboard	27.2	41.3	37.5	38.8	36.2
Chisel	26.7	42.2	38.3	36.6	36.0
Spring Disk	35.0	43.1	38.4	37.0	38.4
No-Till	32.7	44.0	37.5	37.2	37.9
Mean	30.4	42.7	37.9	37.4	

Table 6. Effects of wheel traffic and depth on volumetric water content, 1990

Depth	Spring 1990 Wheel Traffic No	Yes	Mean	Fall 1990 Wheel Traffic No	Yes	Mean
inches	-% v/v			% v/v		
0-6	26.0	34.8	30.4	27.7	36.4	32.1
6-12	42.0	43.4	42.7	36.3	38.6	37.5
12-18	38.3	37.6	38.0	30.8	31.8	31.3
18-24	38.5	36.4	37.5	29.9	31.2	30.6
24-36	----	----	----	31.3	31.5	31.4
36-48	----	----	----	35.2	35.2	35.2
48-60	----	----	----	37.2	34.8	36.0
Mean	36.2	38.1		32.6	34.2	

Table 7. Statistical analysis of bulk densities in subsoiler study.

Variable	Spring 1990	Fall 1990
	Pr > F	
Tillage (T)	.1977	.8796
using Rep * T as an error term		
Subsoiling (SS)	.1447	.3715
T * SS	.1175	.1377
using Rep * T * SS as an error term		
Wheel Traffic (Wt)	.0001	.0001
T * WT	.8142	.5412
SS * WT	.0937	.3091
T * SS * WT	.9510	.6863
using Rep * T * SS * WT as an error term		
Depth (D)	.0001	.0001
T * D	.0985	.0411
SS * D	.5954	.0148
WT * D	.0001	.0001
T * SS * D	.6769	.6441
T * WT * D	.2164	.9490
SS * WT * D	.1879	.8416
T * SS * WT * D	.8905	.1240
C.V. (%)	7.5	7.5

Table 8. Effects of tillage and depth on bulk density, fall 1990.

Trt.	Depth (inches) 0-6	6-12	12-18	18-24	Mean
			g/cm³		
Moldboard	1.10	1.37	1.38	1.43	1.32
Chisel	1.13	1.37	1.36	1.44	1.33
Spring Disk	1.14	1.43	1.43	1.49	1.37
No-Till	1.14	1.40	1.45	1.51	1.38
Mean	1.13	1.39	1.41	1.47	

Table 9. Effects of subsoiling and depth on bulk density, fall 1990.

Trt.	Depth (inches) 0-6	6-12	12-18	18-24	Mean
			g/cm³		
SS	1.12	1.37	1.40	1.46	1.34
NSS	1.13	1.41	1.41	1.47	1.36
Mean	1.13	1.39	1.41	1.47	

Table 10. Effects of wheel traffic and depth on bulk density, 1990.

Trt.	Spring, 1990 Depth (inches) 0-6	6-12	12-18	18-24	Mean	Fall, 1990 Depth (inches) 0-6	6-12	12-18	18-24	Mean
			g/cm³					g/cm³		
Nwt	.81	1.34	1.41	1.51	1.27	.97	1.36	1.41	1.46	1.30
Wt	1.07	1.41	1.44	1.51	1.36	1.28	1.42	1.40	1.47	1.39
Mean	.94	1.38	1.43	1.51		1.13	1.39	1.41	1.47	

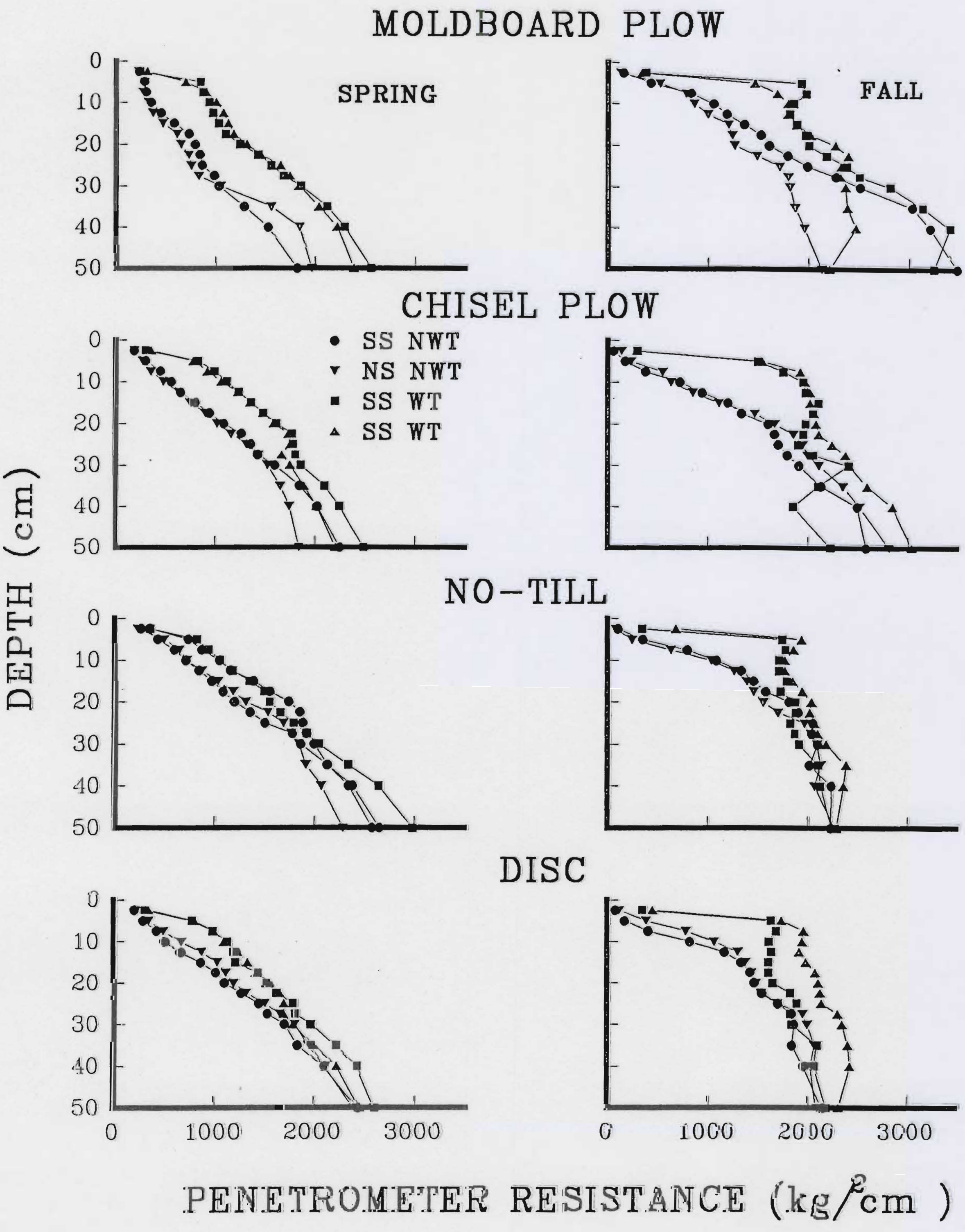

Figure 1. Penetrometer resistance readings for the four tillage systems in the spring and fall for subsoiled (SS), non-subsoiled (NS), wheel track (WT), and non-wheel tracked (NWT) interrows during the 1990 cropping season.

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

Morris, 1990

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

ABSTRACT: This study completed its 20th year in 1990 and will continue. Nitrate movement and yield responses from two initial annual applications of manure have been measured. Results over 20 years show 1986 as the first year the fertilized check yielded significantly better than the manure treatments. This occurred again in 1989 and 1990. In 1987 the fertilized check yielded more than the manure treatments, but not significantly more. Drouth in 1988 limited yields to an average of 50 bu./acre. Soil samples, measuring NO_3-N, were taken to a depth of 4 feet in the fall of 1990. Mineralization of organic N from manure to inorganic N is still providing enough N to maintain all manure treatment yields significantly above the check yields.

This is the 20th 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 23, 1989, and the entire experimental area was moldboard plowed the same day. The experimental area was worked with a field cultivator 2 times on April 25, 1990, for seedbed preparation. The study was planted to Pioneer 3906 corn on May 4, 1990, at 26,000 seeds/acre. Furadan 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) were tank mixed and applied broadcast pre-emergence on May 7, 1990. On May 30, 1990, the plot area was sprayed with Atrazine and Crop Oil Concentrate (2.0 lbs./acre a.i. + 2 quarts/acre, respectively) post-emergence for quackgrass control. Plots were cultivated on June 18 and June 27, 1990. Corn heights were measured on June 25, 1990, and whole plant samples were taken on June 26, 1990. Tasseling and silking dates were recorded and ear leaf samples were taken at mid-silk on August 1-3, 1990. Two 10-foot rows were harvested for silage yields on September 17, 1990. Two-100 foot rows were harvested with a plot combine on October 2, 1990, for grain yields. Grain yield, grain moisture, and grain bushel weight were recorded at harvest. Three soil cores were taken from each plot on October 8, 1990, 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 moisture, grain yields, and silage yields are given in table 1. The fertilizer treatment and all manure treatments had significantly taller plants than the check treatment. The fertilizer treatment had a higher dry weight than the check, solid beef manure, and liquid hog manure treatments. There were no significant differences in height or dry weight between the fertilized treatment and the liquid beef manure treatment. The fertilizer treatment significantly outyielded all other treatments. The yield ranking of the manure treatments was as follows: liquid beef>solid beef>liquid hog. The fertilizer treatment has now yielded more than the manure treatments the last 5 years; significantly so in 1986, 1989, and 1990. In 1986, the fertilizer treatment yielded more than the manure treatments for the first time. The effect of the 1970-71 manure applications on grain yield has decreased to the extent that the fertilizer treatment now has higher grain yields than the manure treatments, but the manure treatments still have higher grain yields and taller and heavier plants than the check treatment. The results of nitrate and ammonium analyses are given in table 2. Nitrate-N levels generally increased with depth while NH_4-N levels decreased with depth. Nitrate-N levels found in the fertilizer treatment were significantly greater than NO_3-N levels found in the manure treatments. Ammonium-N levels in all treatments were essentially the same. Low NO_3-N levels in the manure treatments in 1990 are similar to those found in the fall of 1986.

Over the last 5 years NO_3-N levels in the top 4 feet have varied from year-to-year. In the fall of 1987, 1988, and 1989 the liquid beef treatment had the highest average NO_3-N levels in this soil zone. In the fall of 1990 the solid beef treatment had the highest average NO_3-N value, mostly due to the 8.4 ppm value in the 3-4 foot zone. Nonetheless, enough nitrogen is being released each year from the all old

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

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

manure treatments to maintain yields significantly above the check treatment. A considerable amount of nitrogen has leached below the 4-foot level as indicated by the last deep sampling in the fall of 1987. At that time levels of 20 ppm, 27 ppm, and 30 ppm were found in the 6-8 or 8-10 foot zones of the solid beef, liquid beef, and liquid hog manure treatments. Precipitation from October 1987 to October 1990 has been average or below average in most months, so the NO_3-N levels below the root zone of corn have probably not changed much.

Table 1. Summary of plant measurements - 1990.

Treatment	Early Plant Height	Early Plant (10) Dry Weight	Grain: Moisture at Harvest	Grain: Yield at 15.5% Moisture	Silage: Dry Matter at Harvest	Silage: Silage Yield (D.M)	Silage: Ear Wt. as a % of Silage
	- cm -	- grams -	- % -	- bu/ac -	- - % - -	lb/ac	- % - -
Check	36.6	35.0	24.7	40.4	42.7	6,845	47.5
Fertilized	52.6	73.7	21.5	98.5	49.6	10,860	61.6
Solid Beef Manure	49.4	57.3	21.6	66.8	45.4	9,812	47.9
Liquid Beef Manure	51.2	77.7	21.0	75.0	46.2	8,237	53.3
Liquid Hog Manure	47.0	56.7	22.5	52.6	44.1	7,492	51.7
Signif. Level (%)	97	99	98	>99	>99	97	90
LSD (.05)	10.2	22.8	2.2	22.9	3.2	2,642	NS
CV (%)	10.7	19.5	5.0	18.2	3.6	15.2	11.2

Table 2. Nitrate and ammonium nitrogen levels of a Tara soil 20 years (Fall, 1990) after application of high rates of manure.

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	2.6	7.3	3.6	3.6	2.3	3.9	4.0	4.9	2.5	4.8	5.2	4.2a
1-2	0.4	13.3	0.4	0.9	0.4	3.1	2.7	2.7	2.2	3.1	2.8	2.7b
2-3	5.2	27.7	1.2	0.6	1.2	7.2	2.2	2.2	2.1	2.1	2.0	2.1c
3-4	2.7	14.9	8.4	4.1	7.3	7.5	2.3	2.3	3.3	2.2	2.2	2.5bc
Mean	2.7b	15.8a	3.4b	2.3b	2.8b	Mean	2.8	3.0	2.5	3.1	3.1	

Signif. Level (%):

NO_3-N:
Replication - 86
Treatment - >99 LSD, (.05) 5.6
Depth - 87
Trt. x Depth - 84

NH_4-N:
Replication - 81
Treatment - 70
Depth - >99 LSD (.05) 0.4
Trt x Depth - >99

SOYBEAN TILLAGE NITROGEN INOCULUM STUDY[1]
MORRIS, 1990

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

Abstract: This study was designed to measure the effects that previous nitrogen rates and tillage systems from continuous corn have on subsequent soybean yields and what effect inoculation has on soybean yields in these environments. Yields were significantly higher in moldboard plow and chisel plow systems as compared to ridge till and no-till systems. Soybean yields appeared to be positively affected by previous N rates (higher residual N), but not by inoculation. In general, the higher yielding tillage treatments matured earlier while the higher yielding former N rate plots matured later. Inoculation did not overcome any of the tillage or N rate effects.

Objective: The tillage nitrogen inoculation study was designed to measure the effects on soybean growth, maturity, and yield of soybean inoculation following six years of a continuous corn tillage x N rate x hybrid study.

Experimental Procedure: This experiment was on a Tara silt loam (Pachic Udic Haploboroll) soil that was in a continuous tillage x N rate x hybrid study from 1984-1989. The experimental design was split-split plot replicated 4 times. Established tillage treatments were main plots and included 1) fall moldboard plow - (MP), 2) fall chisel plow - (CP), 3) ridge till - (RT), and 4) no till - (NT). Each tillage block was split into 5 N rates, namely, 0, 40, 80, 120, and 160 lbs./acre of fall applied N as anhydrous ammonia. From 1984-89 each N rate plot was split into 2 corn hybrids which were rotated each year. In 1990 one of the hybrid treatments was seeded to inoculated Evans soybeans and the other to non-inoculated Evans soybeans.

Corn stalks were chopped and appropriate plots were moldboard plowed and chisel plowed on October 31, 1989. Fall MP and CP plots were disked for seedbed preparation on May 22, 1990. Evans soybeans were seeded in 30-inch rows on all tillage systems at 9-10 seeds/foot on May 23. Non-inoculated soybeans were seeded first and then inoculated soybeans were seeded, to avoid any planter seed box residual inoculum contamination. Lasso at 3 lbs./acre a.i. was applied broadcast pre-emergence on May 24. Ridge-till plots were cultivated on June 21 and ridged on July 2. The other tillage treatments were not cultivated. Fusilade was applied post-emergence on July 6 at 0.1875 lb./acre a.i. for control of volunteer corn and escaped grasses. On August 28 the plots were sprayed with Sevin at 1 lb./acre a.i. for grasshopper control. Plant height and lodging were recorded on September 13 and soybean maturity was recorded from September 13-18. The plots were harvested with a plot combine on September 25 recording grain yield and grain moisture. The harvest area was 5 feet by 35 feet.

Results and Discussion: Growing conditions were fair during 1990 with adequate moisture through June and a dry July and August. Mean soybean yield for the study was 30.2 bu./acre. A summary of plant measurements is given in Table 1. The results for analysis of variance for grain yield, grain moisture, lodging, plant height, and maturity date are shown in Table 2.

There were significant effects of tillage and N rate on grain yield, lodging, and maturity date and a significant effect of tillage only on plant height. The MP and CP tillage treatments had a higher grain yield than RT and NT. The MP and CP tillage treatments also lodged more, were taller, and matured earlier than RT.

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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., and Professor, Dept. of Soil Science, respectively, Univ. of Minnesota.

In general, yields were positively correlated with previous N rate with the former 160-lb rate yielding the highest. Lodging was also increased by N rate, but the lodging differences were rather small. It therefore appears that the residual N from previous treatments in some way positively influenced soybean yields. Even though the N rate x inoculum interaction is not significant at the 5% level, it is significant at the 10% level. However, yields (Table 3) show both positive and negative effects of inoculum and no consistent trends.

Grain moisture was significantly affected by tillage, tillage x N rate, inoculum, and the 3-way interaction, but the effects were small. Most of these differences were probably due to the fact that the experiment was harvested about 10 days after maturity and there were significant effects of both tillage and N rate on maturity date. The inoculation by tillage interaction was significant at the 10% level for grain moisture. The data (Table 4) show that inoculation resulted in higher moisture in RT and NT whereas in MP and CP there was no effect of inoculation.

Table. 1 Summary of plant measurements, 1990.

Treatment	Grain Yield	Grain Moisture	Lodging (1-5)	Plant Height	Date of Maturity
	bu/ac	%	1 = erect 5 = flat	inches	from Sept. 1
Tillage					
Moldboard Plow	33.1a	10.3	2.1a	31.6a	15.5b
Chisel Plow	32.2a	10.1	2.1a	33.1ab	15.1b
Ridge Till	26.5b	10.7	1.3b	26.8c	17.2a
No Till	28.9b	10.5	1.8a	29.9b	16.2ab
Signif. Level (%)	>99	99	>99	>99	99
BLSD (.05)	3.2	0.3	0.3	2.2	1.2
CV (%)	11.8	4.9	15.5	10.9	3.9
Previous N Rate (lbs./ac)					
0	28.5c	10.4	1.7b	31.2	15.7b
40	28.6c	10.4	1.7b	29.4	15.8b
80	31.3ab	10.4	1.8ab	29.7	15.9ab
120	30.2bc	10.5	1.9ab	30.3	16.3a
160	32.5a	10.4	2.0a	31.1	16.2ab
Signif. Level (%)	>99	15	97	72	95
BLSD (.05)	1.7	NS	0.3	NS	0.5
CV (%)	11.8	4.9	15.5	10.9	3.9
Inoculation					
Inoculated	29.8	10.5	1.8	30.3	16.0
Non-inoculated	30.6	10.3	1.8	30.4	15.9
Signif. Level (%)	83	99	--	6	69
CV (%)	11.8	4.9	15.5	10.9	3.9

Summary:

1) Soybean yields in various tillage systems were not influenced by inoculation, but were influenced by tillage with MP and CP yielding more than NT and RT.

2) Soybean yields in previous N rate treatments were not influenced by inoculation, but yields were influenced by previous N rate (residual N). Inoculation did not improve soybean yields any more where no N fertilizer had been used as compared to where 160 lbs. N/acre had been used.

3) Grain moisture was the only plant measurement significantly affected by inoculation. However, inoculation increased grain moisture at harvest only from 10.3% to 10.5%. Most of this increase came in the NT and RT systems.

Table 2. Statistical analysis of tillage nitrogen inoculum study, Morris, 1990.

Variable	Grain Yield	Grain Moisture	Lodging (1-5)	Plant Height	Date of Maturity
		Pr > F			
Tillage (T)	.0035	.0098	.0010	.0007	.0108
- - - - - - using Rep * T as an error term - - - - - -					
N Rate (N)	.0001	.8482	.0319	.2814	.0463
T * N	.3633	.0266	.8148	.4161	.6171
- - - - - - using Rep * T * N as an error term - - - - - -					
Inoculum (I)	.1711	.0058	1.000	.9430	.3137
T * I	.4251	.0866	.8887	.8996	.2338
N * I	.0953	.8252	.4217	.6251	.7883
T * N * I	.1357	.0525	.5198	.8587	.5928

Table 3. Effect of previous N rate and inoculum on soybean yield.

Previous N Rate	Non-Inoculated	Inoculated
(lbs./ac)	- - - - bu/ac - - - -	
0	29.3	27.7
40	27.8	29.3
80	31.8	30.8
120	31.8	28.6
160	32.3	32.6

Table 4. Effect of tillage and inoculation on soybean moisture.

Tillage	Non-Inoculated	Inoculated
	- - - - % moisture - - - -	
Moldboard	10.3	10.2
Chisel plow	10.3	10.3
Ridge-Till	10.4	10.7
No-Till	10.5	11.0

COMPARING BARLEY AND CORN PRODUCTION UNDER IRRIGATED AND DRYLAND CONDITIONS IN NORTH-CENTRAL MINNESOTA

George Rehm, Erv Oelke, Mel Weins, and Dan Schmitz[1/]

ABSTRACT: Production of dryland corn on the sandy soils of North-Central Minnesota is frequently severely restricted by dry weather. Production of barley appears to be a viable alternative. For this study, corn and barley were grown under both irrigated and dryland conditions. Best management practices were used for all inputs. For irrigated conditions, corn production would appear to be more profitable. The data from 1990 would indicate that production of barley would be more profitable for dryland conditions.

Introduction:

The majority of the soils in North-central Minnesota have a sandy texture and are low in native fertility. Because of the sandy texture, storage of available water is low and frequent growing season rains are needed for profitable production. In addition, farming enterprises are dominated by livestock and forage production is essential. Traditionally, corn is grown for both grain and forage. Yet, because of soils and climate, yields are frequently low. Barley can substitute for corn in the livestock ration and may be an alternative to corn production in the region. Therefore, this study was conducted to provide an economic basis for comparing barley and corn production under both irrigated and dryland conditions.

Experimental Procedure:

This study was conducted at two sites at the Irrigation Center at Staples. One site was irrigated, the other was not. A checkbook procedure was used for irrigation scheduling for each crop.

The inputs that were used for barley production are summarized below. The fertilizer rates used were based on a yield goal of 100 bu./acre for irrigated barley and 60 bu./acre for dryland barley.

Input and Practice	Irrigated Barley	Dryland Barley
Planting Date	4/21/90	4/21/90
Variety	Excel	Excel
Planting Rate	90 lb./acre	90 lb./acre
Seedbed Preparation	Field Cultivate (twice)	Field Cultivate (twice)
Fertilizer	100 lb. 21-0-0-24/ acre 120 lb. N/acre as 46-0-0 80 lb. K_2O/acre	100 lb. 21-0-0-24/ acre 50 lb. N/acre as 46-0-0 40 lb. K_2O/acre
Herbicide	1 pint Buctril/acre	1 pint Buctril/acre
Irrigation	2 times	-

The inputs that were used for corn production are summarized below. The fertilizer rates were based on a yield goal of 160 bu./acre for irrigated corn and 60 bu./acre for dryland corn.

[1/] Extension Specialist, Extension Specialist, Research Plot Supervisor, Junior Scientist, respectively.

Input and Practice	Irrigated Corn	Dryland Corn
Seedbed Preparation	Field Cultivate (twice)	Field Cultivate (twice)
Planting Date	5/10/90	5/10/90
Variety	Pioneer 3845	Pioneer 3845
Planted Population	32,000	15,000
Fertilizer	20-5-30-10 (starter) 180 lb. K_2O/acre 180 lb. N/acre as 28-0-0	20-5-30-10 (starter) 180 lb. K_2O/acre 40 lb. N/acre as 28-0-0
Herbicide (preemerge)	Bladex + Dual 1.25 pint + 1.25 pint/acre	Bladex + Dual 1.25 pint + 1.25 pint/acre
Irrigation	9.17 inches	-

The forage yields of barley were measured at head emergence and whole plant samples were collected for protein analysis. Grain yields were measured in late July with samples collected for protein analysis.

Corn grain yields were measured in late October. Forage yields were not recorded.

Results and Discussion:

Results from the barley and corn yield measurements are summarized as follows:

Crop	Irrigated	Forage Yield	Grain Yield
		ton D.M./acre	bu./acre
Barley	yes	1.92	102.2
Barley	no	1.86	61.2
Corn	yes	-	161.2
Corn	no	-	33.1

The forage yield of irrigated and dryland barley was nearly equal but the difference in grain yield was substantial. For corn, irrigated yield was approximately 5 times higher than the dryland yield. This difference is typical of past production on the sandy soils of North-Central Minnesota.

There are always questions about the protein content of barley. For the whole plants harvested at early heading, the protein percentage was 13.8% for dryland and 15.1% for irrigated barley. This difference was probably the result of the higher rate of N applied to the irrigated barley. The protein percentage in the grain was 12.7% for both irrigated and dryland conditions.

Costs of annual inputs were also recorded. For both crops, this included the cost of seed, herbicide, power used for irrigation and fertilizer. Tillage and land charges were the same for each crop and were not included.

Annual input costs for dryland barley were $41.25/acre. This cost for dryland corn was $62.31/acre. For the irrigated situation, the annual costs were $63.65 per acre for barley production and $113.58 per acre for corn production. Net return or profit must take the yield and the value of the commodity into consideration. This was not done in this report.

It would appear that irrigated barley may not be a good alternative to irrigated corn. The situation, however, may be much different for dryland situations. The data collected in 1990 indicate that dryland barley may be a good economic alternative to dryland corn in the area.

Tillage effects on N available to irrigated corn from turkey manure and urea N sources[1]

J.F. Moncrief, M.J. Wiens, and J.J. Kuznia[2]

This is the fourth year of a tillage and urea study on irrigated corn on a sandy soil that has had a turkey manure treatment introduced in 1990. This study is divided into four substudies designed to study the following interactions: tillage by N source by N rate, tillage by manure rate by cultivation, tillage by urea rate, and tillage by clearing discs. The presence of corn residue in the row area over 59% delayed corn phenology by two weeks. It did not reduce plant stands if residue was shallowly incorporated with discing. Stands were reduced less if row cleaners were used to clear the row area. Turkey manure performed better in supplying N to corn as tillage was increased to incorporate it. Cultivation also increased the N available to corn from turkey manure, although only subtly. Corn did not respond beyond the 137 pound per acre rate of applied urea. Tillage limited the N response with the conservation treatments. Disc row cleaners increased stands and phenology although effects on soil cover were small.

This is the first year of a two year study to investigate the effect of tillage on the availability of N to corn from urea and turkey manure. Previous to the introduction of the manure variable (since 1987) urea fertilizer was the sole N source and this field was in alfalfa in 1986. Tillage treatments are shown in table 1 (moldboard plowing, spring discing, and no tillage). A small amount of urea was applied with the planter (17 lbs/acre) and the remainder at about the 4-7 leaf growth stage and moved into the soil with irrigation to prevent volatilization losses. Turkey manure was applied in the spring before tillage.

Also evaluated in this study was the effectiveness of the clearing discs on the planter. In one nitrogen subplot clearing discs were raised on half the plot. All other plots were planted with row cleaners in the down position.

This is the fourth year of corn. The previous three years averaged about a 190 bushel per acre grain yield. This left corn residue levels quite high under no till conditions. Row cleaners reduced soil cover by corn residue from 80 to 69% (table 2). They had less influence with other tillage systems. This amount of cover in the row has a dramatic affect on corn emergence and growth. Emergence was delayed two weeks with corn grown under no till and spring discing treatments. Final stands were reduced 5 thousand plants per acre under no till conditions and not affected by discing. This reflects the negative affect of corn residue in the seed furrow with the no till system. Even though soil cover by residue levels were similar for the no till and disc treatments mixing the residue with soil reduced the likelihood of getting corn residue in the seed furrow with spring discing. This prevented the stand loss. Conservation tillage systems resulted in a delay in early growth of 1.2 to 2.8 leaves per plant.

Nitrogen source did not affect soil cover, emergence, early growth, or stand establishment.

Tillage by N source by N rate

Tillage effects on early growth also showed up in grain moisture (table 3). Due largely to the delayed growth the disc treatment resulted in an average yield reduction of 36 bushels per acre. Reduced N availability also contributed to this yield reduction (grain protein). The tillage induced stand reduction was mainly associated with the no till treatment and is likely responsible for the further decline in grain yield.

Although the estimated available N applied as turkey manure was slightly higher than the urea rates, urea resulted in higher yields, grain protein, and N uptake. The assumption that 30% of the organic N in the turkey manure would be available during the growing season was most likely high due the extremely cool spring and the lack of moisture when turkey manure was shallowly incorporated.

This is illustrated by the tillage by N source interaction shown in the middle of table 3. When turkey manure was followed by moldboard plowing, grain and stover yields were the same for urea and manure sources. As tillage was reduced yield differences become larger between urea and manure sources. A similar trend

[1] *Support for this project was provided by the Agricultural Utilization and Research Institute, the Staples Irrigation Center, and the Soil Conservation Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.J. Wiens is a Senior Plot Coordinator at the Staples Irrigation Center, Staples Area Technical College, Staples, MN.*

occurs with total N uptake.

The tillage and rate response interaction is due to the detrimental effects of residue on corn phenology and stand establishment. This influenced the source and rate interaction also.

Tillage by N source by cultivation

The objective of this study is to evaluate the effect of cultivation with a conservation tillage cultivator on the availability of N from turkey manure and urea (table 4).

Tillage and manure rate main effects are similar to the previous study.

Cultivation on July 2 increased N uptake with turkey manure as an N source.

The tillage by manure rate interaction was similar to the previous study. Turkey manure incorporated with tillage resulted in a higher corn response to an increased rate.

Higher level interactions did not show any consistent trends.

Tillage by N rate (urea)

The effect of tillage on the response by corn on applied urea is shown in table 5.

Tillage main effects are similar to the previous studies.

It is unusual that corn did not respond to urea applied beyond the 137 lb/acre rate.

The tillage by N rate interaction is indicative of the detrimental effects of corn residue on growth and yield with the conservation tillage options. The N response was greater as the tillage intensity increased.

Tillage and row cleaners

This study was designed to evaluate the influence of row cleaners on stand establishment and corn phenology (table 6). All plots had urea as a source of N.

Without row cleaners, the fluted coulter had no influence on the amount of soil cover by corn residue in the row. The clearing discs type row cleaners reduced the soil cover in the row by 12% under no till conditions. There was little influence on soil cover with the other two tillage systems. The clearing discs, although the soil cover was reduced only a small amount, increased plant stands by 6 thousand plants per acre under no till conditions.

Although tillage main effects were similar to other studies, the main effects of row cleaners and cultivation were not significant.

Soil Water Nitrate

Soil water access tubes (PVC with ceramic cup) were installed in duplicate at 3 and 5 feet deep in one replication of the high urea and turkey manure treatments. Water samples were taken by applying 1/2 bar of suction on the sample tubes. Samples were taken from June until December. Since only one replication was monitored the values are graphically presented over time but no statistical test are possible.

Figure 1 shows the effect of tillage, N source, and depth on the concentration of nitrate over the growing season. It is difficult to detect treatment influences on soil water nitrate concentrations from June to September. The moldboard treatment had higher concentrations of nitrate in the fall than the no till treatment. Turkey manure also resulted in higher levels of soil water nitrate in the fall. Concentrations were slightly higher at five feet during the fall period.

The interaction with tillage, N source, and depth is shown in figure 2. The moldboard system resulted in lower concentrations of soil water nitrate which is likely due to the increased uptake. Turkey manure resulted in higher soil water nitrate concentrations when moldboard plowed than with urea as an N source.

WADENA COUNTY

Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1990.

Tillage
- No Till
- Spring Disc-twice with light finishing disc on May 4, 1990
- Spring Moldboard Plow-May 7, 1990 then disced and harrowed
  Manure and selected urea plots were split by cultivation on July 2, 1990.

Previous Crop
1984-86 Alfalfa, 1987-89 Corn

1990 Crop
Corn-Pioneer 3790

Planting and Harvest Date

The planter is a 4 row Deutz-Allis Model 385 with 30 inch row spacing, equipped with 2 inch fluted coulters and disc (10 inch diameter) row cleaners mounted on the planter units ahead of the double disc openers. Yetter coulters are mounted on the tool bar supporting the fertilizer hoppers and open the soil for fertilizer.

At planting selected urea plots were split with row cleaners up or down.

A 4 row Hiniker 5000 Econ-O-Till cultivator was used to establish the cultivation split.

	Planting		Harvested	
Crop	Date	Rate	Grain	Stover
Corn	May 7, 1990	33,000 seeds/A	October 8, 1990	October 30, 1990

Fertilizer 1987

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Date Applied
		----	lb/A	----		
17-7-23-6[1]	93 lb/A	16	6	21	6	May 11, 1987
46-0-0[2]	0 lb/A	0	0	0	0	June 16, 1987
46-0-0[2]	75 lb/A	35	0	0	0	June 16, 1987
46-0-0[2]	146 lb/A	67	0	0	0	June 16, 1987
46-0-0[2]	221 lb/A	102	0	0	0	June 16, 1987

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in with 0.75 inch water.
3. The resulting N rates are: 16, 51, 83, and 118 lbs/A.

Fertilizer 1988

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Date Applied
		----	lb/A	----		
24-8-15-8[1]	85 lb/A	20	7	13	7	April 27, 1988
46-0-0[2]	0 lb/A	0	0	0	0	June 1, 1988
46-0-0[2]	137 lb/A	63	0	0	0	June 1, 1988
46-0-0[2]	254 lb/A	117	0	0	0	June 1, 1988
46-0-0[2]	400 lb/A	184	0	0	0	June 1, 1988

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in with 0.75 inch water.
3. The resulting N rates are: 20, 83, 137, and 204 lbs/A.

Fertilizer 1989

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Date Applied
		----	lb/A	----		
20-7-20-7[1]	95 lb/A	19	7	19	7	May 10, 1989
46-0-0[2]	0 lb/A	0	0	0	0	June 6, 1989
46-0-0[2]	72 lb/A	33	0	0	0	June 6, 1989
46-0-0[2]	139 lb/A	64	0	0	0	June 6, 1989
46-0-0[2]	207 lb/A	95	0	0	0	June 6, 1989
46-0-0[2]	0 lb/A	0	0	0	0	June 30, 1989
46-0-0[2]	70 lb/A	32	0	0	0	June 30, 1989
46-0-0[2]	139 lb/A	64	0	0	0	June 30, 1989
46-0-0[2]	200 lb/A	92	0	0	0	June 30, 1989

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in with 0.70 inch water on June 6 and 0.50 inch water on June 30.
3. The resulting N rates are: 19, 84, 147, and 206 lb/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.

1990 Fertilizer and Manure Analysis

Material Analysis	Rate[3]	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		---- lb/A ----				
20-5-30-10[1]	87 lb/A	17	4	26	9	May 7, 1990
46-0-0[2]	0 lb/A	0	0	0	0	June 29, 1990
46-0-0[2]	113 lb/A	52	0	0	0	June 29, 1990
46-0-0[2]	261 lb/A	120	0	0	0	June 29, 1990
46-0-0[2]	457 lb/A	210	0	0	0	June 29, 1990

1. Planter applied 2" below and 2" beside row on all plots.
2. Broadcast as urea and irrigated in with 0.58 inch water.
3. The resulting N rates are: 17, 69, 137, and 227 lb/A.

Analysis and rate of application of manure (average of 12 samples).

Manure Source	Date Applied	Rate	Solids	NH_4	NO_3	Mineral	Organic	Total N	Total P	Total K
		t/A	- % --	-------------------			% ------------			
Turkey[1]	4/24/90	4.0	55.1	.87	.05	.91	1.01	1.92	.35	.42
		6.7	55.1	.87	.05	.91	1.01	1.92	.35	.42

1. Collected in fall and stored near the study until application at Staples Irrigation Center. Source:Turkey finishing operation with wood shavings as a source of litter.

Rate of applied, estimated available N[2], and value[1] of nitrogen, phosphorus, and potassium.

Manure Source	Mineral	Organic	Nitrogen	$	Nitrogen Available Manure	Nitrogen Available + Starter	P_2O_5	$	K_2O	$
	-- Applied N lb/acre ---				---- lb/A -------		lb/A		lb/A	
Turkey	73	81	154	20.02	97	114	64	13.22	40	4.59
	122	136	258	33.54	163	180	107	22.10	68	7.81

1. It is assumed that fertilizer cost .13, .2065, and .1148 per pound of N, P_2O_5, and K_2O respectively.
2. It is assumed that all of the mineral N and 30% of the organic N will be available during the year of application.

Weed Control

1.5 qt/A (1.125 lb/A) Roundup spot sprayed on April 27, 1990.
1.5 pt/A (1.5 lb/A) Bladex + 1 qt/A (1.0 lb/A) 2,4-D Amine on May 11, 1990.
2 pt/A (2.0 lb/A) Dual on May 16, 1990.
1.5 pt/A (0.375 lb/A) Buctril applied to no till and disc treatments to control dandelions on May 30, 1990.
1 qt/A (1.0 lb/A) 2,4-D Amine spot sprayed on thistles on June 5, 1990.

Table 2. Effect of tillage on soil cover by corn and litter residue, corn growth stage and plant stands from 5-21-90 to 6-18-90 at Wadena Co[1].

Tillage	5-20 Residue[2] In Row	5-20 Residue[2] Bet Row	6-18 Growth Stage	Date 5-21	5-23	5-25	5-29	5-31	6-4	6-6	6-12	6-18
	------ % ------		leaves	----------------------			plants/acre x 10^{-3}		--------------------------			
No Till	68.5a	79.7a	3.0c	0.07b	0.36b	2.98c	12.78c	20.11b	23.96b	24.18b	25.34b	25.99b
Disk	52.7b	48.6b	4.4b	0.51b	2.40b	13.14b	24.76b	28.39a	29.26a	29.26a	30.06a	30.20a
Moldboard	16.7c	18.3c	5.8a	13.29a	22.36a	28.97a	30.71a	29.98a	30.86a	31.07a	30.93a	31.15a
Sig.	.001	.001	.002	.001	.001	.001	.001	.006	.013	.007	.009	.028
N-Source												
Urea 227lb/A	44.0a	46.0a	4.4a	4.79a	8.28a	16.41a	24.25a	26.57a	29.19a	29.33a	29.98a	29.91a
Low T.M.	47.8a	48.7a	4.4a	4.43a	8.57a	14.88a	21.13a	24.83a	27.59a	27.30b	28.39a	28.97a
High T.M.	46.0a	52.0a	4.5a	4.65a	8.28a	13.79a	22.87a	27.08a	27.30a	27.89ab	27.95a	28.46a
Sig.	.623	.371	.960	.963	.963	.288	.292	.399	.245	.200	.238	.437

1. Means within the same column with the same letter are not significantly different (α=.10).
2. "In row" is defined as a 4 inch area centered over the row. "Between row" is the remainder.

Table 3. Effect of tillage, nitrogen source, and nitrogen rate on various corn plant characteristics at Wadena Co., 1990[1].

Treatment	Grain Moisture	Grain Yield	Final Stand	Stover Moisture	Stover Yield	Total D.M.	Harvest Index	Grain Protein	Grain N	Stover N	Total N
	--%--	bu/A	Plant $Ax10^{-3}$	--%--	--T/A-	-T/A-		--%--	-------lb/A---------		
Tillage (n=16)											
No Till	34.6a	60.0c	23.7c	33.7a	1.37b	2.79c	.509b	6.53b	30.2c	7.5b	37.9c
Disk	29.6b	96.1b	27.1b	32.1ab	1.74ab	4.01b	.562a	6.70b	50.2b	8.9ab	59.1b
Moldboard	26.5c	131.8a	29.8a	26.4b	2.18a	5.29a	.583a	7.27a	74.5a	10.5a	85.0a
Sig. (Pr > F)	.001	.002	.006	.144	.003	.001	.072	.096	.005	.054	.005
N-Source (n=24)											
Urea	31.3a	106.5a	27.0a	28.5b	1.97a	4.49a	.549a	7.20a	60.3a	10.5a	70.8a
Turkey Manure	29.2b	85.4b	26.7a	33.0a	1.55b	3.57b	.554a	6.47b	42.9b	7.5b	50.4b
Sig. (Pr > F)	.009	.002	.645	.011	.001	.001	.682	.001	.002	.001	.001
N Rate (n=24)											
Low[1]	30.6a	85.3a	27.7a	33.7a	1.64b	3.67b	.542a	6.37b	41.7b	7.5b	49.1b
High[2]	29.8a	106.5b	26.8a	27.8b	1.88a	4.40a	.560a	7.30a	61.5a	10.5a	72.1a
Sig. (Pr > F)	.335	.001	.787	.022	.032	.003	.105	.001	.001	.001	.001

1. Means within the same column with the same letter are not significantly different (α=.10).

Interactions	Grain Moisture	Grain Yield	Final Stand	Stover Moisture	Stover Yield	Total D.M.	Harvest Index	Grain Protein	Grain N	Stover N	Total N
Tillage X N Source (n=8)											
No Till Urea	36.1	70.6	24.7	34.2	1.65	3.32	.500	6.83	37.2	8.9	46.1
No Till T.M.	33.2	49.3	22.7	33.2	1.09	2.26	.518	6.23	23.3	6.1	29.4
Disk Urea	29.8	118.1	27.1	30.7	2.04	4.83	.577	7.08	64.8	10.9	75.7
Disk T.M.	29.3	74.0	27.2	33.6	1.44	3.19	.547	6.32	35.6	7.0	42.5
Mldbd Urea	27.8	130.7	29.3	20.5	2.23	5.33	.570	7.69	79.0	11.6	90.6
Mldbd T.M.	25.1	132.9	30.3	32.3	2.11	5.26	.596	6.85	70.0	9.4	79.4
Sig. (Pr > F)	.287	.011	.190	.014	.001	.004	.155	.817	.143	.313	.133
Till x N Rate lb N/A (n=8)											
No Till Low	34.0	57.9	24.8	37.4	1.24	2.61	.523	6.21	27.3	5.7	33.0
No Till High	35.3	62.1	22.6	30.0	1.50	2.94	.495	6.85	33.2	9.2	42.4
Disk Low	30.3	82.3	26.5	33.7	1.66	3.61	.537	6.24	39.2	7.8	47.1
Disk High	28.8	109.8	27.8	30.6	1.81	4.41	.588	7.16	61.1	10.0	71.1
Mldbd Low	27.5	115.8	29.7	29.9	2.04	4.77	.568	6.66	58.6	8.7	67.4
Mldbd High	25.4	147.7	30.0	22.9	2.32	5.81	.598	7.89	90.3	12.2	102.6
Sig. (Pr > F)	.209	.116	.203	.707	.852	.430	.018	.216	.035	.686	.076
N Source x N Rate lb N/A (n=12)											
Urea Low	31.6	90.8	26.6	34.7	1.80	3.94	.536	6.47	45.1	8.1	53.2
Urea High	30.9	122.2	27.5	22.2	2.15	5.04	.562	7.93	75.5	12.9	88.4
T.M. Low	29.7	79.9	27.4	32.6	1.50	3.39	.549	6.26	38.3	6.8	45.1
T.M. High	28.7	90.9	26.1	33.4	1.60	3.75	.559	6.67	47.6	8.1	55.7
Sig. (Pr > F)	.818	.082	.161	.011	.225	.105	.462	.001	.011	.035	.011

1. Low signifies available nitrogen rate for turkey manure of 114 lb/A (includes 17 lb N/acre as starter fertilizer) of and a nitrogen rate of 69 lb/A for urea.
2. High signifies available nitrogen rate for turkey manure of 180 lb/A (includes 17 lb N/acre as starter fertilizer) of and a nitrogen rate of 137 lb/A for urea.

Table 4. Effect of tillage, N rate as manure, and cultivation on various corn plant characteristics at Wadena Co., 1990[1].

Treatment	Grain Moisture	Grain Yield	Final Stand	Stover Moisture	Stover Yield	Total D.M.	Harvest Index	Grain Protein	Grain N	Stover N	Total N
	--%--	bu/A	Plant Ax10^{-3}	--%--	--T/A-	-T/A-		---%---	--------lb/A--------		
Tillage											
No Till	33.2a	49.2c	23.2c	32.7a	1.14c	2.30c	.499c	6.19b	22.9c	5.8b	28.7c
Disk	29.0b	72.2b	26.3b	24.9a	1.39b	3.10b	.543b	6.31b	34.9b	6.1b	41.0b
Mldbd	24.7c	127.4a	30.2a	32.8a	2.01a	5.02a	.598a	6.72a	65.7a	8.9a	74.6a
Sig. (Pr > F)	.001	.001	.001	.431	.001	.001	.003	.037	.001	.001	.001
N Rate (n=24)											
114 lb N/A	29.7a	74.7b	26.5a	33.6a	1.43a	3.20b	.537b	6.25b	35.6b	6.4b	42.0b
180 lb N/A	28.2b	91.5a	26.6a	33.4a	1.50a	3.76a	.556a	6.56a	47.0a	7.5a	54.5a
Sig. (Pr > F)	.045	.002	.894	.946	.101	.008	.081	.004	.001	.062	.001
Cultivation											
W/ Cult	29.3a	85.4a	26.7a	33.0a	1.55a	3.57a	.550a	6.47a	43.0a	7.5a	50.5a
W/O Cult	28.6a	80.6a	26.4a	34.0a	1.48b	3.38b	.543a	6.34a	39.4a	6.4b	45.8b
Sig. (Pr > F)	.115	.275	.584	.357	.111	.169	.579	.267	.197	.001	.110

1. Means within the same column with the same letter are not significantly different (α=.10).

Interactions											
Tillage X N Rate (n=8)											
Notill 114lb/A	33.4	46.2	23.1	32.3	1.04	2.13	.507	6.30	22.0	5.2	27.2
Notill 180lb/A	32.9	52.2	23.5	33.2	1.24	2.47	.491	6.07	23.9	6.3	30.2
Disk 114lb/A	30.2	59.9	26.0	34.1	1.35	2.77	.510	6.03	27.4	6.3	33.6
Disk 180lb/A	27.7	85.3	26.7	35.8	1.43	3.45	.578	6.60	43.0	6.0	48.9
Mldbd 114lb/A	25.5	118.1	30.5	34.3	1.91	4.70	.594	6.42	57.5	7.7	65.2
Mldbd 180lb/A	24.0	136.7	30.0	31.4	2.11	5.34	.602	7.02	73.8	10.1	84.0
Sig. (Pr > F)	.510	.169	.756	.701	.889	.627	.023	.004	.067	.149	.091
Tillage X Cultivation (n=16)											
No Till W/	33.4	49.3	22.7	33.2	1.09	2.28	.512	6.23	23.3	6.1	29.4
No Till W/O	32.9	49.0	23.6	32.3	1.19	2.35	.485	6.15	22.6	5.4	28.1
Disk W/	29.4	74.0	27.2	33.6	1.44	3.19	.541	6.32	35.7	7.0	42.6
Disk W/O	28.5	70.3	25.4	36.3	1.34	3.00	.543	6.29	34.1	5.3	39.3
Mldbd W/	25.1	132.9	30.3	32.3	2.12	5.26	.595	6.85	70.1	9.4	79.5
Mldbd W/O	24.4	121.9	30.1	33.4	1.90	4.78	.601	6.58	61.2	8.5	69.7
Sig. (Pr > F)	.953	.491	.190	.388	.010	.162	.365	.494	.301	.314	.364
N Rate X Cultivation (n=24)											
114lb/A W/Cult	29.8	79.9	27.4	32.6	1.50	3.39	.546	6.26	38.3	6.8	45.1
114lb/A W/O Cult	29.6	69.6	25.7	34.5	1.37	3.01	.528	6.24	32.9	6.0	38.9
180lb/A W/Cult	28.9	90.9	26.1	33.4	1.60	3.75	.553	6.67	47.7	8.1	55.9
180lb/A W/O Cult	27.5	92.1	27.2	33.4	1.59	3.77	.559	6.45	46.2	6.8	53.0
Sig. (Pr > F)	.203	.137	.014	.391	.143	.102	.263	.357	.414	.366	.498
Till X N Rate X Cultivation (n=8)											
NT 114lb/A W/	31.9	50.0	23.9	35.1	0.98	2.16	.538	6.16	23.3	4.9	28.2
NT 114lb/A W/O	34.9	42.3	22.3	29.5	1.10	2.10	.475	6.45	20.6	5.6	26.2
NT 180lb/A W/	34.9	48.6	21.6	31.3	1.20	2.35	.486	6.30	23.2	7.3	30.5
NT 180lb/A W/O	30.8	55.7	24.9	35.2	1.27	2.59	.495	5.85	24.6	5.3	29.9
Disk 114lb/A W/	31.4	62.8	27.1	30.6	1.45	2.94	.504	6.13	29.1	7.6	36.7
Disk 114lb/A W/O	29.0	57.1	24.9	37.6	1.24	2.59	.515	5.94	25.7	5.0	30.6
Disk 180lb/A W/	27.5	85.2	27.2	36.6	1.42	3.43	.579	6.51	42.3	6.3	48.6
Disk 180lb/A W/O	27.9	85.3	26.0	34.8	1.44	3.46	.576	6.70	43.5	5.6	49.3
Mb 114lb/A W/	26.0	126.8	31.3	32.2	2.05	5.06	.595	6.50	62.5	8.0	70.5
Mb 114lb/A W/O	24.9	109.3	29.7	36.3	1.76	4.35	.594	6.33	52.5	7.5	60.0
Mb 180lb/A W/	24.2	138.9	29.4	32.3	2.18	5.47	.596	7.20	77.7	10.8	88.5
Mb 180lb/A W/O	23.9	134.5	30.5	30.5	2.03	5.21	.609	6.83	70.0	9.5	79.5
Sig. (Pr > F)	.001	.933	.389	.001	.287	.958	.244	.060	.951	.002	.840

Table 5. Effect of tillage and urea nitrogen rate on various corn plant characteristics at Wadena Co., 1990[1].

Treatment	Grain Moisture	Grain Yield	Final Stand	Stover Moisture	Stover Yield	Total D.M.	Harvest Index	Grain Protein	Grain N	Stover N	Total N
	--%--	bu/A	Plant A$x10^{-3}$	--%--	--T/A-	-T/A-		---%---	--------lb/A-------		
Tillage (n=16)											
No Till	35.7a	64.8b	23.3b	33.5a	1.63b	3.16b	.488b	7.22a	37.0b	11.3a	48.3b
Disk	30.4b	105.7a	27.9a	29.7b	1.90ab	4.40a	.566a	7.12a	59.3a	11.6a	70.9a
Moldboard	27.6c	120.0a	29.8a	17.0c	2.05b	4.89a	.570a	7.52a	72.1a	12.0a	84.1a
Sig. (Pr > F)	.001	.006	.005	.001	.118	.014	.006	.481	.014	.953	.031
N Rate (n=12)											
17 lb N/A	28.7c	56.8c	26.2a	27.1b	1.21c	2.55c	.523a	5.87d	25.1c	5.4c	30.5d
69 lb N/A	31.6b	90.8b	26.6a	34.7a	1.80b	3.94b	.536a	6.47c	45.1b	8.1c	53.2c
137 lb N/A	30.9b	122.2a	27.5a	22.2b	2.15a	5.04a	.562a	7.93b	75.5a	12.9b	88.4b
227 lb N/A	33.7a	117.6a	27.7a	22.9b	2.27a	5.06a	.543a	8.87a	78.8a	20.1a	99.0a
Sig. (Pr > F)	.001	.001	.535	.001	.001	.001	.437	.001	.001	.001	.001

1. Means within the same column with the same letter are not significantly different (α=.10).

Interactions											
Tillage X N Rate (n=8)											
No Till 17lb/A	31.8	38.5	22.1	34.5	0.97	1.88	.485	5.99	17.4	5.0	22.4
No Till 69lb/A	36.2	65.8	25.7	39.8	1.50	3.06	.504	6.25	31.3	6.6	37.8
No Till 137lb/A	36.0	75.5	23.7	28.7	1.79	3.58	.497	7.40	43.1	11.2	54.3
No Till 227lb/A	39.0	79.4	21.6	31.1	2.24	4.12	.467	9.22	56.2	22.3	38.5
Disk 17lb/A	28.1	65.9	28.1	34.0	1.33	2.89	.543	5.63	28.2	5.4	33.6
Disk 69lb/A	29.5	101.8	25.9	36.8	1.87	4.28	.564	6.35	49.3	8.2	57.5
Disk 137lb/A	30.2	134.4	28.3	24.6	2.21	5.39	.590	7.80	80.2	13.7	93.9
Disk 227lb/A	33.7	120.7	29.5	23.3	2.17	5.03	.565	8.71	79.7	19.2	98.8
Mldbd 17lb/A	26.2	65.9	28.3	12.7	1.34	2.90	.541	5.99	29.6	5.8	35.4
Mldbd 69lb/A	29.0	104.7	28.2	27.6	2.02	4.49	.540	6.81	54.8	9.5	63.2
Mldbd 137lb/A	26.7	156.6	30.5	13.4	2.45	6.16	.599	8.57	103.2	13.8	117.0
Mldbd 227lb/A	28.4	152.6	32.1	14.3	2.41	6.02	.599	8.70	106.7	19.0	119.6
Sig. (Pr > F)	.194	.031	.160	.626	.836	.188	.747	.092	.017	.856	.038

Table 6. Effect of tillage and row cleaners on residue relative to the row, growth stage and plant stands at Wadena Co[1].

Treatment	5-20 Residue In Row	5-20 Residue Between Row	6-18 Growth Stage	Plant Stand 6-4	Plant Stand 6-12	Plant Stand 6-18
	-------- % --------		--------	------ plants/A x 10^{-3} -----		
Tillage (n=8)						
No Till	73.3a	79.5a	2.94c	21.13b	23.52b	23.63c
Disk	59.5b	55.5b	3.88b	28.53a	29.19a	29.40b
Moldboard	14.0c	18.5c	4.63a	31.47a	32.56a	33.21a
Signif. (Pr > F)	.001	.001	.003	.009	.009	.005
Row Cleaners (n=12)						
W/ Row Cleaners	44.0	46.0	4.38	29.19	29.98	29.91
W/O Row Cleaners	53.8	56.3	3.25	24.90	26.86	27.59
Signif. (Pr > F)	.001	.073	.001	.001	.005	.046
Tillage X Row Cleaners						
No Till w/	66.5	79.0	3.38	24.39	25.92	26.57
No Till w/o	80.0	80.0	2.50	17.86	21.13	20.69
Disk w/	51.0	48.0	4.25	30.27	31.36	30.71
Disk w/o	68.0	63.0	3.50	26.79	27.01	28.10
Mldbd w/	14.5	11.0	5.50	32.89	32.67	32.45
Mldbd w/o	13.5	26.0	3.75	30.06	32.45	33.98
Signif. (Pr > F)	.028	.462	.232	.420	.147	.037

1. Means within the same column with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage, row cleaners and cultivation on various plant characteristics of corn at Wadena Co. 1990[1].

Treatment	Grain Moisture	Grain Yield	Final Stand	Grain Protein	Grain N
Tillage	---%----	bu/A	plants/acre x 10^{-3}	---%---	--%--
No Till (n=32)	36.5a	61.6c	21.5c	7.40b	35.2c
Disk (n=30)	32.7b	118.6b	28.0b	8.01ab	72.6b
Moldboard (n=32)	27.9c	152.4a	31.8a	8.59a	99.7a
Signif. (Pr > F)	.001	.001	.002	.091	.001
Row Cleaners					
W/ Row Cleaners (n=46)	31.9a	110.9a	27.3a	7.97a	69.4a
W/O Row Cleaners (n=48)	32.8a	110.5a	26.9a	8.03a	68.9a
Signif. (Pr > F)	.200	.845	.690	.954	.713
Cultivation					
W/ Cultivation (n=47)	32.8a	111.9a	27.4a	8.05a	70.1a
W/O Cultivation (n=47)	31.7b	109.5a	26.8a	7.95a	68.2a
Signif. (Pr > F)	.005	.542	.488	.588	.591

1. Means within the same column with the same letter are not significantly different (α=.10).

FIGURE-1
SOIL WATER NITRATE IN CORN
FOLLOWING CORN AT STAPLES 1990

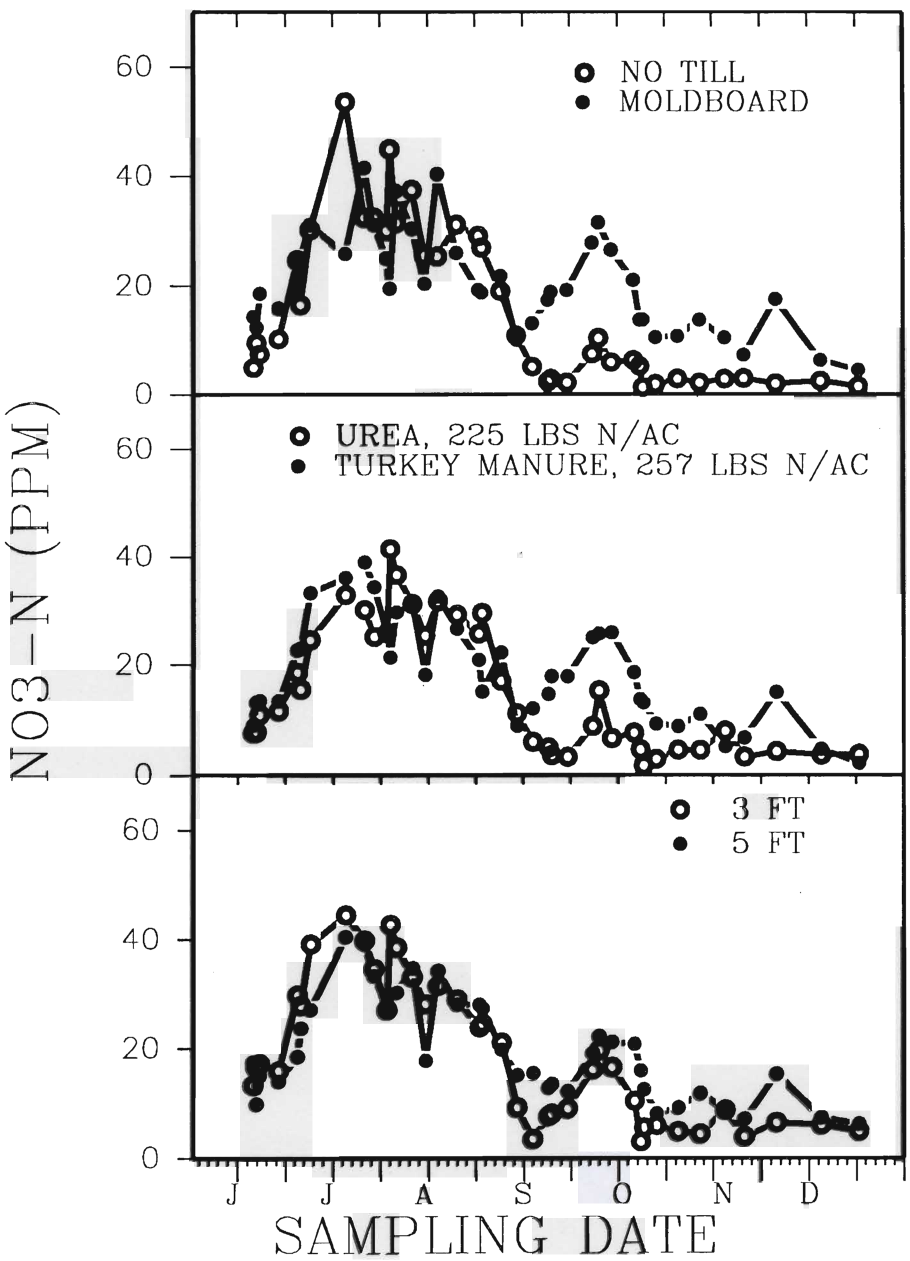
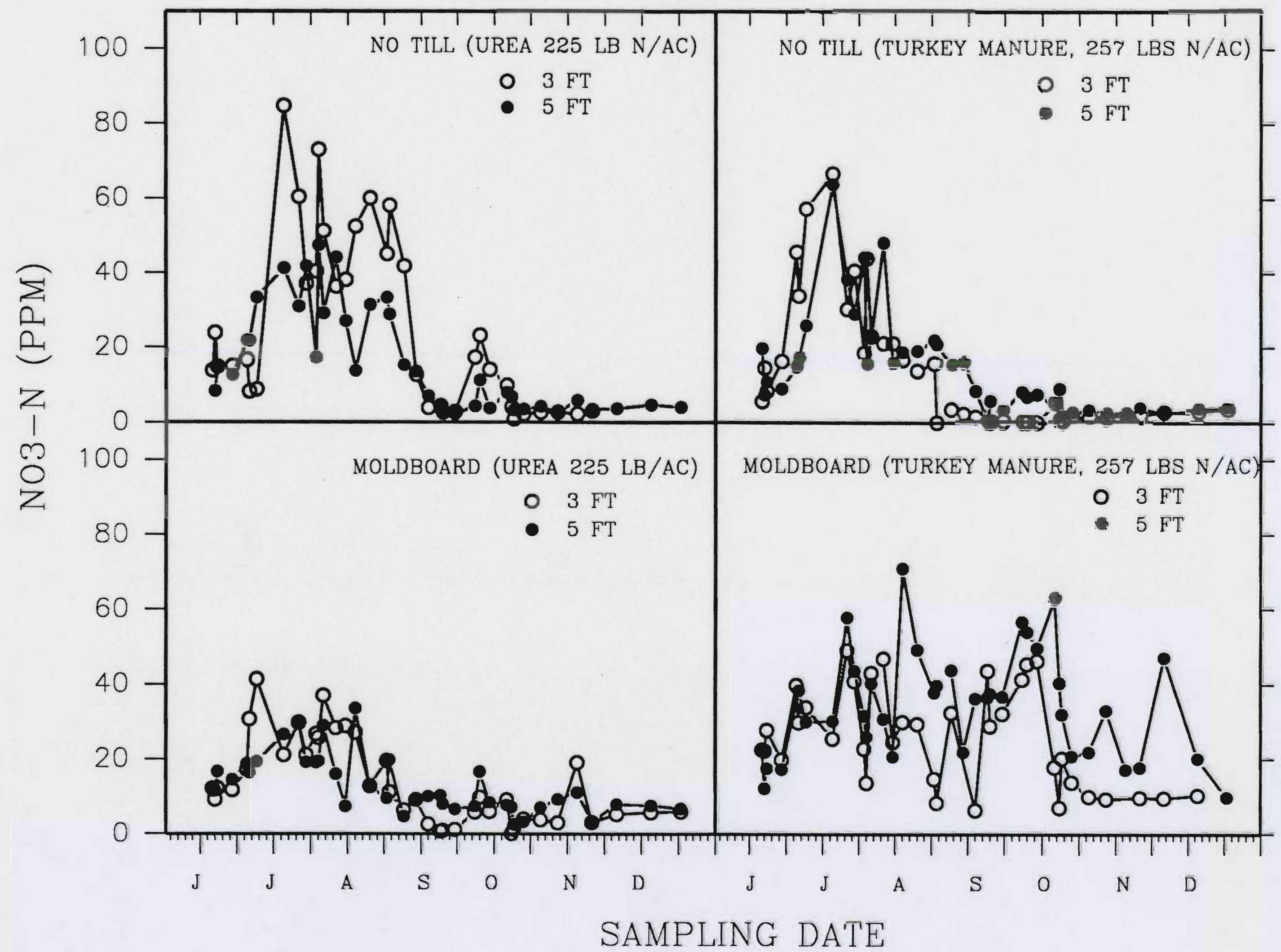


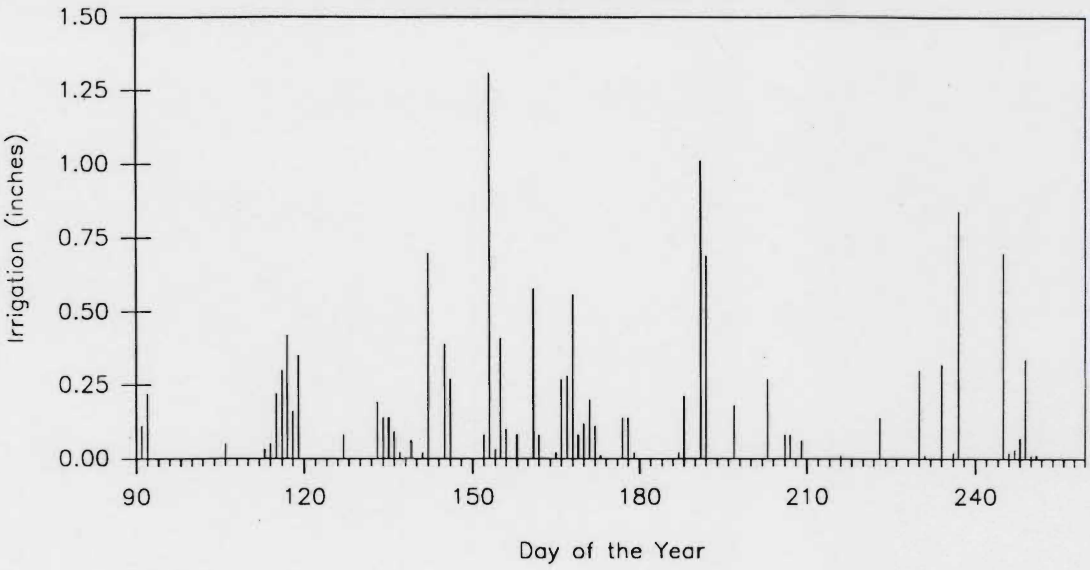
FIGURE-2

SOIL WATER NITRATE BY DEPTH IN CORN FOLLOWING CORN

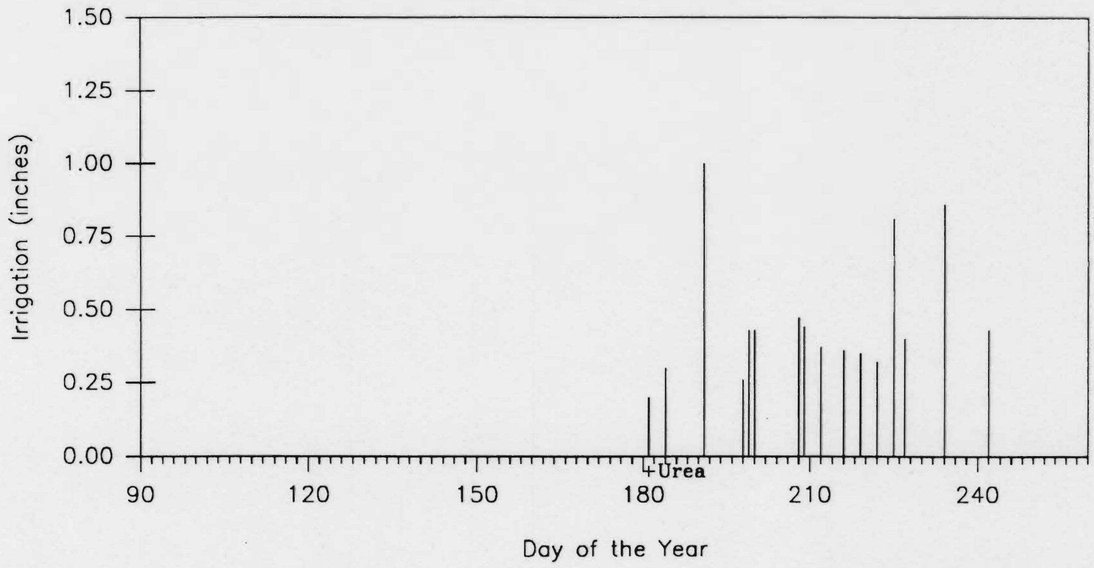
STAPLES 1990



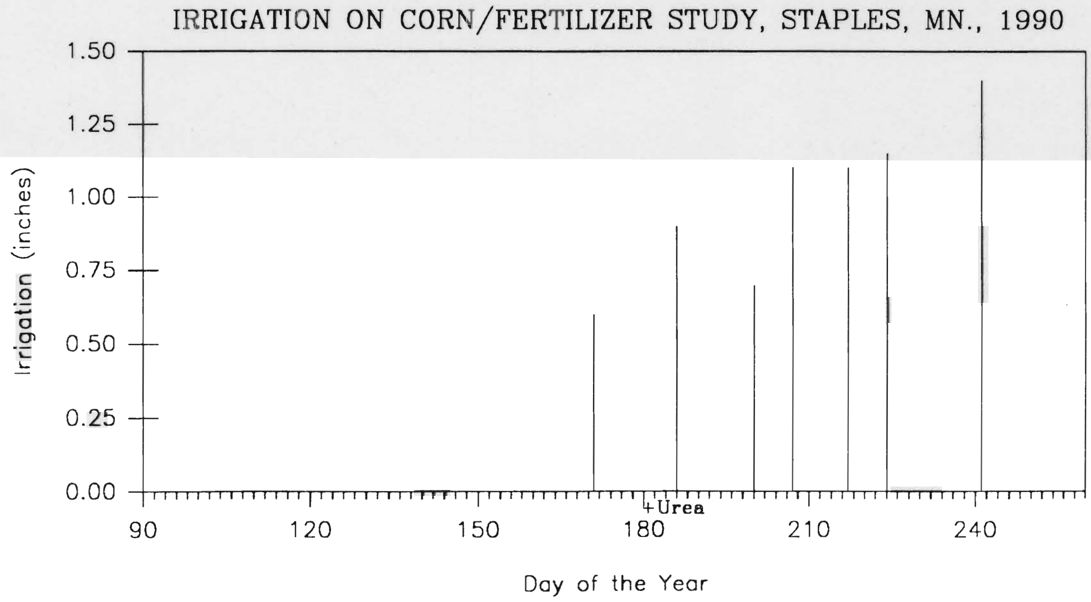
PRECIPITAION,STAPLES, MN., 1990



IRRIGATION ON CORN/ALFALFA STUDY, STAPLES, MN., 1990



IRRIGATION ON CORN/FERTILIZER STUDY, STAPLES, MN., 1990



Tillage effects on N available to irrigated corn from alfalfa and urea N sources[1]

J.F. Moncrief, M.J. Wiens, and J.J. Kuznia[2]

This study is designed to evaluate full width tillage and row cultivation on the N available to corn after alfalfa. Tillage did not affect stand establishment and had only slight influence emergence rate. Conservation tillage systems reduced the amount of N available to corn from alfalfa. At the 83 lb/acre rate all tillage systems had equal yields but slightly lower total N uptake.

The objective of this study is to evaluate the effect of full width tillage and row cultivation in June on the amount of nitrogen available to corn from alfalfa. Alfalfa was killed with herbicide in the spring (table 1). The alfalfa stand was about 8 plants per square foot (table 2).

The soil cover by alfalfa residue after planting is shown in table 3. The planter equipped clearing discs were much more effective at reducing soil cover by alfalfa residue in the row area than with corn residue (see companion paper). Emergence was only delayed by 2 days with the no till treatment and not at all with the spring disc treatment. Final stands were not affected by tillage.

Tillage affected grain moisture, but only slightly. Although tillage affected grain yield and N uptake there was an interaction with rate of urea. At the high N rate grain yields were similar between tillage systems. Although this interaction was similar for nitrogen uptake, it was slightly higher as tillage increased.

Cultivation did not show any consistent trend on growth, N uptake or yield.

Figure 1. shows the soil water nitrate at 3 and 5 feet under moldboard and no till conditions. The moldboard system appeared to have higher levels of nitrate through out the season. Figure 2 shows the individual sampler duplicates within the plots. The variability within plots makes it difficult to identify any treatment trends.

WADENA COUNTY

Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1990.

Tillage
No Till
Spring Disc-twice with light finishing disc on May 4, 1990
Spring Moldboard Plow-May 4, 1990 then disced and harrowed
Plot were split by cultivation on June 26, 1990.

Previous Crop
Alfalfa 1987-89

1990 Crop
Corn-Pioneer 3790

Planting and Harvest Date

The planter is a 4 row Deutz-Allis Model 385 with 30 inch row spacing, equipped with 2 inch fluted coulters and disc (10 inch diameter) row cleaners mounted on the planter units ahead of the double disc openers. Yetter coulters are mounted on the tool bar supporting the fertilizer hoppers and open the soil for fertilizer.

A 4 row Hiniker 5000 Econ-O-Till cultivator was used to establish the cultivation split.

	Planting		Harvested	
Crop	Date	Rate	Grain	Stover
Corn	May 7, 1990	33,000 seeds/A	October 8, 1990	October 30, 1990

[1] *Support for this project was provided by the Agricultural Utilization and Research Institute, the Staples Irrigation Center, and the Soil Conservation Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.J. Wiens is a Senior Plot Coordinator at the Staples Irrigation Center, Staples Area Technical College, Staples, MN.*

Fertilizer 1990

Material Analysis	Rate[3]	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		----	lb/A	----		
20-5-30-10[1]	87 lb/A	17	4	26	9	May 7, 1990
46-0-0[2]	0 lb/A	0	0	0	0	June 29, 1990
46-0-0[2]	26 lb/A	12	0	0	0	June 29, 1990
46-0-0[2]	85 lb/A	39	0	0	0	June 29, 1990
46-0-0[2]	143 lb/A	66	0	0	0	June 29, 1990

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in with 0.29 inch water.
3. The resulting N rates are: 17, 29, 56, and 83 lb/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

1 qt/A (0.75 lb/A) Roundup + 1 qt/A (1.0 lb/A) 2,4-D Amine on April 27, 1990.
1.5 pt/A (1.5 lb/A) Bladex + 1 qt/A (0.75 lb/A) Roundup on May 11, 1990.
2 pt/A (2.0 lb/A) Dual on May 16, 1990.

Table 2. Alfalfa crown counts[1] at Wadena Co. on April 25, 1990[2].

Nitrogen Rate	Tillage: No Till	Tillage: Disk	Tillage: Chisel	Average
	-----	plants/foot[2]	------	------
17 lb/acre	8.8	8.3	8.0	8.4a
29 lb/acre	7.8	7.9	7.4	7.7a
56 lb/acre	8.3	8.2	5.8	7.4a
83 lb/acre	9.3	8.8	7.2	8.4a
Average	8.5a	8.3ab	7.1b	

1. Crown counts were taken when the plot was flagged out and before establishment of tillage and N treatments.
2. The p value for tillage, nitrogen rate, and tillage by nitrogen rate interaction for alfalfa crown counts are 0.163 (n=32), 0.293 (n=24), and 0.710 (n=8) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage on soil cover by alfalfa residue, and corn plant stands from 5-21-90 to 6-12-90 at Wadena Co[1].

Tillage	Date 5-20 Residue: In Row	Date 5-20 Residue: Bet Row	Date: 5-21	5-23	5-25	5-29	5-31	6-4	6-7	6-12
			--------	--------	--------	plants/acre x 10^{-3}	--------	--------	--------	--------
No Till	26.0a	72.0a	8.49b	20.04b	28.75a	30.71a	31.36a	31.15a	31.36a	30.49a
Disk	15.5b	14.0b	6.32b	16.77b	28.75a	31.36a	31.58a	30.49a	31.36a	30.71a
Moldboard	3.0c	7.0b	16.99a	28.97a	30.49a	31.36a	31.36a	30.93a	30.93a	31.15a
Signif. (Pr > F)	.001	.001	.001	.001	.533	.879	.981	.832	.918	.892

1. Means within the same column with the same mean are not significantly different (α=.10).

Table 4. Effect of tillage, nitrogen rate, and cultivation on various corn plant characteristics at Wadena Co., 1990[1].

Treatment	Stover Moisture	Stover Yield	Grain Moisture	Grain Yield	Total D.M.	Harvest Index	Final Stand	Grain Protein	Grain N	Stover N	Total N
	--%--	-T/A-	--%--	-bu/A-	-T/A-		Plants Ax10^{-3}	---%---	--------lb/A--------		
Tillage (n=32)											
No Till	29.1a	3.23a	27.2ab	153.1b	6.85a	.530a	29.78a	6.72b	78.9b	24.3a	103.2b
Disk	24.7a	3.46a	27.5a	160.9ab	7.26a	.525a	30.00a	7.56a	92.8a	25.7a	118.5a
Moldboard	26.1a	3.37a	26.4b	165.8a	6.85a	.538a	30.00a	7.17ab	91.0a	27.8a	118.8a
Sig. (Pr > F)	.276	.646	.135	.081	.393	.570	.846	.034	.027	.651	.104
N Rate (n=24)											
17 lb/A	34.7a	3.03b	27.5a	138.0d	6.30a	.519b	29.65a	6.55c	69.1d	20.6c	89.7d
29 lb/A	28.4b	3.36a	27.1ab	151.0c	6.94b	.516b	29.62a	6.94cb	78.8c	23.2c	103.0c
56 lb/A	25.0b	3.43a	27.1ab	169.2b	7.43c	.542a	30.37a	7.45ab	95.7b	27.5b	123.3b
83 lb/A	18.4c	3.57a	26.5b	181.5a	7.86d	.547a	30.08a	7.66a	105.5a	32.3a	137.9a
Sig. (Pr > F)	.001	.002	.250	.001	.001	.001	.344	.005	.001	.001	.001
Cultivation (n=48)											
Cultivation	26.9a	3.33a	26.8b	160.9a	7.13a	.534a	30.00a	7.30a	89.6a	24.7a	114.3a
No Cultivation	26.3a	3.37a	27.3a	159.0a	7.13a	.527a	29.86a	7.00a	85.6a	27.1a	112.7a
Sig. (Pr > F)	.686	.516	.044	.238	.980	.260	.688	.173	.130	.108	.597
Interactions											
Tillage X N Rate (n=8)											
No till 17 lb/A	37.8	2.79	27.7	123.3	5.71	.514	29.04	6.08	56.6	17.5	74.1
No till 29 lb/A	31.5	3.27	27.5	141.9	6.63	.510	28.97	6.31	68.1	24.2	92.3
No till 56 lb/A	29.1	3.13	27.0	166.5	7.07	.560	30.27	7.33	92.8	23.9	116.8
No till 83 lb/A	18.1	3.72	26.5	180.8	7.99	.536	30.86	7.17	98.2	31.4	129.6
Chisel 17 lb/A	32.9	3.03	27.8	136.8	6.27	.516	29.55	6.66	69.3	18.0	87.3
Chisel 29 lb/A	25.2	3.49	28.1	153.7	7.13	.510	29.91	7.92	92.1	23.3	115.4
Chisel 56 lb/A	20.4	3.78	26.9	173.3	7.88	.523	30.49	7.78	102.5	29.1	131.6
Chisel 83 lb/A	20.1	3.52	27.0	180.0	7.78	.548	30.06	7.87	107.5	32.2	139.7
Mldbd 17 lb/A	33.4	3.28	26.9	154.0	6.92	.526	30.35	6.91	81.5	26.4	107.8
Mldbd 29 lb/A	28.3	3.33	25.8	157.6	7.05	.528	29.98	6.59	79.3	22.2	101.4
Mldbd 56 lb/A	25.4	3.39	27.3	167.7	7.36	.541	30.35	7.23	92.3	29.3	121.6
Mldbd 83 lb/A	17.0	3.47	25.8	183.8	7.82	.557	29.33	7.93	110.8	33.4	144.2
Sig. (Pr > F)	.462	.103	.135	.081	.027	.227	.309	.359	.095	.453	.141

1. Means within the same column with the same mean are not significantly different (α=.10).

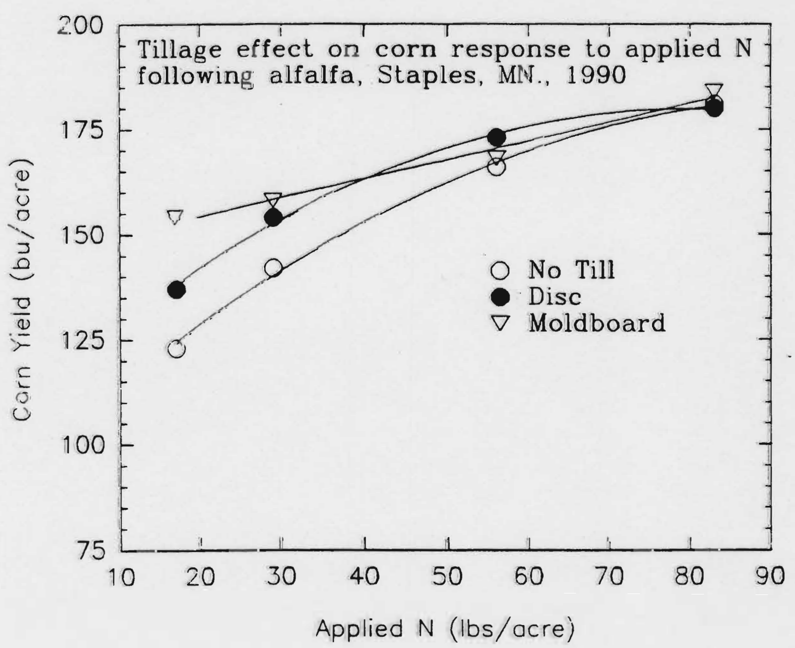


FIGURE -1

SOIL WATER NITRATE BY DEPTH IN CORN FOLLOWING ALFALFA

STAPLES 1990

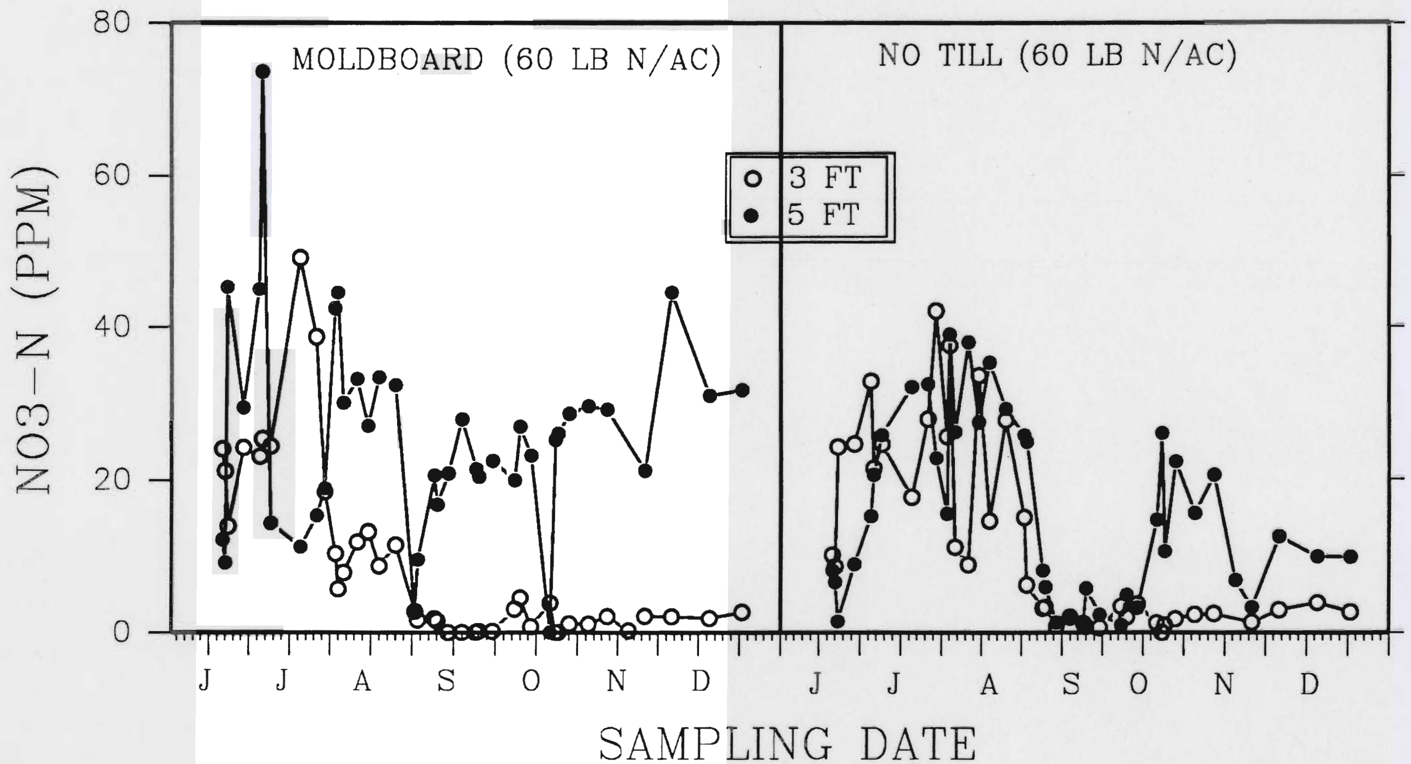
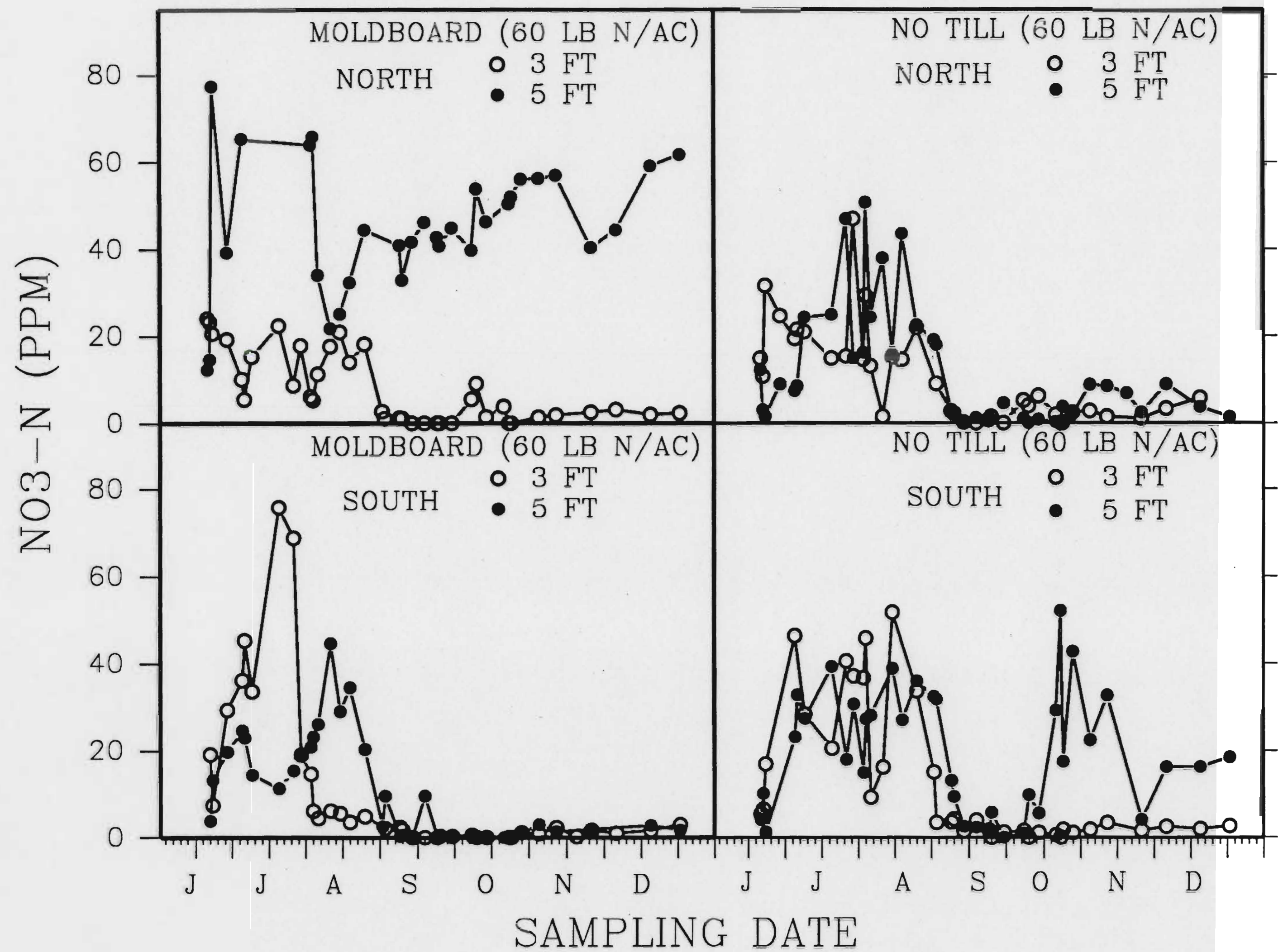


FIGURE –2

SOIL WATER NITRATE BY DEPTH IN CORN FOLLOWING ALFALFA

STAPLES 1990



NITROGEN VALUE OF RED CLOVER GROWN ON A SANDY SOIL

George Rehm, Dan Schmitz, and Andy Scobbie[1/]

ABSTRACT: The severe winter of 1989-90 killed existing stands of red clover at the Staples Irrigation Center. This provided an opportunity for evaluation of nitrogen credits for red clover preceeding a corn crop. Seven rates of N, supplied as 28-0-0, were applied to corn following: 1) a one-year old stand of red clover, 2) a three-year old stand of red clover, and 3) oats. Corn following oats responded to fertilizer N in the same manner as corn following the one-year old stand. The three-year old stand supplied substantial N to the corn. It would appear that current N credits assigned to an established stand of red clover are correct.

Introduction:

It's widely recognized that legumes supply nitrogen to grain crops grown in rotation. Considerable research has focused on the amount of N supplied by soybeans and alfalfa. There is less information about the amount of nitrogen supplied by red cover.

Experimental Procedure:

This study was conducted at the Irrigation Center at Staples. The severe winter of 1989-90 killed red clover at the Center. This was true for stands that were both 1 year old and 3 years old. This provided an opportunity to evaluate the amount of N supplied by red clover stands of two different ages (1 year, 3 years).

Corn was planted on May 10 on 3 areas that were adjacent to each other. In one area, the red clover was one year old before winter kill. In the second area, the red clover was three years old before winter kill. Oats was grown on the third area in 1989. Tillage consisted of 2 passes with a field cultivator. The planted population was 32,000 plants per acre. Potash (300 lb. 0-0-60/acre) was broadcast and incorporated before planting. The preemergence herbicide was a combination of Bladex (1.25 pint/acre) and Dual (1.25 pint/acre).

Six rates of nitrogen (30, 60, 90, 120, 150, 180 lb./acre) were applied to each of the three areas. Each treatment as well as the control (no N) was replicated 4 times. The nitrogen was applied as a sidedress treatment on July 5 and incorporated with the irrigation water. The nitrogen source was 28-0-0.

Irrigation was applied throughout the season as needed. A total of 9.17 inches of irrigation water was applied.

Results and Discussion;

Corn yields are summarized in the following table. All yields are corrected to 15.5% moisture.

N Applied	1 year old Red Clover	Previous Crop 3 year old Red Clover	Oats
lb./acre		bu./acre	
0	141.2	139.0	101.7
30	155.3	157.4	119.4
60	165.3	155.2	150.7
90	179.7	167.9	162.0
120	171.5	149.9	165.0
150	173.3	154.9	159.3
180	177.0	169.6	162.2

[1/] Extension Specialist, Junior Scientist, Assistant Scientist, respectively.

There was a response to the use of nitrogen fertilizers on all three areas. In general, the optimum nitrogen rate was 120 lb./acre when corn followed oats. When corn followed the 3 year old stand of red clover, the optimum N rate was approximately 60 lb. of nitrogen per acre. The 1 year old stand of red clover supplied little or no nitrogen. For this crop sequence, the optimum nitrogen rate was 120 lb./acre.

Current University of Minnesota fertilizer recommendations suggest using a nitrogen credit for red clover of 75 lb./acre. Results from this one site suggest that this credit is appropriate and should not be changed.

CORN NITROGEN RATE STUDY

H. Meredith and Mel Wiens[1/]

ABSTRACT: A nitrogen rate study was initiated in 1990 on an irrigated sandy loam soil on the research area at the Stapes Irrigation Center. The study is to be multi year with N rates of 20, 60, 100, 140, 180 and 220. A 95-day relative maturity hybrid was used as the test crop. The objective of the study is to establish optimum N rates for production of corn under intensive management.

Table 1. N Rates, Corn Yields and Percent Moisture in Grain at Harvest of 95-day Relative Maturity Hybrid, Staples Irrigation Center.

Treatment	Yield	Moisture
lbs N/A	bu/A	%
20	73.2	21.0
60	91.8	23.4
100	124.0	19.3
140	135.7	17.9
180	142.2	18.4
220	134.1	18.4

[1/] Regional Director, TVA; Research Plot Supervisor, Staples Irrigation Center, University of Minnesota, respectively.

LUPIN BEAN FERTILITY STUDY

H. Meredith, Mel Weins, and Andy Scobbie[1]

ABSTRACT: A fertility study initiated in 1984 to determine the nutrient requirements of the lupin bean (Lupinus albus) was continued in 1990. Excellent yields resulted due to wee and insect control, excellent seed quality, and ideal climatic conditions for germination and emergence. The diseases, which plagued the crop and reduced yield in 1989, were again evident on the continuous lupin plot but yields were not reduced as drastically as the previous year. As in past years, no yield increases were noted with any of the nutrient additions.

Table 1. Summary of "Good" Lupin Yields 1985 - 1990, Staples MN.

Yield, bu/A[2]

No	Treatment	1985	1987	1988	1990	
1	Check	71.4	61.8	61.9	61.9[3]	68.7[1]
2	S	71.2	62.8	67.2	61.2	64.0
3	S+K	63.8	61.9	61.1	57.1	59.8
4	S+K+P	68.8	61.8	57.2	61.2	67.0
5	S+K+P+Zn	64.1	56.3	58.0	60.3	67.2
6	S+K+P+Zn+B	64.9	60.8	52.3	56.2	67.2

[2] Yields based on 13.5% moisture and 60 lb/bu
[3] Continuous lupin site
[1] 1st year lupin site

Summary and Conclusions:

The 1990 growing season was quite conducive for lupins and satisfactory yields were achieved. It is reassuring that the highest yield was attained on the zero fertility plots. The range in yield of the four replications was 66.7 to 70.5 with a four rep average of 68.7. A yield reduction on the potassium and phosphate treatments was observed in 1990 as some years previously. Lupins are sensitive to soluble salts whether from the native soil, irrigation water or fertilizer salts.

The lupin plant has great potential for use as a nitrogen builder and as a crop to mobilize sparingly soluble soil nutrients for utilization by succeeding crops. to date, a yield increases has been attained only from applied sulfur in one year, 1988. No response from other applied nutrients has been measured.

The continuous lupin plot will be discontinued after 1990 due to buildup of pathogens, primarily Ascochyta and to a lesser extent from Pleiochaita and Fusarium. Future lupin research plots will follow cereal crops.

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[1] Regional director, TVA; Research Plot Supervisor, Staples Irrigation Center; Assistant Scientist, University of Minnesota, respectively.

TRITICALE PRODUCTION

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

ABSTRACT: Winter and spring Triticale varieties are evaluated under irrigation at the Staples Irrigation Center. Winter varieties unprotected with snow cover do not have the hardiness of rye and as a result, disappointing yields result. Spring triticale varieties are far more promising although yields were not as high as expected.

Table 1. Spring Triticale Trials at the Staples Irrigation Center.

Variety	Straw Yield Tons/A	Grain Yield bu/A	Test Weight lbs/bu
Wapati	2.67	43.4	56.0
Florico	2.53	40.8	57.0
Companion	2.63	39.6	53.9
Plains	2.63	46.5	54.3
Norico	2.66	45.0	58.7
Norita	2.31	39.2	54.1

Table 2. Winter Triticale Trials at the Staples Irrigation Center.

Variety	Straw Yield Tons/A	Grain Yield bu/A	Test Weight lbs/bu
Winteri	1.37	9.2	44.8
81 DED 1015	1.30	11.1	50.3
81 DED 1012	1.45	7.5	49.4
Ind 5-3-3	1.48	11.2	47.9
Ind 3-2-2	1.28	11.0	45.6

[1] Regional Director, TVA; Research Plot Supervisor, Staples Irrigation Center; Assistant Scientist, University of Minnesota, respectively.

WATER QUALITY STUDIES

H. Meredith and Mel Wiens[1/]

ABSTRACT: Each year a limited quantity of water samples are collected and analyzed. The purpose of this study is to monitor, on a limited basis, the quality of water applied to agricultural crops in central Minnesota. The data are represented in the tables follows, 1990.

Table 1. Analysis of Irrigation Well Water in the Perham, MN Area.

	Parts Per Million (PPM)									
Sample #	N	Ca	Mg	Na	P	K	S	Fe	Mn	Zn
1	4.1	81.5	20.3	4.2	.17	3.2	8.2	.79	.14	.27
2	T	33.6	28.4	11.8	.10	2.3	.08	.20	.01	.01
3	0.5	46.7	17.5	2.6	.11	1.2	5.5	.11	.16	T*
4	T	41.6	21.3	2.2	.07	1.5	1.6	.17	.08	T
5	0.7	39.3	20.0	2.2	.07	1.4	1.6	.02	.28	.01
6	13.2	116.2	27.9	2.5	.09	2.4	20.0	.20	.24	.13
7	3.7	64.9	21.0	3.5	.08	1.4	5.9	.02	.28	.02
8	3.5	31.9	18.4	5.1	.07	2.3	5.0	.06	.08	T
9	1.0	73.2	19.4	3.1	.18	1.1	3.5	3.4	.18	T

* T = trace

The following elements were present in concentrations below measurement: aluminum, boron, copper, cadmium, chromium, nickel and lead.

Table 2. Analyses of Irrigation Well Water from Wells in the Perham, MN Area, 1990.

	Pounds of Nutrients Per Acre-Inch Water							
Sample #	N	Ca	Mg	K	S	Calcium Equivalent	$CaCO_3$ Equivalent (Lime)	Lbs N Required to Neutralize Lime in IW Water
1	.90	17.9	4.5	.70	1.8	25.5	63	17.8
2	T	7.4	6.2	.51	.02	17.9	44	12.5
3	.11	10.3	3.8	.26	1.2	16.8	42	11.8
4	T	9.2	4.7	.33	0.4	17.2	44	13.4
5	.15	8.6	4.4	.31	0.4	16.1	40	11.3
6	2.9	25.6	6.1	.53	4.4	36.0	90	25.2
7	.81	14.3	4.6	.31	1.3	22.1	55	15.5
8	.77	7.0	4.0	.51	1.1	13.8	34	9.6
9	.22	16.1	4.3	.24	0.8	23.4	58	16.4

[1/] Regional Director, TVA; Research Plot Supervisor, Staples Irrigation Center, respectively.

Table 3. Analyses of Irrigation Water at the Staples Station, 1990.

	Parts Per Million (PPM)										
Location	N	Ca	Mg	Na	P	K	S	Fe	Mn	Zn	Sample Date
SW Pit	T	30.3	9.1	1.2	.07	4.8	2.0	.42	.18	.02	7/18
NW Pit	21.7	58.2	24.2	1.1	T	4.8	6.5	.04	.07	T	7/18
SE Pit	0.8	34.6	12.3	2.8	T	1.1	2.5	.13	.11	.02	7/10
Center Pivot	5.4	32.3	20.1	1.6	T	1.0	3.7	.03	.03	.02	6/29
Plot Well C	13.7	40.5	22.2	7.1	T	1.2	2.1	.27	.15	T	6/29
Plot Well A	14.4	59.5	23.6	2.0	.04	1.0	3.3	.23	.36	.01	7/2
Plot Well D	9.1	38.8	20.4	2.6	.05	1.1	2.7	.42	.12	T	6/29
Plot Well B	3.5	50.9	26.5	2.1	.05	1.3	1.8	.65	.21	T	7/3
Plot Well B	4.2	48.1	23.0	2.6	T	1.2	1.8	.28	.19	.03	7/18
Plot Well C	8.1	36.6	20.8	2.0	T	1.2	2.1	.23	.10	T	7/18
NW Pit	20.3	25.8	22.7	2.7	T	1.0	6.7	.04	.02	.02	7/3
SW Pit	T	26.5	9.2	1.3	.04	6.8	2.2	.35	.04	T	7/3
Energy Well	1.0	13.9	19.9	9.7	T	2.1	7.7	.06	.04	T	7/3

Table 4. Analyses of Irrigation Well Water from the Staples Station, 1990.

	Pounds of Nutrients Per Acre-Inch Water							
Location	N	Ca	Mg	K	S	Calcium Equivalent	$CaCO_3$ Equivalent (Lime)	Lbs N Required to Neutralize $CaCO_3$ eq.
SW Pit	T	6.7	2.0	1.1	.4	10.1	25.2	7.0
NW Pit	4.8	12.8	5.3	1.1	1.4	21.8	54.5	15.3
SE Pit	.2	7.6	2.7	.2	.6	12.1	30.2	8.4
Center Pivot	1.2	7.1	4.4	1.0	1.5	14.6	36.5	10.2
Farm Well	T	6.6	4.1	.3	1.1	13.6	34.0	9.5
Center Pivot	1.5	4.2	3.7	.2	.8	10.5	26.2	7.3
Plot Well C	3.0	8.9	4.9	.3	.5	17.2	43.0	12.0
Plot Well A	3.2	13.1	5.2	.2	.7	21.9	54.8	15.3
Plot Well D	2.0	8.5	4.5	.2	.6	14.1	35.2	9.8
Plot Well B	.8	11.2	5.8	.2	.4	21.1	52.8	14.8
Plot Well B	.9	10.6	5.1	.2	.4	19.3	48.2	13.5
Plot Well C	1.8	8.0	4.6	.2	.5	15.8	39.5	11.1
NW Pit	4.5	5.7	5.0	.2	1.5	14.2	35.5	9.9
SW Pit	T	5.8	2.0	1.5	.5	8.2	20.5	5.7
Energy Well	.2	3.0	4.4	.5	1.7	10.5	26.2	7.3

Table 5. Analyses of Irrigation Water at the Staples Station, 1990.

Location	Parts Per Million (PPM)										Sample
	N	Ca	Mg	Na	P	K	S	Fe	Mn	Zn	Date
Center Pivot	8.9	53.8	23.6	4.0	T	.91	10.4	.05	.04	.02	8/29
Farm Well	T	26.7	22.9	6.0	T	.91	3.2	.09	.07	.02	7/25
Two Towers	8.7	78.7	16.7	2.5	.06	1.2	8.8	.32	.34	.01	8/29
SE Pit	T	40.3	22.3	1.7	.05	2.5	3.6	.27	.31	.01	7/25
Energy Well	2.7	47.2	21.8	6.7	.06	2.8	10.5	.32	.20	.01	7/25
Center Pivot	3.0	43.7	19.3	5.1	.04	1.2	8.7	.07	.03	.02	7/25
Plot Well D	4.5	38.7	22.7	1.9	.06	1.1	2.8	.94	.14	T	6/29
NW Pit	52.7*	76.7	20.2	2.4	.05	.93	6.4	.15	.23	T	8/9
Plot Well C	3.6	75.1	20.0	2.0	.12	.97	2.8	2.2	.34	.05	7/25
Farm Well	T	47.2	21.3	3.9	.06	.95	3.5	.21	.14	.01	8/9
SW Pit	T	69.4	24.8	2.4	.06	4.7	7.5	.31	.38	.03	8/10
Center Pivot	7.8	68.2	8.9	5.0	.05	1.2	10.4	.16	.13	.01	8/9
Well drilling Well	T	34.5	19.9	12.0	.14	1.0	.19	.69	.01	.01	8/10
Plot Well D	T	81.0	19.8	2.0	.09	1.1	3.4	1.4	.36	T	8/9
Plot Well D	4.4	67.1	19.8	2.0	.08	1.2	3.3	1.3	.29	.01	8/9
SE Pit	2.4	77.1	22.0	2.4	.06	4.0	7.6	.62	.37	.03	8/9
Energy Well	1.6	73.0	22.8	2.4	.06	3.1	11.3	.43	.39	.01	8/10
SW Pit	T	53.6	12.2	6.5	.31	2.8	8.4	.40	.50	T	8/10
NW Pit	5.4	82.6	23.9	1.6	.30	1.3	6.7	.10	.25	.02	7/25
NW Pit	3.9	76.3	25.2	2.6	.07	1.1	6.7	.13	.43	T	8/2
Plot Well B	1.9	80.4	22.0	2.1	.11	1.0	2.3	2.9	.43	.01	7/25
Energy Well	6.1	74.6	22.8	6.6	.07	3.1	11.4	.43	.40	.03	8/2
Energy Well	28.6	55.5	21.1	6.0	.07	2.9	10.2	.41	.28	.02	8/9
SE Pit	1.7	77.0	14.8	1.6	.10	1.7	3.9	.57	.54	.01	8/2
SW Pit	T	37.0	11.8	1.8	.17	4.9	7.2	1.6	.37	.04	8/2

* This value needs to be compared with the two other samples from the same pit.

Table 6. Analyses of Irrigation Water from the Staples Station, 1990.

	Pounds of Nutrients Per Acre-Inch Water						
Location	N	Ca	Mg	S	Calcium Equivalent	$CaCO_3$ Equivalent (Lime)	Lbs N Required to Neutralize $CaCO_3$ eq.
Center Pivot	2.0	11.8	5.2	2.3	20.6	52	15
Farm Well	T	5.9	5.0	.7	14.4	36	10
Two Towers	1.9	17.3	3.7	1.9	23.6	59	16
SE Pit	T	8.9	4.9	.8	17.2	43	12
Energy Well	.6	10.4	4.8	2.3	16.6	42	12
Center Pivot	.7	9.6	4.2	1.9	16.7	42	12
Plot Well D	1.0	8.5	5.0	.6	17.0	42	12
NW Pit	11.6*	16.9	4.4	1.4	24.4	61	17
Plot Well C	.8	16.5	4.4		24.0	61	17
Farm Well	T	16.5	4.4	.6	24.0	61	17
SW Pit	T	10.4	4.7	.8	18.4	46	13
Center Pivot	1.7	15.3	5.4	1.6	24.5	61	17
Well Drilling Well	T	15.0	2.0	2.3	18.4	46	13
Plot Well D	T	7.6	4.4	T	15.1	38	11
Plot Well D	1.0	17.8	4.4	.7	25.3	63	17
SE Pit	.5	14.8	4.4	.7	22.3	56	16
Energy Well	.4	16.1	4.8	1.7	24.3	61	17
SW Pit	T	11.8	4.8	2.5	20.0	50	14
NW Pit	1.2	18.2	2.7	1.8	22.8	57	16
NW Pit	.8	16.8	5.2	1.5	25.6	64	18
Plot Well B	.4	17.7	5.5	.5	17.1	43	12
Energy Well	1.3	16.4	4.8	2.5	24.6	62	17
Energy Well	6.3	12.2	5.0	2.2	20.7	52	15
SE Pit	.4	16.9	4.6	.8	24.7	62	18
SW Pit	T	8.1	2.6	1.6	12.5	31	9

* This value needs to be compared with the two other samples from the same pit.

Irrigation water quality is increasingly becoming of greater concern. The nutrients contained in irrigation water have economic implications to the user. Additionally, routine sampling permits monitoring of selected elements dissolved in irrigation water.

The nutrients of greatest value to the grower are the calcium, magnesium and sulfur contained in irrigation water. Tables 2, 4, and 6 indicate the pounds of the dominate nutrients contained in irrigation water expressed in pounds per acre inch. Calcium carbonate equivalent (lime) is the calcium plus magnesium expressed as calcium carbonate. The column pounds of nitrogen required to neutralize the pounds calcium carbonate equivalent delivered in irrigation water is on a per acre inch basis. If a nitrogen fertilized crop is included in the rotation, this figure is a guide as to the potential neutralization of the lime equivalent contained in irrigation water.

SOUTHERN EXPERIMENT STATION

WASECA, MINNESOTA

WEATHER DATA - 1990

Month	Period	Precipitation 1990	Precipitation Normal[1]	Avg. Air Temp. 1990	Avg. Air Temp. Normal[1]	Growing Degree Days 1990	Growing Degree Days Normal[1]
		- - - inches - - -		- - - - ° F - - - -			
January	1-31	0.26	0.84	25.9	10.0		
February	1-28	1.03	0.99	22.6	16.4		
March	1-31	4.02	1.99	35.5	27.6		
April	1-30	2.80	2.64	45.9	44.7		
May	1-10	1.88		53.8		87.5	
	11-20	2.54		52.1		58.0	
	21-31	.89		60.1		119.0	
	Total	5.31	3.76	55.4	57.7	264.5	334
June	1-10	1.37		62.2		133.5	
	11-20	4.32		73.3		231.0	
	21-30	.99		72.9		220.5	
	Total	6.68	4.48	69.5	67.1	585.0	518
July	1-10	2.23		74.5		235.0	
	11-20	2.21		69.2		190.5	
	21-31	1.70		69.8		218.0	
	Total	6.14	4.02	71.1	71.2	643.5	641
August	1-10	0.91		66.9		170.0	
	11-20	4.60		71.1		209.0	
	21-31	0.94		72.6		246.0	
	Total	6.45	3.99	70.3	68.8	625.0	579
September	1-30	1.50	3.36	64.6	59.8	476.5	311
October	1-31	1.36	2.08	47.7	48.9		38
November	1-30	0.53	1.43	37.5	32.5		
December	1-31	1.63	1.02	15.1	18.0		
Year	Jan-Dec	37.71	30.60	46.9	43.6	2594.5[2]	2421
Growing Season	May-Sep	26.08	19.61	66.2	64.9	2594.5	2383

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

Notes:
1) Highest temperature on July 4 - - - 102 °.
2) Only 8 days of ≥90 ° F.
3) Highest 24-hour precipitation on August 20 - - - 4.02".
4) Last spring frost - - - May 2.
5) First fall frost - - - October 1.

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

Waseca, 1990

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 1990 was 7.1" above normal and tile flow was plentiful. The slightly higher tile drainage with NT was offset by slightly higher NO_3-N concentrations with the MP system. Nitrate-N losses were not different between the two tillage systems. Corn yields, N uptake, and N removal in the grain were all significantly higher for MP compared to NT. Grain yield was 29% less with 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' x 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 1989. The stalks were chopped in October, 1989 and moldboard plots plowed.

On May 20, 180 lb N/A as ammonium nitrate was broadcast applied to the surface of all plots. The moldboard treatment was then field cultivated. Corn (Dekalb 547) was planted on May 8 at a population of 27700 plants/A with a John Deere Max-Emerge planter equipped with ripple coulters. Starter fertilizer was not used because of the high soil tests. Counter was applied at 1 lb (ai)/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3-1/2 lb/A) and Bladex (3 lb/A) applied May 11. Weed and insect control were excellent. Percent surface residue was measured on April 2 and averaged 7 and 98% 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 30 and NT = August 7) and was analyzed for N. Silage yields were taken at physiological maturity by hand harvesting 40' of row from each plot.

Grain yields were taken by combine from 2 - 45' rows. Tile lines flowed from March 27 to September 8. 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 26, 1990.

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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 fifth year of nine where MP yields were significantly higher. Neither leaf N nor grain N concentration was affected by tillage, however.

Precipitation during the growing season was 6.5" above normal. Consequently, tile flow was substantially higher than in previous years and averaged about 8% higher with NT compared to MP tillage (Table 2). Flow-weighted NO_3-N concentration for the season averaged 10% higher with MP tillage. Thus, NO_3-N losses via the drainage water were not different for the two tillage systems. On an annual basis these NO_3-N losses were the equivalent of 55% of the fertilizer N added. This figure is erroneous, however, because much of the NO_3 lost, especially early in the season, would have come from the residual NO_3 remaining in the soil after the 1989 crop. Much of that residual NO_3 was probably due to carryover of unused fertilizer N in the drier years and soil mineralization especially with MP tillage.

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1990.

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	25.8	2.75	8.61	143.6	146.7	1.45	100.8
No Tillage	25.9	2.62	6.66	92.8	104.8	1.28	63.5
Signif. Level (%):[1]	5	83	99	99	99	82	96
CV (%) :	4.5	3.0	2.5	1.4	4.8	7.5	11.

[1] Probability level of significance.

Table 2. Influence of tillage system on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1990.

Month	Tile Flow	NO_3-N Concentration[1]	NO_3-N Loss
	acre-in	ppm	lb/A
	Moldboard plow		
March	0.01	10.0	0.01
April	0.02	17.4	0.10
May	5.94	28.8	35.71
June	6.70	21.4	30.95
July	2.45	25.3	9.04
August	3.86	30.2	22.35
September	0.17	25.8	1.58
Total	19.14	23.0	99.74
	No tillage		
March	0.06	10.7	0.13
April	0.37	13.0	1.03
May	5.74	20.3	25.65
June	7.83	21.2	36.21
July	2.83	25.6	15.60
August	3.59	22.1	17.50
September	0.24	18.3	1.33
Total	20.66	20.9	97.45

Residual NO_3-N in the soil profile at the end of the 1990 growing season showed about 100 lb/A more N remaining with the MP system (Table 3). The largest differences between the two tillage systems occurred in the 2 to 5' zone where substantially more NO_3 accumulated with MP. These results are similar to previous years except that the greatest difference between the two systems usually occurred in the top 1 to 2 feet.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in Oct., 1990.

Profile depth	Tillage System	
	Mb. Plow	No Tillage
feet	- - - - NO_3-N (lb/A) - - - -	
0-1	18.3	13.5
1-2	8.1	6.1
2-3	34.1	8.4
3-4	46.5	23.9
4-5	42.9	29.2
5-6	30.7	21.2
6-7	22.7	16.4
7-8	21.2	15.7
Total (lb NO_3-N/A 0-8')	224.5	134.4

NINE-YEAR SUMMARY

The cumulative totals for the 9-year period (1982-1990) are shown in Table 4. Corn yields over this period have averaged 14.5 bu/A better with moldboard plow tillage. Approximately 16% 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. As a result an equivalent of 51 and 44% of the applied N has been removed in the grain by the MP and NT systems, respectively. Even though total water flow and NO_3-N lost through the tile lines was 9% and 5% higher, respectively, with NT compared to MP tillage, this small difference is considered to be insignificant when considering tile flow variability among the eight plots. The equivalent of 15 to 16% of the fertilizer N applied to these plots has been lost to tile drainage over this 9-year period.

Table 4. Cumulative effects of the two tillage systems over the 9-year period.

Parameter	Tillage System	
	Mb. plow	No tillage
Fert. N applied (lb/A)	1620	1620
Corn grain removed (bu/A)	1232	1102
N removed in grain (lb/A)	825	708
N removed in grain as a percent of applied N (%)	51	44
Tile flow (acre inches)	80.4	87.5
Nitrate-N lost in tile (lb/A)	248.8	260.0
N lost via tile lines as a percent of applied N (%)	15	16

Soil samples were taken in 3- and 6-inch increments to 24" in early November, 1990 and analyzed for total Kjeldahl N. Results shown in Table 5 indicate higher N levels in the top 6 inches with NT, slightly higher N levels in the 6 to 18" layer with MP, and no difference between the tillage systems within the 18 to 24-inch depth. Assuming a bulk density of 1.2 g/cc in the 0-6" depth, 1.25 g/cc in the 6-12" depth, and 1.35 g/cc in the 12-18" depth, we found 178 pounds more soil N in the NT system than in the MP system. This amount accounts for most of the difference shown between the two tillage systems in Table 4.

Table 5. Total N in the 0-24" soil layer as affected by tillage systems.

Depth	Tillage	
	MP	NT
inches	- - - - - - % - - - - - -	
0-3	.242	.288
3-6	.248	.258
6-12	.222	.212
12-18	.148	.142
18-24	.082	.082

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

Waseca, 1990

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

ABSTRACT: A study to determine the influence of time of N application and N-Serve on the uptake of N by corn and the loss of NO_3 to tile drainage was continued in 1990. Results from this fourth year showed significant yield improvement over the control with all N treatments, but no significant differences among the four primary application time/method treatments. Tile lines flowed from late April through late August. Tile flow averaged 11.45" for corn and 14.73" for soybeans. Nitrate-N concentrations and losses were higher for corn than for soybeans. Highest NO_3-N losses in the corn plots occurred with the fall application of N without N-Serve while the highest losses under soybeans occurred with spring application to the previous corn crop. Nitrate-N concentrations and losses from continuous fallow plots that had received neither fertilizer N nor a planted crop for four years were twice that from the fertilized corn. This was due to high levels of NO_3 throughout the 8-foot profile as a result of soil mineralization and no crop uptake.

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

EXPERIMENTAL PROCEDURES

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

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

Anhydrous ammonia was applied at a rate of 135 lb/A for all N treatments while N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 25. Average soil temperature at the 4" depth on that date was 60°F with an average of 49°F over the following 10-day period. Spring preplant treatments were applied on May 4. The sidedress portion (60%) of the split treatments was applied at the V-9 stage on July 2.

The soybean area that was planted to corn in 1990 was field cultivated once before planting. The corn area, however, was fall chiseled and field cultivated once prior to planting soybeans. Surface residue accumulation estimated by the line-transect method on April 2 showed an average of 40 and 69% for the areas that were planted to corn and soybeans, respectively, in 1989. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3737) was planted at 30,200 plants/acre on May 18 with a JD Max-Emerge planter equipped with waffle coulters. A corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A).

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

[2] Professor, So. Exp. Stn.; Professor, Dept. of Soil Science; Assistant Scientist, So. Exp. Stn., Waseca.

Soybeans (Hardin) were planted in 30" rows at 9 beans per foot of row on May 31. Weeds were chemically controlled with a preemergence application of Lasso (3-1/2 lb/A) plus Amiben (3 lb/A). Pursuit (imazethapyr) was applied on June 18 at 0.06 lb/A plus 0.25% v/v X-77 to plots 1, 5, 6, 11, 12, 13, 15, & 16.

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

Stand counts were taken at the V-5 stage and plots were thinned to a uniform population. Eight randomly selected plants were removed from the center rows at silk initiation (July 30) and were chopped, dried, weighed and ground for total dry matter accumulation and analyzed for total N concentration. Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yields and 60' of row for grain yields and moisture. Chemical analyses of whole plant, stover and grain samples were performed by the Research Analytical Laboratory, University of Minnesota. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Periodic samples were collected for alachlor (Lasso), cyanazine (Bladex), and imazethapyr (Pursuit) analyses.

Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from the fallow plots and selected corn and soybean plots on April 18. The same technique was used to sample all fallow and corn plots and selected soybean plots on October 26.

RESULTS AND DISCUSSION

Plant

Whole plant N concentration at the silking stage was not affected by any of the N treatments (Table 1). This is in contrast to 1989 probably because of very favorable conditions for mineralization that released adequate amounts of soil N to the control plots in 1990. Dry matter accumulation was unaffected by time/method of N treatment. Although stover N concentration of the control was lowest, the 135-lb N treatments did not result in significantly (P = 90% level) higher concentrations at physiological maturity (PM). Stover yield at PM was higher than the control for all N treatments with no difference among the four primary time/method treatments. Final population was not significantly different among the N treatments.

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

N application		Whole Plant Silk stage		Stover		Final
Time	N-Serve	N	DM	N	Yield	Population
		%	g/plt	%	TDM/A	ppA x 10^{-3}
Primary trts						
Fall (Oct.)	No	1.76	90	.50	2.36	28.8
Fall (Oct.)	Yes	1.74	103	.51	2.54	28.0
Spr. (April)	No	1.78	86	.48	2.44	28.2
Split[1]	No	1.75	99	.52	2.49	28.0
Additional trts						
Check	-	1.64	79	.44	1.83	28.6
Spr. (April)	Yes	1.69	104	.56	2.55	28.3
Split[1]	Yes	1.82	94	.56	2.47	28.7
		Statistical Analysis				
Latin square (Primary Trts)						
Signif. Level (%):		6	45	12	15	36
CV (%) :		6.4	19.	12.	13.	3.1
Completely randomized (7 trts)						
Signif. Level (%):		17	74	83	96	17
BLSD (.05) :		-	-	-	.52	-
CV (%) :		10.	16.	13.	13.	3.3

[1] 40% preplant + 60% sidedress.

Grain and silage yields were increased significantly over the check (0 lb N/A) by all of the N treatments (Table 2). The 9.0 bu/A difference among the four primary time/method treatments was not significant at the P = 90% level. Grain moisture at harvest was significantly higher (P = 94% level) for the check compared to the N treatments with no difference among the four primary time/method treatments. Grain N concentration and N removal in the grain were increased over the 0-lb N check by all of the N treatments but was not different among the four primary treatments. Total N uptake was increased almost two-fold over the 0-lb N check by all of the N treatments. Although not statistically significant (P = 90% level), a consistent trend of lower N efficiency was noted with the fall N application without N-Serve.

Total N removal in the grain ranged from 92.1 to 101.8 lb/A for the six N treatments (Table 2). Based on these removal amounts, N efficiency (N removed by a treatment - N removed in the check ÷ 135 lb N/A) ranged from 31 to 38% for the six N treatments. Nitrogen efficiency based on total plant uptake ranged from 36 to 48% for the six N treatments. These efficiency values are slightly less than in 1989.

Total N uptake by the plants receiving fertilizer N prior to silking (Fodder N yield at silking) divided by total N uptake at PM shows that from 75 to 86% of the N was accumulated by the plants prior to silking (Table 3). NEW N in the grain (assumed to be taken up by the plant after silking and translocated to the grain) ranged from -31% in the check treatment to between 14 and 25% for all treatments receiving fertilizer N. Under the 1990 conditions there was no affect of time/method of N application on post-silk (NEW N) N uptake into the grain.

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

N application		Grain					Total N
Time	N-Serve	Yield	H_2O	N	N removal	Silage	uptake
		bu/A	%	%	lb/A	TDM/A	lb/A
Primary trts							
Fall (Oct.)	No	146.1	29.2	1.33	92.1	6.33	115.7
Fall (Oct.)	Yes	146.0	29.6	1.44	99.0	6.51	124.9
Spr. (April)	No	142.2	26.6	1.44	96.5	6.31	120.0
Split[1]	No	151.2	28.2	1.42	101.3	6.59	127.1
Additional trts							
Check	-	107.5	32.4	.98	50.3	4.76	66.4
Spr. (April)	Yes	158.0	27.8	1.36	101.8	6.84	130.9
Split[1]	Yes	147.5	27.7	1.40	97.9	6.47	125.3
Statistical Analysis							
Latin square (Primary trts)							
Signif. Level (%)	:	52	56	80	88	21	71
CV (%)	:	5.2	9.4	5.0	4.8	7.2	6.6
Completely randomized (7 trts)							
Signif. Level (%)	:	99	94	99	99	99	99
BLSD (.05)	:	13.3	-	.12	10.6	.75	15.8
CV (%)	:	6.7	8.3	6.6	8.5	8.2	9.9

[1] 40% preplant + 60% sidedress

Water

Weather conditions during the 1990 growing season were slightly warmer than normal but were 6.5" wetter than normal. Rainfall during May through August totaled 8.33" above normal. This resulted in tile flow from April 27 through August 30. Tile drainage volumes shown in Table 4 indicate highest flows in May and June. Drainage from the 16 corn plots averaged 11.45 with a 4.03" range among the four time/method treatments. Soybeans showed greater tile drainage compared to corn with an average of 14.73" from the 16 plots but only a range of 1.71" among the four time/methods. Ideally, drainage should be uniform among the time/method treatments because crop growth was not different; however, normal soil and drainage variability exists in these plots and results in these unfortunate differences.

Monthly flow-weighted NO_3-N concentrations were markedly higher for corn compared to soybeans throughout the year (Table 5).

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

N application		Fodder N Yield at[1]			Grain N Yield at PM		
Time	N-Serve	Silk	PM	Total	OLD[2]	NEW[3]	NEW[3]
		---------- lb N/A					%
Primary trts							
Fall (Oct)	No	99.5	23.6	92.1	75.9	16.2	18
Fall (Oct)	Yes	110.9	25.8	99.0	85.0	14.0	14
Spr (April)	No	95.2	23.5	96.5	71.8	24.7	25
Split[4]	No	107.0	25.8	101.3	81.2	20.1	20
Additional trts							
Check	-	82.8	16.1	50.3	66.7	-16.4	-31
Spr (April)	Yes	110.5	29.0	101.8	81.5	20.3	19
Split[4]	Yes	109.4	27.4	97.9	82.0	15.9	17
Statistical Analysis							
Latin square (Primary trts)							
Signif. Level (%):		27	22	88	19	11	12
CV (%)	:	21.	18.	4.8	26.	112.	109.
Completely randomized (7 trts)							
Signif. Level (%):		44	97	99	11	85	98
BLSD (.05)	:	-	8.3	10.6	-	-	35
CV (%)	:	22.	20.	8.5	28.	151.	182.

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

Fall application of N without N-Serve to corn resulted in consistently higher NO_3-N concentrations compared to the inclusion of N-Serve. However, both fall treatments gave higher NO_3-N concentrations than the spring or split treatments. An opposite trend occurred under soybeans where N had been applied in either October, 1988 or spring 1989 for the 1989 corn crop. In this case, lowest and highest NO_3-N concentrations were associated with the fall and spring treatments, respectively. Nitrate-N concentrations under a 4-yr continuous fallow system (no fertilizer N applied) were approximately 2X and 3X higher than for corn and soybeans, respectively.

Under corn, substantially higher NO_3-N losses occurred with the fall treatment without N-Serve (Table 6). This was due to both higher tile flow and NO_3-N concentration. Little difference was observed among the NO_3-N losses from the fall + N-Serve, spring, and split treatments. Interestingly, NO_3-N losses under soybeans were lowest for the fall N treatments that were applied for the 1989 corn crop compared to the spring-applied treatments. Very high NO_3-N losses occurred under the fallow system where the mineralization of the soil organic matter was the nitrate source. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1990.

N application		Month					Year
Time	N-Serve	April	May	June	July	August	Total
		acre-inches					
		CORN					
Fall (Oct.)	No	0.00	4.61	5.66	0.73	2.93	13.93
Fall (Oct.)	Yes	0.03	3.51	3.71	0.58	2.47	10.30
Spr. (April)	No	0.00	3.48	3.48	0.60	2.34	9.90
Split	No	0.08	3.90	4.68	0.85	2.16	11.67
		SOYBEANS					
Fall (Oct.)[1]	No	0.05	5.44	5.78	1.37	2.45	15.09
Fall (Oct.)[1]	Yes	0.00	4.72	6.15	1.23	2.27	14.37
Spr. (April)[1]	No	0.01	4.33	6.18	1.26	2.10	13.88
Split[1]	No	0.00	4.92	6.22	1.62	2.83	15.59
		FALLOW					
NONE		0.05	4.26	4.34	1.23	1.81	11.69

[1] N applied for the 1989 corn crop.

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1990.

N application		Month					Year
Time	N-Serve	April	May	June	July	August	Total
		mg NO_3-N/L					
		CORN					
Fall (Oct.)	No	-	36.3	38.4	40.6	25.0	34.7
Fall (Oct.)	Yes	38.3	29.9	33.8	37.5	18.8	29.5
Spr. (April)	No	-	28.7	29.6	32.1	19.8	26.9
Split	No	25.0	28.0	29.0	28.1	23.2	27.8
		SOYBEANS					
Fall (Oct.)[1]	No	21.9	15.4	17.1	19.2	12.3	15.1
Fall (Oct.)[1]	Yes	-	17.6	19.5	29.4	13.1	19.0
Spr. (April)[1]	No	16.2	21.3	23.4	28.3	15.3	22.3
Split[1]	No	-	18.8	21.3	21.7	14.2	18.4
		FALLOW					
NONE		42.8	69.8	62.6	57.6	47.4	56.6

[1] N applied for the 1989 corn crop.

Table 6. Nitrate-N loss for each month from the corn, soybean and fallow plots in 1990.

N application		Month					Year
Time	N-Serve	April	May	June	July	August	Total
		lb NO_3-N/A					
		CORN					
Fall (Oct.)	No	0.00	37.68	48.54	6.86	16.25	109.33
Fall (Oct.)	Yes	0.26	23.55	29.70	4.84	10.41	68.76
Spr. (April)	No	0.00	23.40	22.12	4.29	10.53	60.34
Split	No	0.44	25.24	31.02	5.36	11.45	73.51
		SOYBEANS					
Fall (Oct.)[1]	No	0.30	18.58	21.29	5.12	6.40	51.69
Fall (Oct.)[1]	Yes	0.00	18.65	28.05	7.90	7.08	61.68
Spr. (April)[1]	No	0.03	21.66	32.97	7.68	7.78	70.12
Split[1]	No	0.00	20.50	28.91	6.87	8.76	65.04
		FALLOW					
NONE		0.50	61.94	54.66	14.74	18.12	149.96

[1] N applied for the 1989 corn crop.

Nitrate-N losses to the tile drainage water were normalized to tile water flow to minimize the influence of water flow volume among the N treatments on the interpretation of the data (Table 7). Normalized values show highest losses for fall-applied N without N-Serve to corn. Spring applications showed slightly less loss than fall N + N-Serve. On the other hand, fall applications without N-Serve to corn in the year ahead of the soybeans resulted in lower NO_3-N losses compared to the spring and fall with N-Serve applications. Nitrate-N losses for the corn-soybean system were highest for the fall application without N-Serve and lowest for the split application. Additional years with adequate drainage losses are necessary to determine if these findings are consistent over time.

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1990.

Crop[1] System	Time/Method of N Application: Fall, No N-Serve	Fall, N-Serve	Spring, No N-Serve	Split, No N-Serve
	NO_3-N Lost (lb/A/inch of drainage)			
Corn	7.85	6.67	6.09	6.35
Soybean	3.41	4.29	5.06	4.17
C-Sb System	5.54	5.28	5.49	5.10

[1] Continuous fallow (4 years without fertilizer N) = 12.8

Soil

Nitrate-N remaining in the 0-8' soil profile in mid-April was very high in the fallow plots (429 lb/A) compared to those where either soybeans or corn were grown in 1989 (Table 8). Soybeans that had not received fall-applied N averaged 98 lb/A with 69 lb/A remaining in the top 5'. Very low amounts of residual NO_3-N remained in the 0-8' profile when corn receiving no N fertilizer was the previous crop (54 lb/A). Residual NO_3-N remaining from the 1989 crop was increased by 30 to 60 lb/A with the previous fall, spring preplant, and split applications. Distribution of NO_3 within the profile was consistently very high to 8' with the fallow system compared to high levels only in the top one foot following soybeans and unfertilized corn. Corn receiving N showed increased levels of NO_3 down to the 4' depth.

Table 8. Nitrate-N in the soil profile in April, 1990 as influenced by previous crop and N treatment for corn in 1989.

Profile depth	1989 Crop					
			Corn[1]			
	Fallow	Soybean	0 lb N	Fall	Preplant	Split
	lb/A[2]					
0-1	77.1	25.8	20.5	22.3	25.4	25.6
1-2	74.2	9.5	5.4	16.3	23.6	12.3
2-3	67.2	12.6	4.7	10.4	15.6	12.3
3-4	59.8	10.6	4.7	9.3	13.8	13.5
4-5	55.8	10.3	4.0	7.3	13.5	8.4
5-6	39.0	11.2	4.8	6.8	8.7	7.3
6-7	31.4	10.3	5.0	6.3	7.2	6.9
7-8	24.2	8.0	5.1	7.7	6.0	5.6
Total in						
0-5′ profile	334.1	68.8	39.3	65.8	91.9	72.1
0-8′ profile	428.7	98.3	54.2	86.6	113.8	91.9

[1] These fall, spring preplant and split treatments all received N-Serve.
[2] Average of 4 replications

A comparison of the residual NO_3 amounts found in April, 1990 (Table 8) with those amounts found in the same plots in October, 1989, shows the spring NO_3 levels to be approximately the same as in the previous fall for the plots that did not receive fertilizer N (fallow and 0-lb rate). Results from the plots that received N were mixed with the fall and spring preplant applications showing 41 and 22% less soil NO_3 (0-8′), respectively, while 27% more was found in the spring with the split treatment.

Residual NO_3-N remaining in the 0 to 5′ profile after the 1990 season shows approximately the same amount of nitrate as after the 1989 season except in the fallow treatment (Table 9). Approximately 25% less nitrate remained in the fallow plots compared to 1989. However, more nitrate was found in the 5 to 8′ zone for all treatments in 1990. Higher amounts of nitrate were found consistently in the top 5′ with the N-Serve treatments. The reason for these differences is not clear but may be highly related to the excessive amount of precipitation in 1990. Differences among the time of N application were not shown. A comparison between the amount of NO_3-N in the 0 to 5′ profile of the fallow plots this fall with that in the spring (Table 8) shows 69 lb less NO_3N in the fall. Nitrate-N losses through the tile totaled 150 lb/A (Table 6). Thus at least 80 lb of NO_3-N was added to the 0 to 5′ system due to soil mineralization during the growing season.

Table 9. Residual NO-N remaining in the 0-8′ soil profile after harvest as influenced by time of N application and N-Serve.

Profile depth	Fallow	Check	Application Time					
			N-Serve			No N-Serve		
			Fall	Preplant	Split	Fall	Preplant	Split
	lbs NO_3-N/A[1]							
0-1	62.8	27.3	29.7	39.2	38.0	31.2	28.8	33.2
1-2	30.3	5.7	7.3	6.8	9.3	9.8	5.1	11.3
2-3	47.3	3.9	4.7	6.9	9.2	2.6	3.9	9.6
3-4	69.0	4.3	20.2	16.1	17.2	11.4	9.8	10.6
4-5	55.4	6.0	26.7	20.2	19.6	18.4	14.6	11.6
5-6	46.5	7.5	18.2	16.1	17.1	32.5	16.4	33.3
6-7	36.1	7.3	13.7	12.1	13.0	18.3	11.8	14.0
7-8	29.8	6.0	13.1	12.3	10.0	16.4	11.5	10.4
Total in								
0-5′ profile	265	47	89	89	93	73	62	76
0-8′ profile	377	68	134	130	133	141	102	134

[1] Avg. of 4 replications

CONCLUSIONS

The warm and wet conditions resulted in good corn production and excellent tile drainage. Corn production was greatly improved by the various N treatments over the control. However, differences among the time/methods of N application were not generally significant. Tile flow was higher for soybeans while NO_3-N concentrations and NO_3-N losses were higher for corn compared to soybeans. Fall application of N without N-Serve to corn showed highest NO_3 losses while losses in the "residual year" when soybeans were grown were highest for the spring application. Continuous fallowing (no N for four years) resulted in NO_3-N losses 2X to 3X as high as when either corn or soybeans were grown. These data indicate the importance of growing a crop to utilize the N mineralized from these high organic matter soils.

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
G. Randall, J. Anderson, G. Malzer, B. Anderson,
D. Buhler, D. Wyse and J. Nieber

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. Corn yields were not improved with split or sidedress N applications. No tillage resulted in lower yields at two sites and lower nitrate-N concentrations in the soil water at all three sites. Yields from the residual manure treatments (manure applied in 1987 and 1988) were significantly lower than the fertilized plots due to plant use of N in 1989 and leaching of nitrate out of the root zone in 1990. High rainfall amounts leached nitrate that had accumulated in the top five feet in the last 3 years to the 7.5' depth at two sites. When profitability was highest, NO_3-N concentrations in the lysimeter water at 5' averaged between 25 and 30 mg/L.

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 1990 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 four replications was established in the fall of 1986 and was continued in 1990. 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 13, 1989. Spring N fertilizer treatments were applied on May 2 and again on July 5, 1990. Liquid hog manure was not applied in 1989 or 1990. All plots except the no-till treatment were disked on May 3.

Corn (Pioneer 3751) was planted on May 24 at 30,200 plants/A. Lasso (3 lb/A) and Bladex (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 July 6.

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 yields were taken from 20' of row at physiological maturity (Oct. 10). Grain yields and moisture were determined by combine harvesting two rows, each 60' long on Oct. 19. All samples were weighed, dried, ground and analyzed for total N.

Soil samples were obtained from each plot on April 20 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).

[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 3, June 6, July 5, August 2, and September 5.

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 2 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 on July 6 with the ridge plots being ridged at that time.

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 1990. Sixteen N treatments all consisting of anhydrous ammonia applied to chiseled and no-till plots were established. Each of the 64 plots measures 30' wide and 65' long. Chisel plowing was done with a John Deere Mulch Tiller on November 14, 1989. Anhydrous ammonia was applied preplant on May 29. All chisel plots were disked on May 29.

Corn (Pioneer 3751) was planted at 30,200 plants/A on May 30. Prowl (1.5 lb/A) and Bladex (2.5 lb/A) was applied at 2 leaf stage (June 6). Force (8 oz/1000 ft) was applied 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 5-leaf stage (June 27) and 7 to 8-leaf stage (July 5).

Plant sampling procedures at silking and at PM were essentially the same as at the Olmsted Co. site. Soil sampling to the 8-foot depth on May 2 and November 14 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 8, June 8, July 5, Aug. 2, Aug. 31 and Nov. 1 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 manure 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 1990. Twelve N treatments were established for a total of 48 plots. Each plot measures 20' wide by 65' long.

Fall chiseling was conducted on November 13, 1989. The preplant anhydrous ammonia treatments were applied on May 7. A field cultivator was used as secondary tillage just prior to planting.

Corn (Pioneer 3751) was planted at 30,200 plants/A on May 24. 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 27) and the 8 to 9-leaf stage (July 5).

Whole plant and soil sampling procedures were identical to those used in Olmsted Co. Grain yields were taken by hand harvesting two rows each 40' long at physiological maturity (October 9). Stainless steel and PVC suction lysimeters were installed in 1987 at the 5' depth in six treatments (24 plots). PVC suction lysimeters were installed in 1988 at the 5' depth in three additional treatments and at the 7.5' depth in six treatments. These were sampled on May 7, June 6, July 5, Aug. 2, Sept. 5 and Nov. 15 to determine NO_3 and pesticide concentrations in the extracted soil water.

RESULTS AND DISCUSSION

Olmsted County

Corn grain yields in 1990 were increased significantly by the fertilizer N treatments (Table 1). The addition of 75 lb N/A increased yield by 69 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. Although the yields for the fall-applied treatments were not statistically lower (P=95% level) than the spring preplant 150-lb treatment, the 7 to 10 bu/A depression put the fall treatments at an economic disadvantage. Split application of N resulted in the same yield as the single preplant application. This was the first year in four where the no tillage plots yielded less than chisel tillage. Yields from the two manure treatments were significantly less than the fertilizer treatments because no manure had been applied since April, 1988. Under the high rainfall conditions in 1990, the corn suffered from N deficiency early in the season because the residual NO_3 from the manure had been leached below the top three feet. The corn recovered somewhat in August when the roots moved down into a higher zone of nitrate accumulation; hence yields that were 30 to 45 bu better than the control. Average 4-year yields showed greatest economic return to the 150-lb PP application with no advantage to higher rates, fall application, or split treatments.

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 15 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 1989, fall applications of N, regardless of the inclusion of N-Serve, showed much higher NO_3-N concentrations than the spring preplant applications. For the first time in four years no tillage had nitrate-N concentrations about 30% lower than the similar 150-lb rate applied to chisel tillage. Perhaps the no tillage system had reached an equilibrium and mineralization was reduced compared to annual chiseling. Due to no manure applied in 1989 or 1990 and the high precipitation in May-July, nitrate-N concentrations at the 5' depth were greatly reduced for the two manure treatments. However, leaching from the 5-foot depth caused the concentrations to escalate markedly at the 7.5-foot depth. It should be cautioned that these 5 and 7.5-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 potential environmental contribution and ranking of the treatments.

Table 1. Effect of N treatments on the 1990 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	1990	1987-90	5'	7.5'
		lb N/A		------- bu/A ------		---- mg/L ---	
1	Chisel	0	---	76.0	83.6	1	2
2	Chisel	75	Spr., preplant	144.8	155.5	11	8
3	Chisel	150	Spr., preplant	154.9	172.5	29	18
4	Chisel	225	Spr., preplant	156.4	167.1	43	42
5	Chisel	150	Fall, post tillage	145.0	169.4	43	-
6	Chisel	150+NI[1]	Fall, post tillage	147.6	169.1	50	-
7	Chisel	150-Split	50% Spr., preplant 50% SD, 8-leaf	154.2	168.4	47	-
8	No Tillage	150	Spr., preplant	139.6	168.0	20	-
9	Chisel	315[2]	Spr., disked in	108.0	165.9	15	23
10	Chisel	490[2]	Spr., disked in	122.0	168.4	25	49
Significance level (%):				99			
BLSD (.05) :				14.3			
CV (%) :				8.0			

[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 or 1990. Total N rates were 315 and 490 lb N/A/yr or approximately 175 and 265 lb "available" N/A/yr.
[3] September 5, 1990.

Corn yields in the pesticide study were quite variable and thus statistical differences among treatments were not found (Table 2). However, similar to the 4-year average, yields were highest with the moldboard and chisel treatments and lowest with no tillage.

Table 2. Effect of tillage treatments on the 1990 corn yields in Olmsted Co.

Tillage	Grain Yield 1990	1987-90 Avg.
	---------- bu/A ----------	
Moldboard plow	150.7	168.2
Chisel plow	147.2	164.4
Ridge till	140.6	155.7
No tillage	136.2	152.1
Significance level (%):	57	
BLSD (.05) :	-	
CV (%) :	9.0	

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 150-lb spring PP treatment. The highest yield, although not statistically speaking, was obtained with the split 100 + 50-lb treatment. Yields with no tillage were consistently less, and at some N rates were significantly less than with chisel tillage. 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.

Four-year average grain yields also show: (1) optimum N rate to be between 100 and 150 lb/A, (2) no improvement in yield with either split or sidedress N application, and (3) slightly lower yields at all N rates with no tillage compared to chiseling.

Nitrate-N concentrations in the soil water extracted from the 5-foot depth on Aug. 31 related closely to N rate applied (Table 3). Similar to Olmsted Co., NO_3-N concentrations were consistently less with no tillage. Highest nitrate-N concentrations occurred with the 150-lb rate sidedress applied at the 6-leaf stage.

Table 3. Corn yield and NO_3-N concentration in the soil water at 5' as affected by N treatments in Goodhue Co. in 1990.

No.	Treatment: Tillage[1]	Treatment: N rate	Treatment: Time/Method	Grain Yield: 1990	Grain Yield: 1987-90	Nitrate-N[3] Conc. in Water at 5'
		lb N/A		bu/A	bu/A	mg/L
1	Chisel	0	--------	96.4	89.4	6
2	Chisel	50	Spr., preplant (PP)	125.2	128.6	-
3	Chisel	100	Spr., preplant (PP)	134.6	143.4	22
4	Chisel	150	Spr., preplant (PP)	142.4	146.9	39
5	Chisel	200	Spr., preplant (PP)	144.1	147.5	-
6	No tillage	0	--------	88.1	77.4	-
7	No tillage	100	Spr., preplant (PP)	120.2	137.2	17
8	No tillage	150	Spr., preplant (PP)	121.0	141.4	28
9	No tillage	200	Spr., preplant (PP)	126.4	140.0	-
10	Chisel	50+50	Spr. PP + SD 9-lf	142.6	142.4	-
11	Chisel	50+100	Spr. PP + SD 9-lf	141.4	145.6	-
12	Chisel	100+50	Spr. PP + SD 9-lf	146.6	148.2	-
13	Chisel	100	SD 6-lf	134.8	140.0	-
14	Chisel	150	SD 6-lf	143.7	146.2	62
15	Chisel	150+NI[2]	Spr. PP	144.9	150.3	-
16	Chisel	150+NI	SD 6-lf	137.3	145.3	-
	Significance level (%):			99		
	BLSD (.05) :			17.4		
	CV (%) :			9.8		

[1] Chiseling was done in Nov., 1989
[2] NI = N-Serve
[3] Aug. 31, 1990

Winona Co.

Corn grain yields were improved over the 0-lb control by over 55 bu/A with all of the N treatments (Table 4). Yields were optimized by the 100-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.

Four-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 rates greater than 50 lb/A at this site which was in alfalfa from 1983-85. Nitrate-N concentrations in the soil water at 5' after four years of experimentation still are at 13 mg/L where no N has been used. Concentrations ranged between 22 and 64 mg NO_3-N/L for the treatments that received fertilizer N, with a positive relationship to N rate. Nitrate-N concentrations were slightly lower with no tillage. The very high nitrate-N concentration with the split-applied treatment is similar to the results found in Olmsted and Goodhue Counties. Leaching conditions early in the summer apparently contributed to the nitrate-N concentrations at 7.5' being markedly higher than in 1989. These high values throughout the profile must be a result of the previous alfalfa crop which received manure in 1985 and the very dry conditions in 1988 that severely limited yields and N uptake by the crop.

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 1990.

Treatment				Grain Yield		Nitrate-N[2] Conc. in Water	
No.	Tillage[1]	N rate	Time/Method	1990	1987-90	5'	7.5'
		lb N/A		------- bu/A ------		---- mg/L ---	
1	Chisel	0	--------	117.2	126.7	13*	-
2	Chisel	50	Spr., preplant	173.7	153.1		-
3	Chisel	100	Spr., preplant	178.1	155.7	30	40*
4	Chisel	150	Spr., preplant	181.9	157.8	34*	36*
5	Chisel	200	Spr., preplant	187.6	163.0	63	74*
6	No tillage	0	--------	116.9	128.0	-	-
7	No tillage	100	Spr., preplant	178.6	155.8	22	-
8	No tillage	150	Spr., preplant	182.0	151.8	-	32
9	No tillage	200	Spr., preplant	184.7	155.8	49	40
10	Chisel	50+50	Spr. PP + SD 9-lf	179.1	156.7	-	-
11	Chisel	50+100	Spr. PP + SD 9-lf	184.9	160.2	64	59
12	Chisel	150	SD 6-lf	180.8	152.0	-	-
	Significance level (%):			99			
	BLSD (.05) :			12.8			
	CV (%) :			5.8			

[1] Chiseling was done in November, 1989
[2] Sept. 5, 1990
* - Average of only two samples

SUMMARY

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

1) N rates for continuous corn were optimized at between 100 and 150 lb/A at all three sites.
2) No apparent yield advantages were found with split or sidedress applications of N at any of the three sites. Yet, nitrate-N concentrations in the soil water were consistently higher.
3) Yields at two of the sites were lower with no tillage. However, nitrate-N concentrations in the soil water were also lower at all three sites with no tillage.
4) High precipitation and leaching conditions from May-July resulted in lower nitrate-N concentrations in the soil water at the 5-foot depth but increased concentrations at the 7.5-foot depth at the two locations where suction lysimeters are at both depths. Nitrate-N concentrations related very closely to rate of N application.
5) Previous crop and manure history apparently still impacts corn yield and N management at the Winona Co. site.
6) The role of alfalfa and manure contributions to available N for succeeding corn crops needs to be carefully examined and understood before improved N management is a reality on these soils.
7) Nitrate-N concentrations in the soil water at 5' (below the root zone) provide a good basis upon which to compare the environmental risks associated with various N management systems.

ACKNOWLEDGEMENT

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SUPPLEMENTAL APPLICATION OF N TO CORN AFTER HEAVY SPRING RAINFALL[1]

1990

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

ABSTRACT: This was a one-year study conducted because of the high amounts of rainfall that occurred during May and June. The purpose was to determine if a supplemental, sidedress application of N was beneficial to continuous corn where various N rates had already been preplant-applied. Highest grain and silage yields, grain N concentration, N removal and recovery in the grain, and profit were obtained with the 150-lb rate of preplant-applied N. Sidedress application of 50 lb N/A enhanced yields, N concentrations, and profit when the preplant N rates were insufficient (0 and 75 lb/A) but not at the 150-lb rate on this somewhat poorly drained soil. This is not to say that sidedress N applications did not enhance yields and profitability under soil conditions where N losses due to either leaching or denitrification were more severe.

Split and sidedress applications of N are often recommended to maximize N efficiency under high-loss conditions such as irrigated, coarse-textured, sandy soils. These applications are also often suggested on medium and fine-textured soils even though most Minnesota research does not support these "advantages". Because of very high rainfall amounts in May and June in 1990 (11.99 inches, 3.75" above normal), a study was conducted to determine if a sidedress application of 50 lb N/A as anhydrous ammonia (AA) would be beneficial to continuous corn where preplant applications of AA had been preplant-applied.

Experimental Procedures

A factorial design consisting of three preplant N rates (0, 75 and 150 lb N/A) and two sidedress N rates (0 and 50 lb/A) was replicated four times on a Nicollet clay loam (Aquic Hapludoll). The previous crop was corn which had been moldboard plowed in October, 1989. Anhydrous ammonia was preplant applied on May 4 just prior to field cultivation. Corn (Pioneer 3737) was planted on May 8 at 28,420 plants/acre. Lasso (3.5 lb/A) plus Bladex (3.0 lb/A) was applied preemergence on May 11. All plots were cultivated once in mid June. Weed control was excellent.

Supplemental N was applied at 50 lb/A as AA to one half of the plots when corn was in the V7-V8 stage (July 2). Earleaf samples were taken on July 30. Silage yields were taken by hand-harvesting 15' of row on Sept. 27. Grain yield and moisture were obtained on October 4 by combine harvesting the center two rows of each 4-row plot.

Results and Discussion

Main factor analyses showed that leaf N concentration was increased significantly (P=99% level) by both the preplant N rate and the sidedress N treatment (Table 1). However, the preplant x sidedress interaction was highly significant, which indicates that the sidedress N treatment increased leaf N concentration only at the two lower preplant N rates. Sufficient N was available with the 150-lb preplant rate so that sidedressing an additional 50 lb did not increase leaf N. It is noteworthy that leaf N responded this quickly to sidedress N applications made only 28 days before sampling.

Grain yield was increased by both the preplant N treatments and the sidedress treatment (Table 1). The highly significant interaction between preplant and sidedress treatments, however, indicates that yields were only increased by the sidedress treatment when insufficient amounts of N (0 and 75 lb/A) had been preplant applied. Adding an additional 50 lb N/A to the 150-lb preplant AA treatment did not increase yield on this somewhat poorly drained soil even under these high soil moisture conditions. Perhaps a yield increase would have been obtained if: 1) the N had been fall-applied or applied earlier in the spring, 2) a source of N had been used that was more susceptible to N loss under these moist conditions, or 3) the soil would have been very well drained (to promote leaching) or very poorly drained where more denitrification would have been expected.

Grain moisture at harvest was reduced by both the preplant and supplemental N additions. Grain N concentration was increased significantly by the preplant rates but not by the supplemental N.

Fodder N yield was increased by the sidedress N treatment applied to the 0-lb preplant treatment but not to the 75 and 150-lb preplant treatments (Table 1). On the other hand, fodder N concentration was reduced by

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[1] Funding supported by the Southern Experiment Station.

[2] Professor and Assistant Scientist at the Southern Experiment Station.

the sidedress application of N to the 0 and 75-lb preplant N rates. This was probably due to greater translocation of N from the stalk to the grain in these treatments where the combined total rate of N was limiting. Similar to grain yield, silage yields were not increased with the supplemental N addition when the preplant N rate was sufficient (150 lb N/A).

Table 1. Grain yield, silage yield, and N concentrations in the plant as affected by N rate and time of application at Waseca in 1990.

N rate/time	Earleaf N	Grain H_2O	Grain Yield	Grain N	Fodder Yield	Fodder N	Silage Yield
lb/A	%	%	bu/A	%	T DM/A	%	T DM/A
0 PP + 0 SD	1.88	26.7	94.4	1.18	2.07	0.40	5.14
0 PP + 50 SD	2.70	23.9	115.4	1.19	2.46	0.36	6.29
75 PP + 0 SD	2.60	22.5	136.0	1.23	2.93	0.50	7.13
75 PP + 50 SD	2.82	20.5	153.9	1.33	2.67	0.42	7.29
150 PP + 0 SD	2.86	21.2	162.6	1.40	3.16	0.50	8.23
150 PP + 50 SD	2.90	21.1	161.0	1.40	3.08	0.55	7.90
Preplant N rate (lb/A)							
0	2.29	25.3	104.9	1.18	2.27	0.38	5.71
75	2.71	21.5	145.0	1.28	2.81	0.46	7.21
150	2.88	21.1	161.8	1.40	3.12	0.52	8.06
Signif. Level (%):	99	99	99	99	99	99	99
BLSD (.05) :	0.08	1.1	6.5	0.05	0.18	0.05	0.38
Sidedress N rate (lb/A)							
0	2.45	23.4	131.0	1.27	2.72	0.46	6.83
50	2.81	21.8	143.4	1.31	2.75	0.44	7.16
Signif. Level (%):	99	99	99	89	27	73	94
PP rate x SD rate Interaction							
Signif. Level (%):	99	93	99	86	99	96	99
CV (%) :	3.3	4.8	4.9	4.0	6.6	10	5.6

Table 2. N removal in the grain, total N uptake, apparent N recovery, and production economics as influenced by N rate and time of application.

N rate/time	N removal in grain	Total N uptake	N recovery in[1] grain	N recovery in[1] silage	Cost of[2] treatment	Return to[3] fertilizer $/A	Return to[3] fertilizer $/lb of N
lb/A	lb/A		%		$/A	$/A	$/lb of N
0 PP + 0 SD	52.7	69.2	--	--	0	-	-
0 PP + 50 SD	65.0	82.9	25	27	10.50	36.75	0.74
75 PP + 0 SD	79.3	108.6	35	52	9.00	84.60	1.13
75 PP + 50 SD	97.0	119.5	35	40	13.50	120.38	0.96
150 PP + 0 SD	108.0	139.5	37	47	18.00	135.45	0.90
150 PP + 50 SD	106.9	140.5	27	36	22.50	127.35	0.64
Preplant N rate (lb/A)							
0	58.9	76.0					
75	88.2	114.1					
150	107.4	140.0					
Signif. Level (%):	99	99					
BLSD (.05) :	6.1	6.3					
Sidedress N rate (lb/A)							
0	80.0	105.8					
50	89.6	114.3					
Signif. Level (%):	99	99					
PP x SD rate interaction							
Signif. Level (%):	98	84					
CV (%) :	7.4	5.9					

[1] (N removed in grain or taken up in silage - N removed or taken up by the check treatment) : N application rate
[2] Based on N = 12¢/lb and $4.50 for SD application
[3] Based on corn at $2.25/bu.

Nitrogen removal in the grain and total N uptake (silage) were both increased significantly by the preplant and sidedress treatments (Table 2). However, N removal in the grain was not increased when the supplemental N was applied to the 150-lb N treatment. Nitrogen recovery as a percent of the N applied was highest for the 150-lb preplant N treatment. Sidedress application of N did not enhance N recovery either in the grain or in the total above-ground plant (silage).

Economic return was highest with the 150-lb preplant N rate (Table 2). Sidedress application of 50-lb N increased economic return when the preplant N rates were insufficient (0 & 75 lb/A) but not when the 150-lb preplant rate was applied. Highest return per pound of fertilizer N applied was at the 75-lb preplant rate.

N CREDITS FOR MANURE AND ALFALFA

J. A. Lory, G. W. Randall and M. P. Russelle[1]

ABSTRACT: Applications of fertilizer-N to corn can be reduced the first year following a manure application or when the corn crop follows alfalfa in rotation. The objective of this study is to determine first and second year N credits for these two sources of organic-N. In this first year there was no yield response of corn following alfalfa to applications of fertilizer-N or manure at Rosemount and Waseca, MN. Continuous corn yield at the highest fertilizer-N rate was equivalent to the yield of first year corn in rotation with alfalfa. Manure-N availability was predicted based on 25% of the organic-N in the manure being available in the first year after application. The manure N credit for continuous corn closely matched the predicted manure-N availability at Rosemount, whereas the manure N credit at Waseca was 55% of that predicted.

Many dairy farmers apply manure to alfalfa in the spring before they plow down an old stand. This practice is not recommended because it causes an oversupply of N, but the prevalence of the practice requires that we investigate the fate of the excess N. The first objective of this study is to assess the impact of manure on the alfalfa N-credit. Portions of the manure and alfalfa N will not be available to a corn crop until the second and third year after incorporation. Consequently, this study will determine N credits for first and second year corn grown after: (i) previous alfalfa, (ii) spring-applied dairy manure on previous corn, and (iii) spring-applied dairy manure on previous alfalfa. The second objective is to compare the impact of over-application of fertilizer-N and manure-N on soil inorganic-N levels in both continuous corn and alfalfa-corn rotations.

Materials and Methods

Experimental plots were located on a Webster clay loam at the Southern Experiment Station, Waseca, MN and on a Port Byron silt loam at Agronomy Hill, Rosemount Experiment Station, Rosemount, MN.

Plot history

The plots were established in spring of 1988 in a randomized, split-block design with 4 replicates at Waseca and 3 replicates at Rosemount. At both Waseca and Rosemount, portions of established stands of alfalfa were moldboard plowed to establish the corn portion of a alfalfa-corn rotation. The alfalfa was maintained in other blocks. Blazer alfalfa had been seeded in April, 1984 at Waseca and Pioneer 532 alfalfa had been seeded in fall 1985 after oats at Rosemount. Alfalfa was managed for hay production on a 3-cut system, and corn was managed for grain production. Corn plots were chisel plowed at Waseca in fall 1988 and 1989 and plots were chisel plowed in spring 1989 at Rosemount. Fertility levels of P and K, and pH were maintained at or above Minnesota soil test recommendations. At Waseca 0 and 100 lb N/A were applied in spring 1988 and 1989, respectively; at Rosemount, 0 and 30 lb N/A were applied in spring 1988 and 1989, respectively.

Procedures

In spring 1990, before planting corn on all plots, 8 treatments were applied randomly to each previous crop block. Treatments in previous corn were 0 N (control); 60, 100, 140 and 180 lb N/A as urea; and 3000, 7000 and 11,000 gal dairy manure per acre. First year corn following alfalfa treatments were: 0 N (control); 30, 60, 100, and 140 lb N/A as urea; and 3000, 5000, and 7000 gal/A dairy manure per acre. Liquid dairy manure was obtained from the Southern Experiment Station dairy and the Richard Fox farm near Rosemount, MN. These manure sources provided about 18 lb available N/1000 gal at Waseca, and 11 lb available N/1000 gal at Rosemount, based on 25% of the organic N being available the first year. Manure was surface-applied on April 26 at Waseca and April 23 at Rosemount. All plot areas were moldboard plowed, incorporating the manure within 45 min. of application. Urea was surface-applied preplant and disk incorporated.

At Waseca Pioneer 3751 was planted May 29 at 28,400 seeds/A and the stand was thinned to 26,300 plants/A on July 9. To control corn rootworms, Force insecticide (8.7 lb/A actual rate) was applied over the row at planting. Weeds were controlled with a preemergence application of Lasso (3.5 lb/A) and Bladex (3 lb/A). At Rosemount Pioneer 3751 was planted on May 3 at 26,000 seeds/A. To control corn rootworm, Counter (10 lb/A actual rate) was applied over the row at planting. Lasso and Bladex (2 lb/A each) were applied preemergence to control weeds. Atrazine (2 lb/A) was applied May 15 to reduce quackgrass growth.

Plots were harvested October 2 at Waseca and September 29 at Rosemount. Grain and stover dry matter samples were harvested from 40 and 20 ft. of row, respectively. Plant samples were dried at 60°C and ground in preparation for total-N analysis.

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[1] Research Assistant, Univ. of Minnesota, St. Paul; Professor, Southern Experiment Station, Waseca; Soil Scientist, USDA/ARS Dairy Forage Research Center, St. Paul.

Soil samples were taken from each main plot (previous crop) in the spring before applying treatments, and from all treatments in the fall after corn harvest. At Waseca, two 2" dia. cores were taken per plot to a minimum depth of 4 ft and maximum depth of 8 ft, divided into 1 ft increments and combined by depth. At Rosemount, three 2" dia. cores were taken per plot to a depth of 8 ft, divided into 1 ft increments and combined by depth. The 2" cores were not taken within 10 ft of other sampling points. At Rosemount 1" dia. soil cores to a depth of 3 ft were also taken from selected plots on June 21. All soil samples were dried at 40°C, ground to pass through a 2-mm screen, and analyzed for NO_3 and NH_4.

Results and Discussion

First year corn grain and silage yields following alfalfa did not respond to applications of fertilizer-N or dairy manure at Rosemount and Waseca (Tables 1 and 2). Application of manure or urea significantly increased N uptake of corn following alfalfa at both sites. Continuous corn dry matter yield and N-uptake responded to both manure and fertilizer-N applications.

Dairy manure N credits for continuous corn, based on continuous corn grain yield response to fertilizer-N, are presented in Table 3. Continuous corn may have responded to higher rates of manure at both sites. Manure N was 55% less available than predicted at Waseca. The manure at Rosemount had a relatively low N content.

These results emphasize that first-year corn following alfalfa typically does not respond to N applications in the southeast region of Minnesota.

Table 1. Effect of previous crop, dairy manure, and urea-N on corn yield and N uptake at Rosemount, MN in 1990.

Previous crop	N source	Rate	Grain Yield	Grain N uptake	Silage Yield	Silage N uptake
			bu/A	lb/A	T DM/A	lb/A
Alfalfa	Urea	0 lb/A	214	141	9.49	190
		30	211	150	9.49	206
		60	223	155	9.70	213
		100	218	164	9.70	230
		140	223	167	9.75	234
	Manure	3000 gal/A	210	147	9.31	200
		5000	221	163	9.80	226
		7000	216	153	9.50	216
P>F			0.5	0.04	0.6	0.01
CV (%)			4.3	5.9	3.4	5.3
Corn	Urea	0 lb/A	172	99	7.32	131
		60	190	116	8.32	151
		100	203	138	9.18	187
		140	209	153	9.44	206
		180	218	162	9.80	221
	Manure	3000 gal/A	186	112	8.28	149
		7000	194	127	8.82	169
		11000	197	133	8.66	172
P>F			0.01	0.01	0.01	0.01
CV (%)			3.4	4.9	2.8	6.4

Table 2. Effect of previous crop, dairy manure, and urea-N on corn yield and N uptake at Waseca, MN in 1990.

Previous crop	N source	Rate	Grain Yield	Grain N uptake	Silage Yield	Silage N uptake
			bu/A	lb/A	T DM/A	lb/A
Alfalfa	Urea	0 lb/A	154	102	6.84	129
		30	177	124	7.77	156
		60	172	118	7.94	155
		100	159	113	7.12	149
		140	159	115	7.24	150
	Manure	3000 gal/A	170	117	7.45	148
		5000	174	120	7.69	157
		7000	177	117	8.00	152
P>F			0.07	0.12	0.07	0.16
CV(%)			7.2	8.0	13.1	10.5
Corn	Urea	0 lb/A	136	78	5.71	98
		60	146	89	6.50	116
		100	145	92	6.43	120
		140	146	95	6.50	121
		180	167	112	7.19	141
	Manure	3000 gal/A	132	79	5.61	98
		7000	145	93	6.22	121
		11000	150	98	6.59	132
P>F			0.01	0.05	0.01	0.01
CV (%)			7.2	7.5	7.3	7.7

Table 3. Estimated N availability and N credits for dairy manure applied to continuous corn at Rosemount and Waseca, MN.

Location	Manure rate	Estimated N-availability[1]	N-credit[2]
Waseca	3000	55	0
	7000	130	75
	11000	203	110
Rosemount	3000	32	47
	7000	74	78
	11000	116	90

[1] Estimated N availability is based on 25% of the organic N being available the year of application

[2] N credit was determined by comparing continuous corn grain yield after application of manure with fertilizer-N response of continuous corn

CORN AND SOYBEAN PRODUCTION AS INFLUENCED BY BRIGHT SUN[1]

1990

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

ABSTRACT: This one-year study was conducted to determine if foliar applications of Bright Sun, a foliar plant food, would enhance corn or soybean production. Factorial studies with Bright Sun and N applied to corn and Bright Sun and P & K applied to soybeans were conducted on Nicollet and Webster soils at Waseca. Corn production was improved by N application but unaffected by Bright Sun. Soybean production was not improved by either the application of P & K or by Bright Sun. Based on this test, Bright Sun is not recommended for corn or soybeans at this time.

Foliar application of nutrients to corn and soybeans has shown very limited success in numerous trials throughout the Corn Belt. The purpose of this study was to evaluate the efficacy of Bright Sun, a molasses containing foliar plant food, on corn and soybean production in south-central Minnesota.

Experimental Procedures - CORN

A factorial design consisting of three preplant N rates (0, 75 and 150 lb N/A) and two Bright Sun treatments (none and a complete foliar program) was replicated four times on a Nicollet clay loam (Aquic Hapludoll). This previous crop was corn that had been moldboard plowed in October, 1989. Anhydrous ammonia was preplant-applied on May 4 just prior to field cultivation. Corn (Pioneer 3737) was planted on May 8 at 28,420 plants/A. Lasso (3.5 lb/A) plus Bladex (3.0 lb/A) was applied preemergence on May 11. All plots were cultivated once in mid-June. Weed control was excellent. Each plot was 10' wide (4-30" rows) x 55' long.

Bright Sun was applied three times at a rate of 3 gal/A each time using 40+ psi and a total application volume of 18 gal/A. Water was the carrier. The first application was made with a bicycle sprayer on June 21 when the corn was in the V5 stage (12" tall). The second application was made with a Spirit motorized sprayer on July 13 (V11 stage with 0-lb N rate and V12-13 with 75- and 150-lb N rates). A Hy-Boy sprayer was used on July 31 to make the third application (R1 to R2 stage). All applications were made before 9:30 AM or after 5:00 PM without using a surfactant.

Plant population was determined by counting the total number of plants in the two center rows each 55' long. Plant height after tasseling was taken on August 9 by measuring to the top of the tassel on 10 random plants/plot. Silage yields were taken by hand-harvesting 15' of row on September 27. Grain yield and moisture were obtained on October 6 by combine harvesting the center two rows of each 4-row plot with a JD 3300 plot combine. Ear length was determined from a random sample of 10 ears per plot. Kernel weight was determined by weighing 100 kernels that had been oven-dried to remove water.

Grain N concentration was determined by the University's Research Analytical Laboratory using a total Kjeldahl N procedure. Fodder samples taken at physiological maturity were ground and submitted to the University's NIRS Forage Research Laboratory for crude protein, ADF, NDF, and elemental analyses.

Experimental Procedures - SOYBEANS

A factorial design consisting of three preplant phosphate (P) and potash (K) applications (0, 25 lb P_2O_5/A + 40 lb K_2O/A, and 50 lb P_2O_5 + 80 lb K_2O/A) and two Bright Sun treatments (none and a complete program) was replicated four times. The experimental site was a Nicollet clay loam (Aquic Hapludoll) - Webster clay loam (Typic Haplaquoll) complex that was tile drained. The previous crop was corn that had been moldboard plowed in October, 1989. The P and K treatments were broadcast applied on June 6 and immediately incorporated with a field cultivator. Soil tests for the area prior to fertilization averaged: pH = 6.4, Bray P_1 = 21 ppm (VH), and exchangeable K = 156 ppm (VH).

Hardin soybeans were planted in 30-inch rows at a rate of 10 beans/foot of row on June 6. Each plot was 10' wide (4 - 30" rows) x 55' long. Lasso (3.5 lb/A) and Amiben (2.5 lb/A) were applied on June 7. All plots were cultivated on July 16. Weed control was perfect. Pictures were taken on July 13 and 31.

Bright Sun was applied four times at a rate of 3 gal/A each time using the same procedures as for corn. The first and second applications were made on July 13 (V5 stage) and July 31 (R2 stage), respectively, using a Spirit motorized sprayer. The third application was made with a bicycle sprayer on August 28 (R4 stage). The fourth application was made by hand on September 5 (R5 stage) using a backpack sprayer and a boom.

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[1] Partial support for this project was provided by Cargill.

[2] Professor and assistant scientist, Southern Experiment Station, Waseca, MN

Plant height was determined on October 6 by measuring 10 random plants per plot. All plants from a 3-foot section of row in each plot were cut at the soil surface on October 8. The plants were separated into the bottom 12" versus the rest and pod counts were made on each plant portion. Soybean seed yields and moisture were obtained on October 11 by harvesting the center two rows of each plot with a specialized ALMACO SPC-40 plot combine.

Seed weight was determined on 100 random seeds. Protein and oil content based on 13% moisture were determined by Dr. J. Orf's soybean research project.

Results and Discussion - CORN

Corn grain yield, grain N concentration, ear length, plant height, kernel weight, fodder yield and silage yield were all increased over the control by the 75- and 150-lb preplant N treatments (Table 1). Grain and silage yield, grain N concentration and plant height were significantly higher for the 150-lb N rate compared to the 75-lb rate. Grain moisture was reduced with increasing N rate. Plant population was not influenced by N rate.

The application of Bright Sun did not have any effect on grain moisture, grain yield, N concentration, plant population, plant height, kernel weight, ear length, fodder yield, and silage yield (Table 1). Moreover, there was no interaction between N rate and Bright Sun application. This indicates that Bright Sun did not influence corn production even when N was limiting.

Table 1. Grain yield, moisture, plant height, kernel weight and dry matter yield as influenced by N rate and Bright Sun in 1990.

N rate	Bright Sun	Grain H_2O	Grain Yield	Grain N	Plant Popl'n	Plant Height	Kernel Weight	Ear Length	Fodder Yield	Silage Yield
lb/A		%	bu/A	%	ppA x 10^3	cm	g/100	in/ear	--- TDM/A ----	
0	No	24.0	85.4	1.12	28.0	230	17.7	6.12	2.14	4.96
0	Yes	24.6	82.8	1.12	27.8	226	18.2	5.88	1.96	4.67
75	No	19.7	128.1	1.18	28.1	251	19.0	7.42	2.82	7.25
75	Yes	20.2	131.1	1.17	27.9	243	18.6	7.35	3.03	7.29
150	No	19.2	148.5	1.27	28.1	254	19.6	7.55	3.16	7.98
150	Yes	18.8	149.4	1.29	28.1	254	19.3	7.48	2.91	7.74
N rate										
0		24.3	84.1	1.12	27.9	227	17.9	6.00	2.05	4.81
75		20.0	129.6	1.17	28.0	247	18.8	7.39	2.93	7.27
150		19.0	149.0	1.28	28.1	254	19.4	7.51	3.04	7.86
Signif. Level (%):		99	99	99	69	99	96	99	99	99
BLSD (.05) :		1.0	6.3	0.05	-	7	1.2	.19	0.20	0.26
Bright Sun										
No		21.0	120.6	1.19	28.1	245	18.8	7.03	2.70	6.73
Yes		21.2	121.1	1.29	28.0	240	18.7	6.90	2.64	6.56
Signif. Level (%):		34	12	14	79	83	13	88	56	85
N rate x Bright Sun Interaction										
Signif. Level (%):		40	31	22	37	46	27	40	91	56
CV (%) :		5.0	5.4	3.9	0.8	2.9	5.8	2.8	7.8	4.1

NIRS analyses of the fodder (not ensiled) indicated that crude protein, acid detergent fiber (a measure of non-digestible fiber), neutral digestible fiber, (more easily digestible cell walls) K and Ca were all increased by the preplant N rates over the control (Table 2). The highest N rate resulted in the highest protein levels and K concentrations. Phosphorus and Mg concentrations were not influenced by the N rates.

Bright Sun increased crude protein of the fodder by 10% and resulted in a slight increase in K concentration (Table 2). Some of this protein increase could have been due to the liquid fertilizer adsorbed onto the fodder tissue rather than absorbed into the cell tissue. There were no interactions between N rates and Bright Sun applications.

Results and Discussion - SOYBEANS

Soybean seed yield, moisture, protein and oil content were not influenced by P and K application rates (Table 3). Bright Sun significantly reduced soybean seed yield but did not affect seed moisture, protein or oil content. Because no phytotoxicity symptoms were observed and visual observations did not reveal height differences, one can suspect that physical disturbance caused by walking through the bushy and somewhat lodged soybeans to apply the last two treatments may have caused this yield depression. Application of foliar materials by ground driven means was impossible because severe traffic damage would have resulted. There was no interaction between P & K rate and Bright Sun application.

Table 2. Nutrient concentrations in the fodder at physiological maturity as influenced by N rate and Bright Sun in 1990.

N rate	Bright Sun	Crude Protein	ADF	NDF	P	K	Ca	Mg
lb/A		%						
0	No	3.25	41.5	63.4	0.22	1.15	0.17	0.15
0	Yes	3.79	42.1	63.5	0.22	1.20	0.17	0.14
75	No	3.93	44.1	67.6	0.22	1.26	0.20	0.15
75	Yes	4.16	43.9	66.8	0.22	1.27	0.21	0.15
150	No	4.70	44.2	66.9	0.22	1.29	0.22	0.15
150	Yes	5.13	44.5	66.8	0.22	1.31	0.23	0.15
N rate								
0		3.52	41.8	63.4	0.22	1.18	0.17	0.14
75		4.05	44.0	67.2	0.22	1.26	0.21	0.15
150		4.91	44.3	66.9	0.22	1.30	0.22	0.15
Signif. Level (%): 99		99	99	22	99	99	78	
BLSD (.05) :		.30	0.8	1.5	-	.03	.02	-
Bright Sun								
No		3.96	43.2	66.0	0.22	1.23	0.22	0.15
Yes		4.36	43.5	65.7	0.22	1.26	0.20	0.15
Signif. Level (%): 99		54	35	54	95	61	46	
N rate x Bright Sun Interaction								
Signif. Level (%): 41		32	16	4	61	18	32	
CV (%) : 7.4		1.9	2.3	4.9	2.4	11.	6.6	

Table 3. Soybean seed yield, protein and oil content as influenced by three levels of phosphorus and potassium fertilizer and Bright Sun.

P_2O_5 rate	K_2O rate	Bright Sun	Seed H_2O	Seed Yield	Seed Protein	Seed Oil
------ lb/A ------			%	bu/A	%	%
0	0	No	12.1	50.2	35.6	17.0
0	0	Yes	12.0	45.9	35.6	16.8
25	40	No	12.2	51.8	35.8	16.8
25	40	Yes	12.1	46.4	35.9	16.8
50	80	No	12.2	52.2	36.1	16.6
50	80	Yes	12.1	45.7	35.9	16.8
Rate of P_2O_5+K_2O						
----- lb/A ----						
0	0		12.0	48.0	35.6	16.9
25	40		12.1	49.1	35.9	16.8
50	80		12.2	49.0	36.0	16.7
Signif. Level (%):			29	47	90	85
Bright Sun						
No			12.2	51.4	35.8	16.8
Yes			12.0	46.0	35.8	16.8
Signif. Level (%):			62	99	18	<1
P_2O_5+K_2O x Bright Sun Interaction						
Signif. Level (%):			5	48	36	41
CV (%)	:		2.2	4.1	1.0	1.1

Soybean yield components (plant height, seed weight, and pod count) were also not influenced significantly (P = 95% level) by the P & K rates (Table 4). Bright Sun did significantly reduce the number of pods on the lower portion of each plant but did not influence the other yield components. Again, interactions between Bright Sun and P & K applications were not evident.

Table 4. Plant height, seed weight and pod distribution on plant as influenced by three levels of phosphorus and potassium fertilizer and Bright Sun.

P_2O_5 rate	K_2O rate	Bright Sun	Plant Height	Seed Weight	Pod Distribution Bottom 1'	Pod Distribution Above 1'	Pod Distribution Total
------ lb/A ------			in.	g/100 seeds	---------- No. pods/plant ----------		
0	0	No	35.5	18.6	18.5	23.0	41.5
0	0	Yes	35.2	18.5	14.0	19.8	33.8
25	40	No	36.2	19.0	17.7	21.2	39.0
25	40	Yes	36.0	18.8	15.5	22.2	37.8
50	80	No	36.8	18.7	13.5	21.0	34.5
50	80	Yes	36.0	18.9	13.0	20.5	33.5
Rate of P_2O_5+K_2O							
---- lb/A ----							
0	0		35.4	18.6	16.2	21.4	37.6
25	40		36.1	18.9	16.6	21.8	38.4
50	80		36.4	18.8	13.2	20.8	34.0
Signif. Level (%):			88	78	94	31	87
Bright Sun							
No			36.2	18.8	16.6	21.8	38.3
Yes			35.8	18.7	14.2	20.8	35.0
Signif. Level (%):			70	30	95	66	92
P_2O_5+K_2O x Bright Sun Interaction							
Signif. Level (%):			17	45	62	79	76
CV (%) :			2.6	1.9	18.	11.	12.

Conclusions

Foliar applications of Bright Sun to corn and soybeans did not result in yield or quality improvement under the soil and climatic conditions of this study.

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

1990

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 13% at Waseca. Soil test K also decreased from 15 to 30% at Waseca. Even though soil test differences occurred among the treatments at Morris, the high variability made interpretation very difficult. Soybean yields were increased about 13% over the long-term control plots at the two sites when soil test Bray P_1 was greater than 30 lb/A. Reducing soil test K from about 250 lb/A to 175 lb/A resulted in a 7 to 8 bu/A soybean yield reduction 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 soybeans on the high P and K rate study at the two branch stations in 1990.

	Location	
Variable	Morris	Waseca
Planting date	5/21	6/1
Row spacing	30"	30"
Planting rate (plants/A)	9-10 seeds/ft	10-11 seeds/ft
Variety	Evans	Hardin
Herbicide	3# Lasso/A (Bdct)	3.5# Lasso + 3# Amiben/A (Bdct)
Harvest date	9/24	10/11
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 1989. 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.

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 1985-89 rates resulted in highly significant differences in soil test P and soil test K at Waseca. At Waseca soil test P ranged from 10 to 99 lb/A (Table 2). Soil test P declined about 13% compared to 1989. Soil test K declined by about 15% since 1989 where the 100-lb rate was applied but by over 25% where no K was applied. Soybean yields were increased significantly by P but plateaued at soil P levels higher than 30 lb/A. Yields were also decreased significantly on those plots that did not receive K and had soil test K values of 170 to 175 lb/A.

[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.

At Morris, Bray P_1 ranged from 13 to 35 lb/A while Olsen's $NaHCO_3$ test ranged from 12 to 29 lb P/A (Table 3). Due to extremely high variability, these differences were not statistically significant at the P = 90% level. Considering this variability, both soil test P and K declined at this site in 1990.

Table 2. Soil test values, seed moisture, and seed yield as influenced by 17 years' application of P and K at Waseca.

No.	P and K Treatments Total 1973-84	1985-89[1]	Soil Test[2] pH	P	K	Soybean Moisture	Yield
	------ lb P_2O_5 + K_2O/A ------			--- lb/A ---		%	bu/A
2	0 + 1200	0 + 100	6.7	10	278	12.5	42.6
3	600 + 1200	0 + 100	6.6	30	239	12.8	55.5
4	1200 + 1200	0 + 100	6.8	67	251	12.7	53.6
5	600 + 1200	100 + 100	6.7	71	254	12.8	54.5
6	1200 + 0	100 + 0	6.8	99	171	12.1	47.5
7	1200 + 600	100 + 0	6.7	91	175	12.1	47.0
	Signif. Level (%):		32	99	99	91	99
	BLSD (.05) :		-	15	48	-	5.9
	CV (%) :		2.7	15.0	12.	2.7	6.4

[1] Treatments applied each fall. P was discontinued for treatments 6 & 7 in 1988.
[2] Samples were taken in October before 1990 treatments were applied.

Table 3. Soil test values, seed moisture, and seed yield as influenced by 17 years' application of P and K at Morris.

No.	P and K Treatments Total 1973-84	1985-89[1]	Soil Test[2] pH	P_1	P_{ol}	K	Soybean Moisture	Yield
	------ lb P_2O_5 + K_2O/A ------			------- lb/A -------			%	bu/A
2	0 + 1200	0 + 100	7.9	13	12	424	13.2	26.2
3	600 + 1200	0 + 100	7.9	30	27	344	13.0	30.6
4	1200 + 1200	0 + 100	7.9	35	29	366	13.3	35.4
5	600 + 1200	100 + 100	7.9	27	24	388	13.3	34.1
	Signif. Level (%):		13	50	50	60	98	95
	BLSD (.05) :		-	-	-	-	0.2	7.4
	CV (%) :		0.8	78.	71.	17.	1.0	13.

[1] Treatments applied each fall.
[2] Samples were taken in October before 1990 treatments were applied.

CONCLUSIONS

Long term (12-yr) additions to these two soils created a wide range in soil test P levels. Soybean yields were optimized over the no P treatments at soil test P levels of 30 lb/A at Waseca. Yields were reduced when soil test K dropped to <175 lb/A at Waseca. At Morris, soybean yields were significantly improved with the higher soil test P levels. Soil test P declined by about 13% at Waseca. Soil test K was reduced by 15% when K was added and by over 25% when no K was added at Waseca. Additional years will be needed to more accurately determine the decline rates.

CONSERVATION TILLAGE FOR CORN AND SOYBEAN PRODUCTION[1]

Waseca, 1990

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

ABSTRACT: This was the 16th and final year of a study to evaluate five primary tillage systems for corn and soybean production on a Nicollet-Webster soil complex. Surface residue amounts ranged from 4% with MP tillage to 97% with NT. Corn yields were reduced by about 80 bu/A with NT due primarily to very aggressive foxtail growth. Yields were not different among the MP, CP, RP and SD systems but were enhanced 7 bu/A by the former starter fertilizer applications with all tillage systems. Intensive soil sampling showed marked decreases in soil pH in the top two inches with NT and in the surface of the RP ridge. Soil test P and K were highly stratified in the CP, RP, SD and NT systems. Starter fertilizer applied for 10 of 16 years greatly increased soil test P and K in the top 6" of all tillage systems.

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 and Nicollet 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).

Ridges for the RP treatment in 1990 were built in June, 1989. The MP and CP treatments were performed on Nov. 3. On May 2 all plots received 150 lbs N/A as ammonium nitrate broadcast on the surface. On May 4 the MP and CP treatments were field cultivated once with the chiseled plots receiving a prior disking. The SD treatment was disked twice.

Corn (Pioneer 3578) was planted in 30" rows at a rate of 29,900 plants/A on May 18 with a John Deere 7100 planter. B&H ridge cleaners were attached for the RP treatment. No starter fertilizer was used. Broadcast P and K were not applied for the 1990 crop because of very high soil tests. Soil tests from moldboard plow plots averaged: pH = 6.9, $Bray_1$ extractable P = 66 lb/A and exchangeable K = 370 lb/A. Lasso (3.5 qts/A) + Bladex (3 lb/A) were applied broadcast to all plots on May 30. All plots except NT were cultivated with a Hiniker 5000 cultivator on June 15. As a result of the herbicides plus cultivation, weed control was excellent on all plots except no tillage.

Surface residue coverage was measured by the line-transect method on April 2 prior to spring tillage. Soil samples were taken in 2- and 3-inch increments from all plots on July 18. Yields were taken by combine harvesting the center two rows from each plot where starter and no starter fertilizer had been applied previously.

RESULTS

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

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

[2] Professors, Southern Experiment Station, Univ. of Minnesota and The Leopold Center, Iowa State U., respectively.

Table 1. Influence of tillage methods for corn after soybeans on surface residue before spring tillage at Waseca in 1990.

Treatment	Surface Residue Coverage
	%
No tillage (NT)	97
Fall plow (MP)	4
Fall chisel (CP)	13
Ridge plant (RP)	60
Spring disk (2x) (SD)	62
Significance Level (%):	99
BLSD (.05) :	7
CV (%) :	10.

Corn yields were significantly affected by both tillage system and the previous starter fertilizer treatments (applied from 1979-1988) (Table 2). No tillage resulted in significantly reduced yield compared to all other tillage systems with no difference among the MP, CP, RP and SD systems. The primary reason for the very low NT yield was poor weed control. Over 6" of rain in May prevented herbicide application until 12 days after planting. By this time corn emergence curtailed application of Roundup to the carpet of foxtail that did not appear to be affected by the Lasso and Bladex application. Weed control was excellent in the other tillage systems due to secondary tillage and cultivation in conjunction with the herbicides. The residual effects of the previous starter fertilizer treatments increased corn yield by 7.0 bu/A regardless of tillage system. Grain moisture at harvest was slightly higher for the NT system.

Table 2. Influence of tillage method and residual starter fertilizer on corn production at Waseca in 1990.

Tillage	Starter Fertilizer	Moisture	Yield
		%	bu/A
No tillage	Yes	22.9	67.4
	No	23.6	60.2
Fall plow	Yes	21.9	151.3
	No	22.2	142.4
Fall chisel	Yes	20.3	147.2
	No	22.1	139.9
Ridge plant	Yes	21.2	146.7
	No	22.2	142.1
Spring disk (2x)	Yes	20.8	147.5
	No	20.0	140.3
MAIN EFFECTS			
Tillage System			
No tillage		23.3	63.8
Fall plow		22.1	146.8
Fall chisel		21.2	143.6
Ridge plant		21.7	144.4
Spring disk (2x)		20.4	143.9
Signif. Level (%):[1]		94	99
BLSD (.05) :		-	10.2
Starter Fertilizer			
Starter		21.4	132.0
No starter		22.0	125.0
Signif. Level (%):[1]		71	95
INTERACTION			
Tillage x Starter			
Signif. Level (%):[1]		39	1
CV (%) :		7.6	8.2

[1] Probability level of significant difference between means.

Soil samples taken on July 18 from all plots show a substantial effect of tillage over this 16-year period on soil pH (Table 3), soil P (Table 4), and soil K (Table 5). Soil pH was depressed by about 1.0 unit in the surface 0 - 2" layer of the NT system and in the ridge area of the RP system. Individual plots in the NT system were as low as 4.9 and may explain the foxtail growth and very poor weed control. Differences in soil pH did not appear between the no starter and starter fertilizer systems.

Extractable soil P and exchangeable K were greatly influenced by both tillage system and starter fertilizer history. Both P and K were very uniformly distributed throughout the 0 - 6" layer with MP tillage. On the other hand substantial stratification occurred throughout the 0 - 12" layer with the NT, CP, RP and SD systems. Greatest stratification occurred in the ridge of the RP system. Soil test P and K within the top 6" were considerably higher in the plots that had received 10 years of starter fertilizer regardless of tillage system. This may have led to the higher yields shown in Table 2. Stratification of P & K was greater were starter fertilizer had been applied.

Table 3. Soil pH after 16 years of continuous tillage.

	Starter[1]	Tillage System[2]					
Depth	fert.	NT	MP	CP	RP-R	RP-V	SD
inches							
0-2	No	5.4	6.6	6.2	5.6	6.1	6.6
2-4	No	6.0	6.9	6.5	6.0	6.6	6.8
4-6	No	6.4	7.0	6.8	6.5	6.8	7.1
6-9	No	6.6	7.0	7.1	6.7	6.8	7.2
9-12	No	6.7	7.3	7.1	6.8	6.8	7.2
0-2	Yes	5.5	6.6	6.4	5.8	6.2	6.3
2-4	Yes	5.9	6.8	6.7	6.1	6.6	6.4
4-6	Yes	6.5	6.9	6.9	6.6	6.8	6.8
6-9	Yes	6.6	6.9	7.1	6.7	6.8	7.0
9-12	Yes	6.7	7.1	7.2	6.7	6.8	7.0

1 Starter fertilizer was applied for 10 years (1979-1988).

2 RP-R = Ridge plant - ridge, RP-V = Ridge plant - valley.

Table 4. Extractable soil P (Bray 1) after 16 years of continuous tillage.

	Starter[1]	Tillage System[2]					
Depth	fert.	NT	MP	CP	RP-R	RP-V	SD
inches		ppm					
0-2	No	38	22	29	44	30	32
2-4	No	27	22	22	24	19	19
4-6	No	15	22	15	13	11	11
6-9	No	12	13	8	10	8	8
9-12	No	6	6	5	9	5	6
0-2	Yes	50	37	32	65	54	45
2-4	Yes	30	39	20	46	23	25
4-6	Yes	18	32	11	22	14	13
6-9	Yes	14	17	6	17	9	11
9-12	Yes	10	9	4	16	7	7

1 Starter fertilizer was applied for 10 years (1979-1988).

Table 5. Exchangeable soil K after 16 years of continuous tillage.

Depth	Starter[1] fert.	Tillage System[2] NT	MP	CP	RP-R	RP-V	SD
inches		ppm					
0-2	No	216	179	201	244	207	227
2-4	No	185	193	168	177	145	157
4-6	No	142	187	140	134	117	129
6-9	No	122	141	108	118	93	102
9-12	No	99	107	95	104	97	94
0-2	Yes	265	201	187	283	244	258
2-4	Yes	186	216	149	177	165	160
4-6	Yes	136	201	122	134	123	127
6-9	Yes	118	145	99	124	96	113
9-12	Yes	101	110	89	109	102	93

[1] Starter fertilizer was applied for 10 years (1979-1988).

SUMMARY - 1990

This was the fourth crop of corn grown following soybeans in this long-term study with continuous corn from 1975 through 1982 and soybeans in 1983, 1985, 1987, and 1989. Surface residues prior to planting were greater than 50% with NT, RP, and SD tillage. Due primarily to poor weed control, corn grain yields with NT were about 80 bu/A less than with MP, CP, RP and SD tillage. Residual effects of starter fertilizer increased corn yields by 7 bu/A regardless of tillage systems. Grain moisture was slightly higher with NT but was unaffected by starter fertilizer.

SIXTEEN-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 6. 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 6.) Moldboard plow tillage in this sequence has resulted in corn yields being about 5% higher (7 bu/A) than for CP, RP and SD tillage on the starter fertilizer plots. When no starter was used this difference increased to 7% (10 bu/A). 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 6. 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 & 89	1984, 86, 88 & 90
		bu/A			
No tillage	Yes	129.2	140.6	34.5	100.4
"	No		136.0	34.3	89.2
Fall plow	Yes	154.5	170.9	51.0	147.0
"	No		170.8	50.2	141.5
Fall chisel	Yes	144.4	161.8	47.7	138.8
"	No		155.5	45.5	128.4
Ridge plant	Yes	149.2	161.5	46.9	139.8
"	No		156.4	47.2	132.6
Till plant (flat)[1]	Yes	144.9	154.8	46.8	141.7
"	No		157.4	47.1	134.2

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

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

George Rehm, Andy Scobbie, and Dan Schmitz[1/]

ABSTRACT: The rate of K_2O that can be applied in a band without causing emergence and early growth problems is a major concern for ridge-tillers. This study was conducted to evaluate the fall application of 0, 20, 40, 80, 160 lb. K_2O/acre in a band. This banded K_2O was applied in the center of the ridge in the fall at a depth of 3.0 to 3.5 inches. The rate of K_2O applied in this way had no significant effect on corn emergence, early growth and yield in each of the 3 years of study.

Introduction:

Many farmers who have switched to ridge-till planting systems have complained about problems associated with using starter fertilizers. They seek an alternative. 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 late fall. There is reason to believe that the use of this practice could substitute for the use of a starter fertilizer at planting.

There is also concern that high rates of potash fertilizer applied in the fall might cause problems with emergence and early growth. This concern is valid and field trials were needed to evaluate the impact of banded potash applied in the center of the ridge on early growth of corn and subsequent yield.

Experimental Procedures:

This study was initiated in the fall of 1987 at the Southern Experiment Station at Waseca and continued through the 1989 growing season. The plots used for the trial in 1988 were used again in 1990. Treatments in 1990 were reapplied to the plots used in 1988. A separate site was used for the trial in 1989. Soil samples were collected in the fall of 1987 and 1988 for use in 1988 and 1989, respectively. The results of the analysis are summarized in Table 1. All treatments were applied to existing ridges. Soybeans were the previous crop in all years.

Table 1. Relevant soil properties for the experimental sites.

Soil Property	Year 1988, 1990	1989
pH	7.9	6.1
phosphorus (Bray), ppm	-	28.0
phosphorus (Olsen), ppm	13.5	-
potassium (1N $NH_4C_2H_3O_2$), ppm	120	117

Five rates of K_2O (0, 20, 40, 80, 160 lb./acre) were knifed into the center of existing ridges in late October in 1987, 1988, and 1989. The bands, using 0-0-60 as the source of K_2O, were placed at a depth of 3.0 to 3.5 inches below the soil surface. Adequate N as 82-0-0 was applied to all treatments each fall.

Corn was planted in either late April or early May. Recommended practices were used throughout the growing season to assure optimum corn yields.

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

Results and Discussion:

Grain yields are summarized in Table 2. The rate of applied K_2O had no significant impact on yield. The soil test levels for K are considered to be in the medium range. The soil, however, was able to supply adequate K for corn production under these growing conditions. As would be expected, year-to-year yields varied with rainfall.

[1/] Extension Specialist; Assistant Scientist and Junior Scientist, respectively.

Table 2. The effect of rate of potash fertilizer applied in the center of existing ridges on the yield of corn at Waseca.

K_2O Applied	1988	Year 1989	1990
lb./acre	- - - - - - -	bu./acre - - - - - -	
0	84.4	160.1	147.1
20	81.7	166.9	148.5
40	78.4	161.8	149.4
80	86.3	161.6	147.5
160	83.6	162.3	151.7

Stand counts are summarized in Table 3. The emergence was not affected by the rate of K_2O applied in the band. Emergence was also uniform over the three years of the study.

Table 3. The effect of rate of potash fertilizer applied in the center of existing ridges on corn stand measured at 4 weeks after emergence at Waseca.

K_2O Applied	1988	Year 1989	1990
lb./acre	- - - - -	plants/20 ft - - - - - -	
0	33	34	34
20	33	34	34
40	33	34	33
80	34	35	33
160	34	34	33

These data indicate that relatively high rates of K_2O can be safely applied in the center of existing ridges in the fall and not have a negative effect on corn emergence.

The rate of K_2O applied in the band had no significant effect on early growth of corn (Table 4). These results are consistent with emergence and yield measurements.

Table 4. The effect of rate of potash fertilizer applied in the center of existing ridges on weight of young corn plants at 4 weeks after emergence at Waseca.

K_2O Applied	1988	Year 1989	1990
lb./acre	- - - - -	gm/6 plants - - - - - -	
0	29	27	49
20	31	31	46
40	29	30	48
80	35	29	51
160	31	30	50

Summary;

Banded application of phosphate and potash fertilizers can be very effective alternatives to broadcast usage in ridge-till planting systems. The results of this study indicate that relatively high rates of K_2O can be applied in a band in the center of the ridge in the fall. No emergence, early growth, and yield reductions were measured with this practice.

EFFECTS OF NUTRIENT SOURCES, APPLICATION TIMING AND RATE ON ALFALFA PRODUCTION[1/]

M.A. Schmitt, C.C. Sheaffer and G.W. Randall[2/]

Farmers often have questions regarding the effect of manure application on alfalfa. Although alfalfa is grown on fewer acres than corn in Minnesota, alfalfa removes more nutrients on a per acre basis. However, since alfalfa can produce its own nitrogen (N), many livestock producers are reluctant to apply manure to alfalfa fields.

The primary goal of this project is to evaluate the feasibility of using livestock manures as a fertilizer material on alfalfa fields such that the immediate nutrient demands of the alfalfa are met and the residual nitrogen (N) fertility from the manure and the alfalfa meet subsequent corn crop requirements.

Materials and Methods

A long-term project was started to examine the effects of manure fertilization on alfalfa. Trials were established at University of Minnesota Agricultural Experiment stations at Rosemount and Waseca. At Rosemount, hog manure was used on a shallow Waukegon silt loam soil lying on outwash gravel subsoil. At Waseca, dairy manure was used on a Nicollet clay loam soil.

Three rates of manure (3000, 6000, and 12000 gallons per acre) were broadcast and incorporated immediately prior to establishment of the alfalfa. Three inorganic commercial fertilizer treatments were also used--applied to give equivalent P and K application rates as contained in the three rates of manure.

Topdress application methods were also included. The two higher rates of manure were also applied as annual applications (applied at one-half rates) after first cutting. A topdressed inorganic fertilizer treatment was also applied.

Along with measures of overall dry matter yield at each harvest, plant samples were collected at each harvest for total nutrient analysis. After the second year, before the alfalfa was plowed, subplots were undercut and crown counts, crown and taproot dry matter yields and N contents measured. Soil samples were collected to a depth of two feet in one-foot increments during the growing season and analyzed for nitrate-N and ammonium-N. In this paper, only the production variables will be addressed along with the soil N concentrations.

Results

<u>First Cutting Yields in Establishment Year</u>

The most visual treatment differences in this study were observed during the establishment period. The alfalfa growth in the manured plots was always taller and darker green than the nonmanured plots--this most likely due to the increased N levels in the soil at a time when symbiotic N fixation is not at maximum production. Even though the stray weeds are obvious, the estimated weed contributions in the initial cuttings of all of the stands was statistically insignificant. Weeds were not a factor in any of the plots after the first cutting at all locations.

The effect of the three rates of preplant inorganic fertilizer and manure treatments on forage dry matter production at Rosemount in 1989 is listed in Table 1. The first cutting yields increased with the manure treatments up until the highest manure rate, at which the alfalfa was noticeably lodged. Since the soil tests at Rosemount were categorically "high" (Bray P at 35 ppm and K at 200 ppm), it is conceivable that the response of the alfalfa was most likely due to factors other than just the P and K.

The plots established at Rosemount in the spring of 1990 had similar results as those plots established in 1989. The manure additions increased yields compared to the control up to the highest rate of manure (Table 1). The added inorganic fertilizer increased first cutting production only with the highest rate treatment.

[1/] This project was supported, in part, by the Potash and Phosphate Institute

[2/] Extension Soil Scientist, Department of Soil Science, Agronomist, Department of Agronomy and Plant Genetics, and Soil Scientist, Southern Experiment Station, respectively.

The increasing rates of manure resulted in lower yields of alfalfa at the Waseca plot site (Table 1)--which tested "low" for both P (8.5 ppm) and K (94 ppm). However, the forage yields increased significantly as the rate of inorganic fertilizer increased, as would be predicted by the soil test levels. The decrease in alfalfa production with increasing manure rates can be primarily attributed to a major stand problem. The combination of manure additions and large-scale application equipment created a severe compaction problem, resulting in almost no stand in the wheel tracks. This problem was corrected during the 1989 growing season.

Production Year Yields

Despite slight yield increases with the inorganic fertilizer rates at Rosemount, there was no statistically significant difference between the control treatment and the inorganic fertilizer treatment means (Table 2). As previously mentioned, the relatively high soil test values for P and K would give credence to current University of Minnesota soil test recommendations and interpretations.

The application of manure did significantly increase alfalfa dry matter yields at Rosemount compared to the unfertilized control treatment (Table 2). The lowest manure rate increased alfalfa yields more than the highest rate of inorganic fertilizer, suggesting that the yield increase was not due to the manure's added P and K. There was a significant yield response up to the 6000 gallons per acre rate of manure. Above this rate, similar yields were measured.

At Waseca, the yield response to both commercial fertilizer and manure was statistically significant (Table 2). While the lowest rate of inorganic fertilizer did not result in a significant increase in alfalfa yield, the low rate of fertilizer produced 0.44 tons of dry matter more than the control. The middle and high fertilizer rate each produced a significant increase in dry matter production. The increase in tonnage was almost a direct linear correlation with the rate of fertilizer application. With the low soil test levels for P and K at this site, the increase in yield was predictable.

Soil Nitrate Levels

Nitrate-N concentrations measured in the soil provide an indicator as to the amount of N that can potentially be lost by leaching, denitrification and/or plant uptake. Since a properly nodulated alfalfa plant symbiotically fixes atmospheric nitrogen for plant use, nitrate-N quantities in manure-treated plots above the quantities in the control plots represent the nitrate contributions from the manure. Throughout the 1989 growing season, there were statistically significant differences in soil nitrate-N due to manure rate differences--these differences being somewhat related to the relative application rates of the manure. In July and thereafter, the low manure rate nitrate-N concentrations were not different from the control and after August, the medium manure rate was not different from the control.

At Waseca, fewer samplings were taken, yet the same results were observed. In 1989, there was a significant effect of the manure rate on soil nitrate-N. The first sampling in 1990 showed significant nitrate-N differences in the medium and high manure rates, but subsequent samplings resulted in no statistical differences among treatments.

The soil nitrate-N results are of importance due to the concern for groundwater quality. If significant amounts of nitrate-N were present in the soil while a crop was not growing, the nitrate-N could be subject to downward movement. Thus, the elevated levels measured in 1989 could pose a potential risk, especially if alfalfa growth were limited. However, since alfalfa is a deep-rooted perennial and requires substantial amounts of N, nitrate-N available in the soil system is likely to be used by the growing alfalfa. Thus the diminishing quantities of soil nitrate-N are likely due to plant uptake.

Summary

Manure applications generally have a positive significant effect on alfalfa dry matter production. This response can be measured with the first cutting of the newly established alfalfa as well as with full production year values. The response to manure is probably due to more than just P and K since a yield response occured even when soil tests for P and K would not have indicated a yield response.

Inorganic fertilizer applications resulted in yield increases when the soil tests for P and K were low and no yield increases when the soil tests were high. Topdressing either manure or commercial fertilizer did not result in consistent, explainable results.

Although the manure brings certain weed concerns to the stands, these did not persist past the first cutting. While manure adds substantial amounts of N to the soil, the nitrate-N concentrations from the manure treatments were not statistically different from each other or the control 17 months after application.

Table 1. Dry matter production from first cuttings in the establishment year of alfalfa as effected by preplant incorporated nutrients.

Treatments	Rosemount 1989 DM Yield	Rosemount 1990 DM Yield	Waseca 1989 DM Yield
	T/A	T/A	T/A
Control	1.55	1.15	1.37
Manure 3000 GPA	1.79	1.58	1.45
6000 GPA	1.96	1.89	1.16
12000 GPA	1.62	2.05	1.30
Fertilizer, Low*	1.60	1.22	1.48
Medium*	1.70	1.36	1.51
High*	1.76	1.59	1.58
Pr.>F	0.0004	0.0001	0.003
LSD(.10)	0.149	0.272	0.148

* - The inorganic fertilizer rates were calculated based on the manure rates and the estimated P and K quantities contained within (see Table 2 for rates).

Table 2. Alfalfa dry matter yield means for the first full year of production as influenced by nutrient management in 1990.

Nutrient Source	Time of Application	Application Rate Rosemount	Application Rate Waseca	DM Yields Rosemount	DM Yields Waseca
				- - - - T/A	- - - -
None	-	-	-	3.81	2.84
Manure	Preplant	3000 gpa	3000 gpa	4.31	3.40
Manure	Preplant	6000 gpa	6000 gpa	4.60	4.12
Manure	Preplant	12000 gpa	12000 gpa	4.55	4.49
Fertilizer[1]	Preplant	0+90+69	0+33+69	3.87	3.28
Fertilizer	Preplant	0+180+138	0+66+138	3.97	3.71
Fertilizer	Preplant	0+360+276	0+132+276	4.17	4.57
Manure	Topdress[2]	6000 gpa	6000 gpa	4.47	2.93
Manure	Topdress[2]	12000 gpa	12000 gpa	4.98	2.82
Fertilizer[1]	Topdress[2]	0+180+138	0+66+138	4.21	2.97
Pr.>F				0.0001	0.0001
LSD(.10)				0.36	0.45

[1] - Expressed as lbs of $N+P_2O_5+K_2O$.

[2] - Topdress treatments were applied by two annual applications after first cutting in 1989 and 1990.

Table 3. Two-foot soil nitrate-N concentrations from plots receiving preplant incorporated manure applications in 1989.

Location	Date	Control	Manure Rate (GPA) 3000	6000	12000	Pr.>F	LSD(.10)
		- - - - - pp2m NO_3-N - - - - - -					
	1989						
Rosemount	May 1	14.2	17.6	16.9	17.8	0.47	-
	May 31	16.9	41.4	79.5	106.2	<0.01	31.5
	June 22	17.2	42.5	68.8	103.3	<0.01	17.2
	July 11	4.8	14.0	34.6	70.8	<0.01	20.8
	Aug. 3	3.5	4.3	14.1	38.4	<0.01	3.9
	Aug. 28	3.7	3.6	12.1	32.9	<0.01	10.1
	Nov. 1	1.6	1.7	2.1	15.4	<0.01	4.8
	1990						
	April 12	15.6	14.2	27.3	39.1	0.27	-
	May 3	12.7	14.9	18.1	40.7	0.03	15.0
	May 31	9.8	9.9	15.3	19.6	0.13	-
	June 25	11.1	10.6	14.4	15.6	0.44	-
	July 18	11.8	9.7	8.6	13.7	0.37	-
	Aug. 20	5.9	7.1	7.1	7.3	0.37	-
	1989						
Waseca	July 5	18.1	25.2	38.1	48.1	<0.01	5.7
	July 27	17.1	24.6	36.1	55.0	<0.01	7.3
	Sept. 11	7.3	15.7	32.8	47.4	<0.01	12.5
	1990						
	April 27	14.5	14.0	21.8	28.9	<0.01	4.3
	May 23	10.2	11.2	16.0	17.7	0.21	-
	June 22	6.9	7.9	7.2	10.0	0.41	-
	July 23	3.9	2.8	4.1	5.0	0.17	-

WATER QUALITY RESEARCH WITH NITROGEN AT THE HERMAN ROSHOLT WATER QUALITY RESEARCH FARM, WESTPORT, MN 1990 [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. Corn grain yields when no fertilizer N was applied were 20-40 bu/A higher when the previous crop was soybeans rather than corn. Nitrogen fertilizer significantly increased corn grain yield when 160 lbs N/A was applied with continuous corn and 215 lbs/A corn-soybean sequences. The small yield increases obtained with rates over 105 lbs N/A under continuous corn and 50 lbs N/A under corn soybean sequence would be difficult to justify environmentally. Early sidedress applications tended to be inferior in yield, to late applications, especially at the lower rates of N application. High amounts of precipitation during 1990 apparently leached some of the fertilizer N which had been applied early. Nitrification inhibitors increased yield when used at the lower rates of fertilizer N. Rates of fertilizer N in excess of plant need resulted in higher concentrations of nitrate-N in the percolate water.
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, 1989 and 1990. Concentration of nitrate-N in the percolate water increased as the rate of fertilizer N increased. Method of water collection influenced the actual concentration measured.

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.

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

Experimental Procedures

Small Plot N Management/Crop Production Phase: 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 1990 the entire experiment was planted to corn. The 25 N treatments within each sub-plot consisted of a control (zero N) plus four N rates (60, 120, 180, and 240 kg 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 on April 19th before planting and on October 29th after harvest. The soil samples were analyzed for ammonium and nitrate concentration and the data is reported in tables 4 and 5. Spring samples were taken on corn following corn and only the check plots of the corn following soybeans. Fall samples were taken from both studies.

Corn (Pioneer 3790 - 95 day R.M.) was planted on May 11 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 7-21-7 as a band below the seed and Counter was banded in the row at planting. Dual(1.75 #/A) and Bladex (1.75 #/A) was applied on May 16th for weed control in the corn. For additional weed control the corn was cultivated twice. The first cultivation was on June 21th, and second on July 3rd, ridges were also built on July 3rd. Nitrogen treatments were applied on June 20th (early-4 leaf) and on July 2nd (late-8 leaf). The irrigation program (traveling boom) was started on July 10th and continued through August 15th with 5 inches of water being applied through irrigation. An additional 21.32 inches of water was obtained during the growing season as rainfall.

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. In 1990 soybeans were planted in the corn-soybean rotation treatments. 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 20, and one-third at the 8-leaf growth stage (July 2). 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 3790 - 95 day R.M.) was planted on May 11 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 7-21-7 as a band below the seed. Counter was banded in the row at planting. Lasso (3.0 #/A) and AAtrex 90 DF (1#/A) were sprayed on May 14th for weed control.

Soybeans were planted on May 22nd at the rate of 63 #/A. Lasso at 3#/A was used for weed control on May 25th.

The irrigation program (traveling boom) was started on July 10th and continued through August 15th with 5.0 inches of water being applied through irrigation and an additional 21.32 inches of water coming through rainfall during the growing season.

Grain yields were obtained on October 24th 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 1990 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:

When no fertilizer N was applied corn yields were 20-40 bu/A higher when the previous crop was soybeans. Across the entire experiment corn grain yields were essentially the same utilizing a chisel system of tillage or the ridge tillage. Yield increases were obtained with fertilizer N up to rates of 215 lbs/A for corn following soybeans and 160 lbs/A following corn. However, most of the yield increase from fertilizer N was associated with rates of 105 lbs/A for continuous corn and 50 lbs/A for corn following soybeans. Early sidedress applications tended to be inferior in yield, to late applications, especially at the lower rates of N application. High amounts of precipitation during 1990 apparently leached some of the fertilizer N which had been applied early. Nitrification inhibitors increased yield when used at the lower rates of fertilizer N. Rates of fertilizer N in excess of plant need resulted in higher concentrations of nitrate-N in the percolate water.

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 the movement of the N below the 0-2 ft sampling region. Since yields were not high , and 1990 growing season precipitation was high it would seem feasible that at least a major 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. 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 soybeans plots (table 6). Water samples collected by the wick lysimeters had higher NO_3-N concentrations than the water collected in the pan lysimeters.

Large Plot Groundwater Phase:

Results displayed in table 7 suggest that there was no yield advantage to the application of fertilizer N over 160 lbs/A in 1990 which corresponded to the results that were obtained in 1987, 1988, and 1989. Higher rates of fertilizer N resulted in higher concentrations of NO_3-N in the water samples collected in the pan and wick samplers (table 8). Concentration of NO_3-N was higher in the corn-corn rotation than the respective soybean-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. Westport, MN. 1990

Total N-Rate	Early N	Inh.	Late N	Tillage	Yield	Corn Grain N-content	N-removal
#/A	#/A		#/A		Bu/A	%	#/A
Control	----	--	----	C	71.8	1.13	38.1
50	50	--	----	C	97.6	1.12	51.7
50	----	--	50	C	114.9	1.28	69.6
50	35	--	15	C	107.4	1.19	60.5
50	50	NS	----	C	108.3	1.14	58.5
50	----	NS	50	C	124.9	1.40	82.8
50	35	NS	15	C	116.8	1.29	71.4
105	105	--	----	C	125.6	1.36	80.9
105	----	--	105	C	129.3	1.34	81.5
105	70	--	35	C	128.8	1.43	87.1
105	105	NS	----	C	125.7	1.44	85.8
105	----	NS	105	C	126.8	1.44	86.4
105	70	NS	35	C	124.4	1.38	81.4
160	160	--	----	C	134.2	1.50	95.1
160	----	--	160	C	131.4	1.32	82.0
160	105	--	55	C	127.4	1.41	84.7
160	160	NS	----	C	127.6	1.52	91.7
160	----	NS	160	C	134.4	1.42	90.5
160	105	NS	55	C	124.3	1.40	82.5
215	215	--	----	C	130.7	1.35	83.8
215	----	--	215	C	124.3	1.30	76.4
215	145	--	70	C	126.7	1.49	89.0
215	215	NS	----	C	131.9	1.50	93.8
215	----	NS	215	C	130.5	1.53	94.4
215	145	NS	70	C	126.2	1.49	88.8
Control	----	--	----	R	62.4	1.08	31.8
50	50	--	----	R	102.4	1.13	54.7
50	----	--	50	R	121.2	1.26	72.5
50	35	--	15	R	102.2	1.15	55.1
50	50	NS	----	R	105.8	1.27	63.3
50	----	NS	50	R	119.6	1.29	72.5
50	35	NS	15	R	114.9	1.28	69.8
105	105	--	----	R	139.4	1.46	96.0
105	----	--	105	R	128.0	1.43	86.4
105	70	--	35	R	111.3	1.42	75.0
105	105	NS	----	R	127.4	1.30	78.4
105	----	NS	105	R	127.6	1.41	84.8
105	70	NS	35	R	122.8	1.39	80.2
160	160	--	----	R	135.2	1.40	89.6
160	----	--	160	R	125.6	1.38	82.1
160	105	--	55	R	125.2	1.41	83.1
160	106	NS	----	R	134.5	1.50	95.4
160	----	NS	160	R	126.3	1.39	82.7
160	105	NS	55	R	131.8	1.36	84.9
215	215	--	----	R	140.3	1.48	98.0
215	----	--	215	R	127.2	1.51	90.4
215	145	--	70	R	125.3	1.44	85.4
215	215	NS	----	R	124.9	1.51	88.8
215	----	NS	215	R	135.5	1.47	94.3
215	145	NS	70	R	128.8	1.43	86.9

Table 1. continued. Continuous Corn Split Plot Statistical Analysis

	Corn Grain Yield Bu/A	Corn Grain N-Content %	Corn Grain N-Removal #/A
Tillage			
Chisel	124.5	1.37	81.2
Ridge Till	124.2	1.37	81.3
P-Value	8	15	1
N-Rate X Method X Inhibitor			
N-Rate #/A			
50	111.3	1.23	65.2
105	126.4	1.39	83.7
160	129.8	1.41	87.0
215	129.3	1.45	89.1
P-Value	99	99	99
BLSD (.05)	2.8	0.03	2.3
Method			
1. 4 leaf	124.4	1.37	81.6
2. 8 leaf	126.7	1.38	83.1
3. Split 2/3 1/3	121.5	1.37	79.1
P-Value	96	34	99
BLSD (.05)	2.7		2.2
Inhibitor			
None	123.3	1.35	79.6
N-Serve	125.0	1.39	82.9
P-Value	86	99	99
N-Rate X Method	99	99	99
N-Rate X Inhibitor	97	98	99
Method X Inhibitor	96	82	92
N-Rate X Method X Inhibitor	52	55	75
N-Rate X Method X Inhibitor X Tillage			
N-Rate X Tillage	17	48	66
Method X Tillage	91	66	96
Inhibitor X Tillage	21	99	98
N-Rate X Method X Tillage	88	92	76
N-Rate X Inhibitor X Tillage	59	92	87
Method X Inhibitor X Tillage	99	95	99
N-Rate X Method X Inhibitor X Tillage	48	75	96

Table 2. Influence of N-rate, nitrification inhibitors, method of application and tillage on **corn** grain yields, N-concentration, and N removal following soybeans. Westport, MN. 1990

Total N-Rate	Early N	Inh.	Late N	Tillage	Yield	Corn Grain N-content	N-removal
#/A	#/A		#/A		Bu/A	%	#/A
Control	----	--	----	C	96.5	1.01	45.8
50	50	--	----	C	117.1	1.33	73.5
50	----	--	50	C	131.8	1.37	85.5
50	35	--	15	C	117.8	1.18	66.2
50	50	NS	----	C	112.8	1.18	62.6
50	----	NS	50	C	123.7	1.26	73.8
50	35	NS	15	C	130.9	1.36	84.0
105	105	--	----	C	119.0	1.33	74.5
105	----	--	105	C	133.8	1.36	86.0
105	70	--	35	C	123.1	1.37	79.6
105	105	NS	----	C	126.9	1.31	78.9
105	----	NS	105	C	111.9	1.30	68.9
105	70	NS	35	C	133.0	1.39	87.8
160	160	--	----	C	126.0	1.43	85.4
160	----	--	160	C	131.9	1.44	89.7
160	105	--	55	C	141.8	1.42	95.4
160	160	NS	----	C	123.4	1.54	89.7
160	----	NS	160	C	115.8	1.38	75.7
160	105	NS	55	C	131.1	1.44	89.2
215	215	--	----	C	130.8	1.39	86.2
215	----	--	215	C	133.3	1.49	94.3
215	145	--	70	C	134.2	1.42	90.1
215	215	NS	----	C	129.1	1.39	85.0
215	----	NS	215	C	129.3	1.22	74.5
215	145	NS	70	C	134.3	1.44	91.3
Control	----	--	----	R	102.3	1.11	53.6
50	50	--	----	R	120.2	1.19	67.6
50	----	--	50	R	123.1	1.39	80.9
50	35	--	15	R	129.9	1.26	77.3
50	50	NS	----	R	120.1	1.27	72.1
50	----	NS	50	R	124.5	1.33	78.2
50	35	NS	15	R	119.4	1.16	65.3
105	105	--	----	R	135.4	1.51	96.8
105	----	--	105	R	131.0	1.42	88.0
105	70	--	35	R	111.6	1.29	68.0
105	105	NS	----	R	127.0	1.44	86.4
105	----	NS	105	R	131.7	1.21	74.8
105	70	NS	35	R	125.3	1.36	80.8
160	160	--	----	R	136.6	1.44	92.8
160	----	--	160	R	112.0	1.44	76.4
160	105	--	55	R	124.7	1.37	80.6
160	106	NS	----	R	135.7	1.43	91.7
160	----	NS	160	R	133.6	1.39	87.9
160	105	NS	55	R	130.8	1.32	82.0
215	215	--	----	R	125.4	1.55	91.7
215	----	--	215	R	135.4	1.43	91.4
215	145	--	70	R	132.6	1.47	92.0
215	215	NS	----	R	145.8	1.41	97.4
215	----	NS	215	R	138.8	1.44	94.2
215	145	NS	70	R	135.6	1.42	91.1

Table 2. continued. Corn Soybean Rotation Split Plot Statistical Analysis

	Corn Grain Yield	Corn Grain N-Content	Corn Grain N-Removal
	Bu/A	%	#/A
Tillage			
Chisel	126.7	1.36	82.0
Ridge Till	128.5	1.37	83.5
P-Value	73	47	95
N-Rate X Method X Inhibitor			
N-Rate #/A			
50	122.6	1.27	73.9
105	125.8	1.35	80.9
160	128.6	1.42	86.4
215	133.7	1.42	89.9
P-Value	99	99	99
BLSD (.05)	2.8	0.03	2.4
Method			
1. 4 leaf	126.9	1.38	83.3
2. 8 leaf	127.6	1.36	82.5
3. Split 2/3 1/3	128.5	1.35	82.5
P-Value	49	84	23
BLSD (.05)			
Inhibitor			
None	127.4	1.38	83.7
N-Serve	127.9	1.34	81.8
P-Value	35	99	95
N-Rate X Method	99	99	99
N-Rate X Inhibitor	56	72	11
Method X Inhibitor	92	99	99
N-Rate X Method X Inhibitor	99	41	99
N-Rate X Method X Inhibitor X Tillage			
N-Rate X Tillage	33	98	99
Method X Tillage	99	99	99
Inhibitor X Tillage	99	61	94
N-Rate X Method X Tillage	95	88	84
N-Rate X Inhibitor X Tillage	99	47	95
Method X Inhibitor X Tillage	99	90	99
N-Rate X Method X Inhibitor X Tillage	99	99	99

Table 3. Continuous Corn And Corn Soybean Combine Split Plot Statistical Analysis Westport, MN 1990

	Corn Grain		
	Yield	N-Content	N-Removal
	Bu/A	%	#/A
Previous Crop			
Corn	124.2	1.37	81.3
Soybeans	127.6	1.36	82.8
P-Value	99	24	60
N-Rate X Method X Inhibitor X Tillage			
N-Rate #/A			
50	116.9	1.25	69.6
105	126.1	1.37	82.3
160	129.2	1.41	86.7
215	131.5	1.44	89.5
P-Value	99	99	99
BLSD (.05)	1.9	0.02	1.6
Method			
1. 4 leaf	125.7	1.37	82.4
2. 8 leaf	127.1	1.37	82.8
3. Split 2/3 1/3	125.0	1.36	80.8
P-Value	93	64	94
BLSD (.05)			
Inhibitor			
None	125.4	1.37	81.7
N-Serve	126.5	1.37	82.4
P-Value	84	20	69
Tillage			
Chisel	125.4	1.37	81.6
Ridge Till	126.4	1.37	82.4
P-Value	77	29	75
N-Rate X Method	99	99	99
N-Rate X Inhibitor	67	87	95
N-Ratr X Tillage	44	99	99
Method X Inhibitor	95	72	96
Method X Tillage	99	99	99
Inhibitor X Tillage	97	99	22
N-Rate X Method X Inhibitor	93	63	98
N-Rate X Method X Tillage	98	90	87
N-Rate X Inhibitor X Tillage	99	74	93
Method X Inhibitor X Tillage	98	12	81
N-Rate X Method X Inhibitor X Tillage	93	99	99
N-Rate X Method X Inh. X Tillage X Provious Crop			
N-Rate X P-Crop	99	99	99
Method X P-Crop	99	71	95
Inhibitor X P-Crop	55	99	99
Tillage X P-Crop	5	23	75
N-Rate X Method X P-Crop	76	68	56
N-Rate X Inh. X P-Crop	96	95	97
N-Rate X Tillage X P-Crop	5	33	39
Method X Inh. X P-Crop	95	99	99
Method X Tillage X P-Crop	76	54	93
Inhibitor X Tillage X P-Crop	99	88	99
N-Rate X Method X Inh. P-Crop	89	31	91
N-Rate X Method X Tillage X P-Crop	75	98	83
N-Rate X Inh. X Tillage X P-Crop	74	82	93
Method X Inh. X Tillage P-Crop	99	99	99
N-Rate X Method X Inh. X Tillage X P-Crop	99	99	99

Table 4. 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 1990.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium Spring	Ammonium Fall	Nitrate Spring	Nitrate Fall
#/A	#/A		#/A			-----ppm-----		-----ppm------	
Control	---	---	---	C	1	3.2	1.8	5.5	4.0
					2	2.4	1.4	1.8	4.4
50	50	---	---	C	1	3.5	2.2	8.3	10.0
					2	2.8	1.6	4.0	5.7
50	---	---	50	C	1	3.2	2.1	5.2	6.2
					2	2.3	1.2	3.1	5.3
105	105	---	---	C	1	2.8	2.1	7.5	5.4
					2	2.6	1.8	6.7	44.3
105	---	---	105	C	1	2.9	1.9	7.4	11.5
					2	2.4	1.7	3.8	13.9
160	160	---	---	C	1	3.5	4.1	8.1	2.1
					2	2.2	1.5	9.5	3.2
160	---	---	160	C	1	3.1	2.6	8.4	4.6
					2	2.4	1.7	5.5	12.6
160	105	---	50	C	1	3.6	2.5	6.6	4.6
					2	2.2	1.6	3.1	10.4
160	160	NS	---	C	1	3.2	2.2	15.2	5.7
					2	2.7	1.6	11.4	5.2
160	---	NS	160	C	1	6.9	3.0	10.1	6.2
					2	3.8	1.8	10.2	5.3
160	105	NS	50	C	1	3.1	4.8	11.3	10.7
					2	2.5	1.5	6.2	8.2
215	215	---	---	C	1	5.8	5.8	13.3	4.5
					2	3.5	3.0	16.2	4.2
215	---	---	215	C	1	9.9	16.1	17.8	3.1
					2	3.4	4.0	19.0	4.2
Control	---	---	---	R	1	2.9	2.0	6.8	11.4
					2	3.3	1.5	2.3	6.9
50	50	---	---	R	1	3.3	1.9	9.7	12.7
					2	1.9	1.6	4.3	3.3
50	---	---	50	R	1	3.1	1.9	7.5	7.5
					2	2.8	1.7	2.5	2.8
105	105	---	---	R	1	3.6	2.1	12.0	5.8
					2	3.6	1.8	8.8	3.6
105	---	---	105	R	1	3.6	2.5	18.7	2.9
					2	5.0	2.0	3.6	3.3
160	160	---	---	R	1	3.3	2.6	14.2	6.9
					2	3.0	1.8	6.5	2.8
160	---	---	160	R	1	4.8	2.4	16.5	12.9
					2	2.9	1.9	10.7	5.1
160	105	---	50	R	1	3.0	2.2	11.8	10.8
					2	2.7	1.4	5.8	7.5
160	160	NS	---	R	1	3.1	2.4	13.3	17.5
					2	2.7	2.0	9.4	5.7
160	---	NS	160	R	1	3.3	10.5	13.1	4.4
					2	3.1	4.7	10.0	5.8
160	105	NS	50	R	1	3.5	2.3	10.6	6.8
					2	2.8	1.5	3.6	5.2
215	215	---	---	R	1	4.4	2.0	17.2	3.9
					2	3.0	1.6	9.6	3.3
215	---	---	215	R	1	3.2	4.0	11.2	7.5
					2	3.1	1.9	9.2	3.4

Table 5. Influence of N-rate, nitrification inhibitors, methods of application and tillage in **corn following soybeans** 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 1990.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium Fall	Ammonium Spring	Nitrate Fall	Nitrate Spring
#/A	#/A		#/A			-----ppm-----		-----ppm------	
Control	---	---	---	C	1	1.4	2.7	4.2	7.4
					2	1.3	2.2	2.0	4.6
50	50	---	---	C	1	2.3		3.6	
					2	1.7		2.2	
50	---	---	50	C	1	1.6		3.2	
					2	1.3		1.8	
105	105	---	---	C	1	2.4		3.2	
					2	1.3		2.5	
105	---	---	105	C	1	2.5		8.1	
					2	1.3		5.0	
160	160	---	---	C	1	2.7		9.6	
					2	1.7		7.1	
160	---	---	160	C	1	2.8		8.4	
					2	1.8		10.4	
160	105	---	50	C	1	3.5		5.1	
					2	1.8		5.6	
160	160	NS	---	C	1	2.6		5.7	
					2	1.6		4.6	
160	---	NS	160	C	1	7.1		10.5	
					2	2.1		8.3	
160	105	NS	50	C	1	3.2		8.0	
					2	1.6		4.6	
215	215	---	---	C	1	2.5		11.0	
					2	1.6		6.5	
215	---	---	215	C	1	5.0		20.6	
					2	1.8		13.5	
Control	---	---	---	R	1	1.8	2.5	2.9	4.9
					2	1.6	2.4	1.5	2.3
50	50	---	---	R	1	1.5		4.1	
					2	1.3		2.8	
50	---	---	50	R	1	2.0		6.1	
					2	1.8		3.7	
105	105	---	---	R	1	2.0		4.7	
					2	1.4		2.6	
105	---	---	105	R	1	3.2		8.5	
					2	1.5		6.9	
160	160	---	---	R	1	2.7		6.0	
					2	1.9		5.7	
160	---	---	160	R	1	3.3		6.5	
					2	2.2		6.6	
160	105	---	50	R	1	2.1		7.7	
					2	1.5		5.0	
160	160	NS	---	R	1	6.3		8.9	
					2	4.9		6.7	
160	---	NS	160	R	1	2.9		10.7	
					2	1.6		7.2	
160	105	NS	50	R	1	2.3		3.7	
					2	1.5		4.6	
215	215	---	---	R	1	1.7		6.2	
					2	1.1		4.5	
215	---	---	215	R	1	2.0		8.0	
					2	1.7		5.9	

Table 6. Nitrate-N concentration of water collected in pan and wick lysimeters in the small plot area, Westport, MN 1990.

N rate		Pan corn-corn	Pan corn-beans	Wick corn-corn	Wick corn-beans
#/A		ppm NO_3-N			
0		8.7	1.7	-	8.4
105	early	1.3	1.8	-	25.9
105	late	21.4	6.0	30.8	-
215	early	31.6	5.3	-	22.3
215	late	1.7	1.0	-	21.0

Table 7. Corn grain yields from large plot area Westport, MN 1990.

Total N-Rate	Early N	Late N	Crop Rotation	Grain Yield	Grain N-Content	Grain N-Removal
#/A	#/A	#/A		Bu/A	%	#/A
160	105	55	Corn-Corn	126.9	1.37	82.2
215	140	75	Corn-Corn	122.0	1.36	78.4
160	105	55	Soybeans-Corn	50.1		

Table 8. Nitrate-N concentration of water collected from the pan and wick lysimeters in large plot area, Westport, MN 1990.

N rate	Rotation	NO_3-N
Pan		
lb N/A		ppm
160	corn-corn	9.2
215	corn-corn	38.8
160	soybeans-corn	No samples
Wick		
160	corn-corn	48.9
215	corn-corn	79.0
160	soybeans-corn	19.9

RESIDUAL EFFECTS OF NITROGEN FERTILIZER TREATMENTS AND TILLAGE ON GRAIN YIELD, UPTAKE AND NO_3^- LEACHING IN IRRIGATED CORN[1]

Manjula Vivekanandan, G.L. Malzer and J.L. Anderson[2]

Abstract

Irrigation of coarse textured soils increase the leaching potential of applied nitrogen. This study was initiated in 1987 to study the effects of tillage, Nitrification inhibitor (DCD), and N rates (fertilizer treatments given in 1987 and 1988 only) on crop yields, water percolation and NO_3-N leached in a corn-corn-soybean rotation in central Minnesota. During the first two years of the study (I) N rate increased corn yield and concentration of NO_3 in the percolating water, and (II) urea treated with DCD reduced the NO_3 concentration in the percolating water. In the third year of the study (1989), tillage or fertilizer treatments applied during the first two years of the study did not have any effects on soybean yields or, water and NO_3 movement. However, in the fourth year of the study (1990), tillage treatments did influence the corn grain yields. No-till systems had significantly lower yields than roto-till systems. There was no evidence for residual fertilizer effects on grain yield or N uptake. Tillage treatments didn't have any influence on the amount of water percolated or total amount of N leached. However, NO_3-N concentration in roto-till treatments were significantly higher than no-till treatments. Residual effects of prior fertilizer treatments were reflected in the total amount of NO_3 leached during the early season leaching events. However, these differences didn't exist in late season leaching events. Nitrate leached through the profile was directly related to the amount of water percolated.

Introduction

Irrigation of coarse textured soils in central Minnesota increases the leaching potential of applied nitrogen. Nitrate leaching in these soils can be reduced by adopting efficient fertilizer management practices. The objective of this study was to evaluate the influence of tillage, residual effects of nitrification inhibitor treated fertilizer and N rates on crop yields, water percolation and NO_3-N leached in a 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 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 corn. Water was pumped through the irrigation system at 13.8 kPa

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

[1] Funding provided by the Center for the Impact of Agricultural Practices on Water Quality.
[2] Postdoctoral Associate, Professor, and Assoc. Professor, respectively, Dept. of Soil Science, University of Minnesota.

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.

Corn (Pioneer 3790) was planted in the spring of 1990 at seed density of 28,000 seeds/A. The crop rotation was corn-corn-soybeans-corn. Soil temperature, wind speed, air temperature, and rainfall were measured at regular intervals during the four growing seasons. The fourth year research data will be reported here.

Treatments consisted of a factorial arrangement of 2 tillage treatments (roto-tillage 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 140 lbs N/A treatments.

Corn was harvested from a four ft. row at the 12 leaf and silking stage for dry matter production and N uptake (data not presented). Grain and stover yields were obtained by harvesting two 20 ft. rows at black layer stage. Subsamples from stover, cob and grain components were analyzed for total Kjeldahl N. Corn grain yields were reported at 15.5% moisture.

Soil water percolate was collected throughout the growing season from the bottom of the lysimeters following rainfall events. The amount percolated and the NO_3-N in the leachate was measured to quantitate concentration, flow rate and total N lost by leaching.

1990 was a wet year compared to the prior three years of the study. Monthly precipitation was 2.1, 7.3, 3.1, 2.4, 2.5 and 4.0 inches for May, June, July, August, September and October respectively. Four inches of supplemental irrigation water was applied between the 9th of July and 7th of August.

Results and Discussion

Corn grain yields averaged 103 bu/A even though there was no fertilizer applied. Yields from no-till treatments were 5 bu/A lower than roto-till treatments (Table 2). Nitrogen removal with the grain was not influenced by tillage. Prior fertilizer treatments (applied in 1987 and 1988) did not influence grain yield or N uptake (Table 2).

Table 2. Influence of tillage, residual fertilizer N on grain yield and N uptake of corn, 1990.

Tillage	N rate*	Grain yield	Grain N uptake
	lb N/A	bu/A	lb/A
Roto-till	0	105	52
	70	105	51
	140	106	52
	140 + DCD	108	56
No-till	0	101	46
	70	99	48
	140	103	54
	140 + DCD	100	48
LSD(0.05)		NS	NS
Tillage			
Roto-till		106	53
No-till		101	50
LSD(0.05)		4.7	NS
N rate			
	0	103	49
	70	102	50
	140	105	53
	140 + DCD	104	52
LSD(0.05)		NS	NS

* Nitrogen fertilizer treatments were given in 1987 and 1988 only.

Soil inorganic N (NO_3+NH_4-N) in surface 12" before planting (spring, 1990) ranged from 37 to 65 lb N/A. Relatively higher levels of inorganic N levels in the control plots when compared to 1989 (52 lb N/A in 1990; and 26 lb N/A in 1989) may have resulted from previous year of soybeans. There were no significant differences due to tillage treatments or prior N fertilizer treatments. At the end of the season (Fall, 1990) soil inorganic N levels ranged from 12 to 15 lb N/A.

Water leachate was collected from the lysimeters 10 times during 1990. The leaching events were grouped into 3 phases considering the growth stage and water use pattern of corn (Table 3). Total amount of water percolated throughout the season amounted to 9.3 inches; this compares with 0, 2.4, and 7.7 inches for 1987, 1988, and 1989, respectively. Tillage treatments did not influence the amount of water percolated or the amount of N leached. However, the NO_3-N concentration from the roto-till plots were significantly higher than in no-till plots throughout the growing season (Table 3). Residual effects of prior fertilizer treatments were reflected in the total amount of NO_3 leached during planting to silking stage but not with the later time intervals. However, these differences were not evident during silking to black layer and post harvest stage leaching events.

Table 3. Tillage and residual effects of N fertilizer and DCD on water percolation and NO_3-N concentration in the leachate.

	Planting-Silking			Silking-Blacklayer			Post harvest		
Tillage	H_2O in	N lb/A	NO_3-N ppm	H_2O in	N lb/A	NO_3-N ppm	H_2O in	N lb/A	NO_3-N ppm
Roto-till	5.1	16	15	1.2	13	60	2.0	4	11
No-till	6.7	13	10	1.2	7	34	2.4	4	7
LSD(0.05)	NS	NS	4	NS	NS	21	NS	NS	3
N rate* lb/A									
0	5.5	11	11	1.6	12	46	2.4	4	8
70	6.3	14	12	1.6	11	44	2.4	4	8
140	5.9	15	13	0.8	8	49	2.0	4	11
140 + DCD	6.3	19	15	1.2	10	52	2.0	4	9
LSD(0.05)	NS	4.5	NS	NS	NS	NS	NS	NS	NS

* Nitrogen fertilizer treatments were given in 1987 and 1988 only.

Concentrations of NO_3-N in the leachates were higher during silking to black layer stage than the planting to silking and post harvest stages. Intensive rainfall events which occurred prior to this leaching interval perhaps resulted in dilution effects in the early season leaching events. The minimal percolation during silking to black layer period probably resulted in higher concentration of NO_3-N during this period.

Nitrate movement through the soil profile was correlated to the amount of percolated water (Fig. 1). As the amount of water percolated increased, the NO_3-N concentration decreased (Table 3), and the total amount of NO_3-N leached increased in both tillage treatments (Fig. 1).

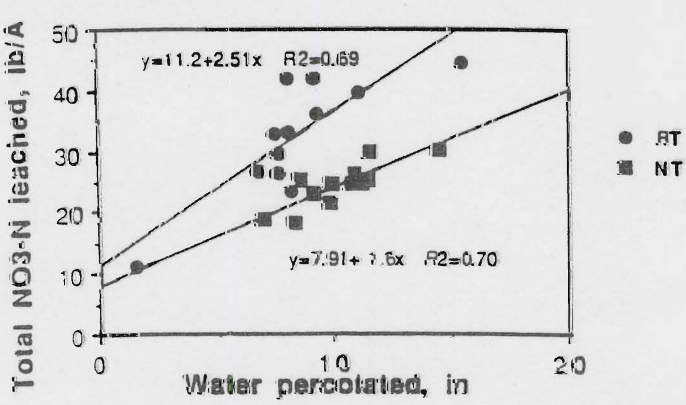

Fig 1. Relationship between water percolated and total N leached throughout the season, 1990.

LAND TREATMENT OF SEWAGE SLUDGE INCINERATOR ASH[1]

Carl Rosen, Dave Birong, and Louise America[2]

ABSTRACT: The fourth year of an ongoing 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. The evaluation this year was done on sweet corn. 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. There was a slight but significant increase in yield of fertilizer grown plants compared to ash grown plants. The Olsen P soil test seemed to predict response to the ash amended soils better than the Bray P1 or Nitric acid extractants. There was slight, but significant increase in nitric acid extractable Cd and Cr at 6-12" soil depths when ash was applied compared to control an fertilized plots. Other heavy metals did not appear to move out of the top 6" of soil. Tissue analysis revealed that both P sources increased P levels in the plant; however, at equivalent P rates, stover P concentrations were greater with the fertilizer source compared to the ash source. There were no differences in P concentrations in cob and kernel tissue due to P source. Tissue concentrations of Zn and Cu were higher with ash applications compared to fertilizer applications. Tissue levels of Cd increased slightly with ash applications. Other heavy metals such as Pb, Ni, and Cr did not accumulate in the kernels, husk, 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 fourth year of an ongoing 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 an Estherville sandy loam with an initial pH of 5.7 and Bray P1 of 17 ppm.

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 three 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 1989. Loading rates of Cd, Ni, Cr, and Pb based on the digest analysis and application rates were less than the annual maximum application rates set by the Minnesota Pollution Control Agency. A Gandy fertilizer spreader was used to broadcast applications of 0-0-60 (200 lbs/A) and 45-0-0 (195 lbs/A). Sludge ash and phosphate fertilizer were applied by hand. The entire plot area was disked to a depth of 4-6". A randomized complete block design with four replications was used. Field corn (Funks G-4100 hybrid) was planted on May 10, 1990 at a population of 32,000 plants/A in 30" rows along with a furrow application of Counter insecticide. The stand was very poor due to cool wet conditions and was therefore plowed up on June 14. Sweet corn (Jubilee) was planted on June 18 at a population of 25,000 plants/A in 30" rows. 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 14 at a depth of 18". Water samples were collected on September 4 and 13 and October 11, approximately 3 or 4 days after at least 1" of rainfall or irrigation was supplied. On August 3, 4 whole

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

[2] Extension Soil Scientist, Junior Scientist, Research Technician, respectively, Soil Science Department, University of Minnesota.

plants were sampled from each plot at the ends of the two middle rows. At this sampling, plant development corresponded to the 8-12 leaf stage. The entire plot was sidedressed with 70 lb N/A as ammonium nitrate on July 2 and 140 lb N/A as ammonium nitrate on July 19. Ear leaf samples were collected from each plot at the mid-silking stage (August 20). Plots (20' from the middle two rows) were harvested for unhusked, husked, and stover yields on September 13. Subsamples of stover, husk, and kernel plus cob were 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 1 N HCl. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

Soil samples were collected on September 4 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 and soluble salts were determined on a 1:1 soil - water mixture.

RESULTS

Soil and Water Samples. Elemental analyses of the water collected in the suction cup lysimeters are presented in Table 1. Concentrations of Cd, Pb, Ni, and Cr were generally below detection limits of the ICP spectrophotometer. Phosphorus concentrations did not show any consistent trend due to treatment. Other elements such as Cu, Zn and B were at background levels. 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 and the Bray P1 extractant extracted more P from the soil amended with ash than with fertilizer. 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. Soluble salts were not affected by treatment. Ammonium acetate and nitric acid extractable Na increased slightly with increasing ash rates. All nitric acid extractable elements except K and Co increased with ash applications. Of particular interest is 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). Soil pH and soluble salts were not affected by treatment. DTPA and nitric acid extractable Cu tended to increase with ash application. Nitric acid extractable Na, Fe, Cr increased with ash application. Concentrations of nitric acid extractable Cd and Cr were higher with ash application compared to 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 Cd tended to increase with increasing ash rates.

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 low P soils. Unhusked (green) and husked yield increased with ash and fertilizer application compared to the check. Yields were higher in phosphate fertilized plots compared to ash amended plots. Reasons for the differences in yield between the ash and fertilizer plots are not precisely known. Toxicity due to trace metals or high soluble salts does not appear to be involved. Stover yield increased with ash and fertilizer application compared to the control plot. There was no difference in stover yield between fertilizer and ash amended plots. These results clearly indicate that application of ash can increase yield, but the magnitude may not be the same as with fertilizer.

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 fertilizer source was superior to the ash source in supplying P. Both Cu and Zn concentrations tended to increase with ash applications; however, both of these nutrients are essential for plant growth and levels reported are well below those considered toxic to plants or animals. Although generally low, concentrations of Cd increased with ash application. The other heavy metals, Pb, Ni, and Cr 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 0-46-0 plots than with the ash plots. Phosphate fertilizer increased tissue Mn and Cr, but decreased Cu and Zn concentrations compared to the ash treatments. Concentrations of Cd increased in ear leaf tissue with both fertilizer and ash applications.

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 and Mg decreased and Ca increased when fertilizer was applied. Levels of Zn and Cu in stover were greater with ash application compared to P fertilizer application. Concentrations of Cd increased with increasing ash rate. Concentrations of P in the cob were not consistently affected by treatment (Table 9). Cob Zn significantly decreased when P fertilizer was applied. Levels of P in kernels increased with fertilizer and ash treatments compared to those in the control plots (Table 10). Kernel Zn, Cu, B, and Mn decreased with increasing ash and fertilizer application. Concentrations of Pb, Ni, Cr, and Cd in kernels were either at background levels or below detection limits of the ICP. Husk P increased with increasing ash and fertilizer application. Husk Zn increased with increasing ash application, but decreased with increasing fertilizer application. Concentrations of Cd in husk tissue increased with both ash and fertilizer application

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. For the first time in four years, there appeared to be some uptake of Cd by the plant. Concentrations of Cd were well below those considered toxic for plants or animals. Further experimentation at this same site is required to evaluate longer term effects of incinerator ash on element movement in the soil 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
Sept 4		ppm														
control	--	0.07	1.9	198	52	<0.33	0.05	9	0.03	0.17	<0.03	0.04	<0.66	<0.02	<0.02	<0.01
70	Fert.	0.11	2.7	300	78	<0.20	0.04	9	0.02	0.10	<0.03	0.05	<0.45	<0.03	<0.02	<0.01
140	Fert.	0.08	2.9	158	44	<0.20	0.04	10	0.05	0.05	<0.03	0.04	<0.50	<0.02	<0.02	<0.01
280	Fert.	0.08	4.3	335	87	<0.21	0.05	28	0.13	0.12	<0.03	0.05	<0.62	0.04	<0.02	<0.01
70	Ash	0.07	1.8	186	47	<0.20	0.04	14	0.03	0.04	<0.03	0.05	<0.37	<0.02	<0.02	<0.01
140	Ash	0.08	2.2	266	67	<0.39	0.16	11	0.08	0.11	<0.04	0.05	<1.30	<0.04	<0.02	<0.01
280	Ash	0.09	2.3	237	63	<0.20	0.04	11	<0.00	0.06	<0.03	0.05	<0.47	<0.02	<0.02	<0.01
Sept 13																
control	--	0.06	1.5	139	37	<0.20	<0.02	7	0.02	<0.04	<0.03	0.03	<1.90	<0.02	<0.02	<0.01
70	Fert.	0.10	2.1	246	63	<0.20	0.03	8	0.02	0.04	<0.03	0.04	<1.20	<0.03	<0.02	<0.01
140	Fert.	0.07	2.9	138	38	<0.20	<0.04	10	<0.05	<0.05	<0.03	0.04	<0.94	<0.03	<0.02	<0.01
280	Fert.	0.09	3.8	283	74	<0.20	0.03	21	0.09	0.06	<0.04	0.05	<3.91	0.03	0.02	0.01
70	Ash	0.05	1.2	122	31	<0.20	<0.02	7	0.01	<0.01	<0.03	0.04	<3.05	<0.02	<0.02	<0.01
140	Ash	0.08	1.8	187	47	<0.21	0.05	7	0.06	<0.06	<0.03	0.04	<1.62	<0.03	<0.02	<0.01
280	Ash	0.07	1.7	166	44	<0.20	0.03	8	<0.00	<0.01	<0.03	0.04	<1.63	<0.02	<0.02	<0.01
Oct 11																
control	--	0.05	2.0	201	53	<0.20	0.03	9	0.02	1.13	<0.03	0.03	<0.82	<0.03	<0.02	<0.01
70	Fert.	0.10	2.4	321	84	<0.20	0.04	10	0.02	0.47	<0.03	0.04	<0.56	<0.02	<0.02	<0.01
140	Fert.	0.08	2.5	153	43	<0.20	0.03	11	0.03	0.28	<0.03	0.04	<1.01	<0.02	<0.02	<0.01
280	Fert.	0.08	4.0	349	92	0.52	0.06	26	0.11	0.22	<0.06	0.04	<1.05	0.04	0.02	<0.01
70	Ash	<0.10	1.7	196	51	<0.20	0.04	14	0.02	0.17	<0.03	0.04	<0.48	<0.03	<0.02	<0.01
140	Ash	0.09	2.1	307	77	<0.47	0.12	12	0.10	<0.95	<0.04	0.05	<1.10	<0.05	<0.02	<0.01
280	Ash	0.09	2.3	225	61	<0.20	0.03	11	<0.00	<0.25	<0.03	0.04	<0.85	<0.02	<0.02	<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	Soluble Salts	BrayP1	OlsenP	NH_4OAc Extractable				DTPA Extractable							
						K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb P_2O_5/A			mmhos/cm	ppm													
Control	-	4.9	0.65	21.0	12.8	160	1749	254	8.0	96.7	67.5	1.4	1.01	1.39	3.02	0.07	0.12
70	Fert.	4.8	0.63	58.3	32.8	143	1777	246	8.3	103.1	72.6	1.4	0.97	1.55	3.50	<0.09	0.26
140	Fert.	4.8	0.60	118.5	63.8	161	1670	235	8.2	101.4	75.5	1.5	0.98	1.55	3.28	0.09	0.12
280	Fert.	4.9	0.63	208.0	108.8	141	1694	233	8.6	98.1	67.1	1.6	1.02	1.35	3.22	<0.09	0.12
70	Ash	4.8	0.65	82.0	40.5	165	1716	242	7.4	102.7	70.2	2.8	2.76	1.87	3.44	0.14	0.22
140	Ash	5.2	0.55	154.5	59.0	152	1848	291	10.3	88.7	44.8	4.5	4.86	2.32	3.33	<0.06	0.38
280	Ash	5.2	0.65	240.5	75.0	158	1882	312	11.9	86.0	31.5	7.3	8.07	2.24	3.21	0.07	0.55
Significance		*	NS	**	**	NS	NS	**	*	*	**	**	**	**	NS	-	**
BLSD(0.05)		0.4	-	22.4	10.3	-	-	36	3.1	14	26.2	0.7	0.78	0.35	-	-	0.16
Contrasts																	
Ctrl vs Rest		NS	NS	**	**	NS	NS	NS	NS	NS	NS	**	**	**	NS	-	*
Fert vs Ash		**	NS	**	**	NS	*	**	*	**	**	**	**	**	NS	-	**
Linear Fert.		NS	NS	**	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS
Linear Ash		**	NS	**	**	NS	*	**	**	**	**	**	**	**	NS	-	**
Quad Ash		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	-	75	179	2730	420	1645	185	9	146	5.1	3.5	1.3	5.47	5.00	0.79	0.31	1.48	93	0.93	0.53	16.2
70	Fert	118	163	2883	440	1786	214	10	170	5.5	3.6	1.3	6.31	5.80	0.92	0.40	1.69	102	1.03	0.57	18.0
140	Fert	203	187	2704	405	1750	220	8	177	5.2	3.5	1.2	5.92	5.39	0.91	0.33	1.66	94	1.08	0.57	18.0
280	Fert	326	172	2863	421	1881	260	11	184	5.8	3.7	1.3	6.37	5.28	1.05	0.36	1.70	97	1.10	0.61	19.4
70	Ash	189	188	2782	414	1768	214	10	166	8.0	7.6	1.3	6.62	5.42	1.28	0.54	1.64	96	1.01	0.63	18.7
140	Ash	392	180	3366	549	1942	249	15	170	13.4	14.7	1.4	8.27	5.84	2.28	0.88	1.75	102	1.02	0.62	19.4
280	Ash	675	195	3745	598	2181	300	20	179	20.7	24.7	1.6	10.55	6.08	3.67	1.37	2.08	114	1.10	0.73	20.9
Significance		**	NS	**	*	**	**	**	*	**	**	**	**	**	**	**	**	**	**	**	*
BLSD (0.05)		58	-	421	138	125	24	1.9	26	1.8	2.2	0.1	0.70	0.63	0.30	0.14	0.17	8.8	0.1	0.06	3
Contrasts																					
Ctrl. vs Rest		**	NS	*	NS	**	**	**	**	**	**	*	**	**	**	**	**	**	**	**	**
Fert. vs Ash		**	NS	**	**	**	**	**	NS	**	**	**	**	NS	**	**	**	**	NS	**	NS
Linear Fert.		**	NS	NS	NS	**	**	NS	**	NS	NS	NS	*	NS	NS	NS	*	NS	**	**	*
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	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	Soluble Salts	BrayP1	OlsenP	NH_4OAc Extractable K	Ca	Mg	Na	DTPA Extractable Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb P_2O_5/A			mmhos/cm	ppm													
Control	-	6.1	0.33	3.8	2.3	62	1617	261	8.9	28.2	9.6	0.2	0.55	<0.31	1.24	<0.03	<0.03
70	Fert.	5.9	0.35	5.0	2.8	67	1628	251	8.5	29.4	9.3	0.3	0.56	<0.30	1.74	<0.08	<0.03
140	Fert.	6.0	0.30	5.3	3.3	68	1621	255	8.8	29.4	9.3	0.3	0.60	<0.31	1.43	<0.02	<0.04
280	Fert.	6.0	0.40	9.0	6.0	87	1933	311	12.7	28.4	10.5	0.3	0.57	<0.34	1.64	<0.06	<0.03
70	Ash	6.1	0.40	4.8	2.8	71	1793	284	11.1	29.7	12.1	0.3	0.61	<0.31	1.64	<0.02	<0.04
140	Ash	6.2	0.38	5.5	3.0	66	1680	269	10.2	26.1	9.9	0.5	0.64	<0.42	1.36	<0.02	<0.04
280	Ash	6.1	0.33	6.5	4.0	71	1786	291	11.9	27.2	9.7	0.3	0.73	<0.37	1.44	<0.02	<0.06
Significance		NS	NS	**	**	NS	NS	NS	*	NS	NS	NS	NS	-	NS	-	-
BLSD (0.05)		-	-	2.6	2.0	-	-	-	3.3	-	-	-	-	-	-	-	-
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	*	-	NS	-	-
Linear Fert.		NS	NS	**	**	*	NS	NS	**	NS	NS	NS	NS	-	NS	-	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Linear Ash		NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	**	-	NS	-	-
Quad Ash		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	-	47	41	2289	572	1545	306	11	48	3.9	2.4	0.8	4.74	3.37	1.15	0.22	1.5	64	0.69	0.55	8.1
70	Fert.	34	44	2316	565	1572	297	12	46	4.1	2.6	0.9	4.66	4.40	1.15	0.23	1.5	71	0.67	0.54	9.2
140	Fert.	43	43	2344	565	1523	288	12	46	4.0	2.7	0.8	4.72	3.69	1.12	0.22	1.5	66	0.68	0.55	10.2
280	Fert.	51	44	2275	569	1506	305	13	52	4.1	2.7	0.8	4.61	4.17	1.14	0.23	1.5	65	0.66	0.55	10.4
70	Ash	43	44	2633	642	1621	323	13	54	4.5	2.9	0.9	4.89	4.57	1.26	0.27	1.6	72	0.75	0.57	9.6
140	Ash	59	42	2370	617	1561	327	13	55	4.1	2.7	0.9	4.68	3.66	1.29	0.28	1.6	68	0.69	0.57	10.0
280	Ash	42	41	2408	661	1663	377	14	49	4.9	3.1	0.9	5.04	3.99	1.38	0.26	1.7	75	0.73	0.59	10.9
Significance		NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Contrasts																					
Ctrl vs Rest		NS	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	NS
Linear Fert.		NS	NS	NS	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	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	Soluble Salts	Bray P1	Olsen P	NH_4OAc Extractable K	Ca	Mg	Na	DTPA Extractable Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb. P_2O_5/A			mmhos/cm	ppm													
Control	-	7.2	0.25	3.5	2.0	57	1511	205	6.1	15.3	10.8	0.2	0.62	<0.33	0.72	<0.06	<0.05
70	Fert.	6.9	0.23	4.0	2.8	65	1134	182	6.7	16.4	10.7	0.3	0.50	<0.42	1.10	<0.08	<0.04
140	Fert.	7.2	0.25	4.5	2.8	57	1333	181	4.3	14.3	10.2	0.2	0.54	<0.30	0.55	<0.09	<0.05
280	Fert	7.2	0.23	6.3	4.3	59	1470	173	6.2	15.4	12.1	0.2	0.58	<0.39	0.81	<0.06	<0.05
70	Ash	7.3	0.23	3.5	2.3	62	1329	190	6.0	14.7	14.1	0.2	0.60	<0.27	0.85	<0.07	<0.04
140	Ash	7.4	0.25	5.8	3.8	49	1953	193	5.6	14.3	10.1	0.3	0.66	<0.30	0.76	<0.04	<0.07
280	Ash	7.3	0.25	8.3	4.3	60	1527	180	6.3	17.4	13.2	0.3	0.72	<0.41	1.17	<0.07	<0.03
Significance		NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
BLSD (0.05)		-	-	3.5	2.0	-	-	-	-	-	-	-	-	-	-	-	-
Contrasts																	
Ctrl vs Rest		NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Fert. vs Ash		**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Linear Fert.		NS	NS	*	**	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
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 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	-	118	38	3019	2062	992	378	11	77	3.0	2.3	1.0	3.09	3.67	1.01	0.21	1.5	40	0.65	0.36	11.9
70	Fert.	98	41	3390	1230	951	344	9	63	2.7	1.9	0.8	2.96	5.07	0.98	0.20	1.3	37	0.54	0.34	8.2
140	Fert.	109	41	7208	1957	849	340	11	71	2.6	2.0	1.0	2.72	3.14	0.94	0.20	1.4	38	0.60	0.31	12.5
280	Fert.	125	45	8399	2971	891	374	12	87	2.8	2.5	1.6	3.00	4.83	0.97	0.23	1.6	41	0.67	0.32	15.8
70	Ash	112	39	5381	2132	860	361	10	80	2.8	2.2	1.0	2.79	9.51	0.93	0.22	1.4	42	0.63	0.32	10.0
140	Ash	147	38	6177	4572	918	453	15	106	3.5	2.9	1.5	3.23	4.64	1.20	0.26	1.8	39	0.83	0.37	22.7
280	Ash	133	40	6317	2355	958	394	13	89	3.3	2.8	1.1	3.24	5.80	1.06	0.27	1.5	47	0.65	0.36	11.5
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contrasts																					
Crtl vs Rest		NS	NS	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	NS	NS	NS	NS
Linear Fert.		**	NS	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	*	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 5. Effect of sludge ash and phosphate fertilizer on whole plant dry weight at the 8-12 leaf stage, green yield and husked yield and dry yield for ears, husks and stover.

Treatment	P Source	Early plant yield 8-12 leaf	Green yield	---------- Husked Ears ---------- >5.5"	<5.5"	Unuseable	Total	----- Dry Matter ----- Ears	Husks	Stover	% Moisture in kernals
lb P_2O_5/A		g dw	T/A	T/A	T/A	T/A	T/A	Lbs/A	Lbs/A	Lbs/A	
Control	-	114.0	4.62	1.62	1.88	0.12	3.62	1550	345	4070	76.8
70	Fert.	168.3	5.89	3.20	1.25	0.10	4.56	2106	423	4785	74.5
140	Fert.	176.5	6.30	2.95	1.52	0.11	4.59	2128	545	5129	75.0
280	Fert.	188.3	6.16	3.33	1.18	0.12	4.63	2240	496	5112	75.8
70	Ash	146.5	5.64	2.21	1.93	0.13	4.27	1917	441	4525	74.5
140	Ash	164.8	5.84	2.22	1.81	0.09	4.12	1936	571	4903	73.8
280	Ash	182.8	5.62	2.46	1.68	0.15	4.28	2002	455	4642	74.5
Significance		**	**	**	NS	NS	**	**	*	*	**
BLSD (0.05)		22.2	0.42	0.63	-	-	0.30	186	141	651	0.01
Contrasts											
Control vs Rest		**	**	**	NS	NS	**	**	**	**	**
Fert. vs Ash		*	**	**	**	NS	**	**	NS	NS	*
Linear Fert.		**	**	**	NS	NS	**	**	*	**	NS
Quad. Fert.		**	**	**	NS	NS	**	**	*	*	**
Linear Ash		**	**	*	NS	NS	**	**	NS	NS	**
Quad. Ash		*	**	NS	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	-	2.92	0.25	4.86	0.45	0.35	63	139	28	48	46	6.7	6.4	3.0	1.50	1.0	0.38
70	Fert.	2.82	0.30	4.40	0.45	0.30	53	126	26	51	35	4.8	6.3	3.0	1.54	1.0	0.34
140	Fert.	2.76	0.33	4.22	0.43	0.30	50	120	22	47	28	3.4	5.8	1.7	1.08	1.5	0.40
280	Fert.	2.76	0.43	3.93	0.47	0.32	54	129	25	48	24	3.0	5.6	<1.5	0.99	0.8	0.29
70	Ash	2.90	0.28	4.66	0.46	0.32	53	127	27	50	46	6.0	6.0	1.8	1.17	0.8	0.54
140	Ash	2.92	0.31	4.60	0.47	0.32	52	129	26	45	49	6.2	6.1	3.0	1.43	0.9	0.49
280	Ash	2.78	0.33	4.36	0.47	0.34	47	117	24	38	52	6.1	6.1	3.3	1.51	1.0	0.65
Significance		NS	**	**	NS	NS	*	*	NS	**	**	**	*	-	NS	NS	NS
BLSD (0.05)		-	0.02	0.40	-	-	11	16	-	5	7	0.8	0.6	-	-	-	-
Contrasts																	
Ctrl vs Rest		NS	**	**	NS	*	**	**	NS	NS	*	**	*	-	NS	NS	NS
Fert vs Ash		NS	**	**	NS	NS	NS	NS	NS	**	**	**	NS	-	NS	NS	**
Linear Fert.		NS	**	**	NS	NS	NS	NS	NS	NS	**	**	**	-	*	NS	NS
Quad Fert.		NS	NS	NS	NS	*	**	**	NS	NS	*	**	NS	-	NS	NS	NS
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	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	-	3.24	0.30	2.60	0.77	0.44	42	337	48	81	27	10.1	4.9	4.6	1.7	1.0	0.44
70	Fert.	3.22	0.33	2.67	0.83	0.43	38	309	52	86	23	8.4	5.2	4.6	1.7	1.0	0.47
140	Fert.	3.15	0.35	2.74	0.87	0.44	40	314	51	95	20	6.7	5.2	4.9	1.7	1.1	0.51
280	Fert.	3.19	0.48	2.61	0.97	0.48	39	319	55	98	19	5.8	5.7	4.9	1.7	1.7	0.53
70	Ash	3.09	0.31	2.62	0.81	0.42	38	299	47	84	32	9.3	4.8	4.5	1.6	1.0	0.47
140	Ash	3.33	0.34	2.45	0.94	0.48	39	324	50	74	38	9.8	5.0	4.6	1.7	1.0	0.52
280	Ash	3.31	0.36	2.45	0.97	0.50	39	322	52	67	40	9.9	5.1	4.5	1.6	1.0	0.61
Significance		**	**	*	**	**	NS	NS	NS	*	**	**	NS	NS	NS	NS	*
BLSD (0.05)		0.13	0.02	0.23	0.06	0.05	-	-	-	20	4	0.7	-	-	-	-	0.1
Contrasts																	
Ctrl vs Rest		NS	**	NS	**	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	*
Fert. vs Ash		NS	**	**	NS	NS	NS	NS	NS	**	**	**	*	NS	NS	NS	NS
Linear Fert.		NS	**	NS	**	*	NS	NS	NS	*	**	**	*	NS	NS	*	*
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS
Linear Ash		*	**	NS	**	**	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	**
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 8. Effect of sludge ash and phosphate fertilizer on elemental composition of stover at harvest.

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	-	1.72	0.16	2.45	0.39	0.30	45	127	29	47	29	6.5	6.3	1.9	0.8	0.7	0.28
70	Fert.	1.52	0.16	2.33	0.36	0.24	45	118	24	41	17	4.2	5.4	<1.3	0.7	1.1	0.20
140	Fert.	1.62	0.20	2.31	0.42	0.27	40	122	27	47	15	3.4	5.7	<1.5	0.7	0.6	0.23
280	Fert.	1.61	0.30	2.22	0.46	0.28	44	122	30	50	12	2.6	6.0	1.5	0.7	0.6	0.27
70	Ash	1.60	0.17	2.30	0.39	0.27	46	124	31	42	27	6.0	6.0	<2.0	0.8	0.7	0.30
140	Ash	1.57	0.19	2.41	0.43	0.28	45	121	32	37	33	5.8	6.1	2.0	0.9	0.7	0.36
280	Ash	1.55	0.20	2.39	0.41	0.26	48	117	25	31	31	5.1	5.5	<1.5	0.7	0.6	0.43
Significance		*	**	NS	**	NS	NS	NS	NS	**	**	**	**	-	NS	NS	NS
BLSD (0.05)		0.1	0.23	-	-	-	-	-	-	6	5	0.6	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	-	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
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	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	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		%			ppm												
Control	-	0.81	0.11	0.79	310	663	<2.9	14	12	10	37	5.1	3.1	<0.84	0.40	0.42	<0.10
70	Fert.	0.71	0.10	0.67	264	498	<2.6	13	12	8	26	3.6	2.5	<0.84	0.42	0.41	<0.11
140	Fert.	0.77	0.11	0.68	283	507	<2.0	14	9	7	19	2.5	2.5	<0.84	0.38	0.43	<0.08
280	Fert.	0.73	0.13	0.68	300	483	<2.2	15	11	7	15	1.7	2.3	<0.84	0.42	0.50	<0.14
70	Ash	0.80	0.12	0.75	329	603	<2.2	14	12	10	38	4.8	2.9	<0.84	0.46	0.48	<0.10
140	Ash	0.77	0.11	0.77	303	540	<2.2	14	11	8	37	4.3	2.7	<0.84	0.42	0.45	<0.13
280	Ash	0.76	0.13	0.77	322	558	<2.4	14	15	7	43	4.1	2.8	<0.84	0.49	0.48	<0.20
Significance		*	**	NS	NS	**	NS	NS	NS	**	**	**	*	-	NS	NS	-
BLSD (0.05)		0.08	0.02	-	-	93	-	-	-	2.2	6	0.4	0.5	-	-	-	-
Contrasts																	
Ctrl vs Rest		*	NS	NS	NS	**	-	NS	NS	**	**	**	**	-	NS	NS	-
Fert. vs Ash		*	NS	**	**	**	-	NS	NS	NS	**	**	**	-	NS	NS	-
Linear Fert.		NS	**	NS	NS	**	-	NS	NS	**	**	**	**	-	NS	NS	-
Quad Fert.		NS	*	NS	NS	**	-	NS	NS	*	**	**	NS	-	NS	NS	-
Linear Ash		NS	*	NS	NS	*	-	NS	NS	**	*	**	NS	-	NS	NS	-
Quad Ash		NS	NS	NS	NS	NS	-	NS	NS	NS	NS	NS	NS	-	NS	NS	-

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

Table 10. Effect of sludge ash and phosphate fertilizer on the elemental composition of kernel 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	-	2.54	0.47	1.43	292	2221	5.3	34	12	20	38	6.1	5.0	<1.0	0.7	0.50	0.10
70	Fert.	2.38	0.49	1.37	247	2157	5.1	33	9	18	35	4.8	4.4	1.0	0.7	0.54	0.11
140	Fert.	2.37	0.53	1.42	261	2309	4.9	35	9	17	35	3.7	4.6	<1.1	0.6	1.06	0.09
280	Fert.	2.33	0.59	1.42	243	2373	4.6	36	7	18	35	2.2	4.1	1.2	0.6	0.57	0.11
70	Ash	2.42	0.53	1.46	279	2314	4.7	37	9	19	40	5.5	4.9	<0.9	0.7	0.85	0.18
140	Ash	2.34	0.54	1.42	250	2338	4.9	38	8	17	41	4.7	4.4	<1.1	0.7	0.55	0.11
280	Ash	2.40	0.62	1.49	277	2582	4.5	40	10	16	46	4.9	4.6	<1.0	0.7	0.55	0.15
Significance		NS	**	NS	**	*	NS	*	NS	*	**	**	**	-	NS	NS	NS
BLSD (0.05)		-	0.45	-	31	280	-	5.5	-	2.7	2.1	0.7	0.4	-	-	-	-
Contrasts																	
Ctrl vs Rest		**	**	NS	**	NS	NS	NS	NS	**	NS	**	**	-	NS	NS	NS
Fert. vs Ash		NS	NS	NS	*	NS	NS	**	NS	NS	**	**	*	-	NS	NS	NS
Linear Fert.		**	**	NS	**	NS	NS	NS	NS	NS	**	**	NS	-	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	-	NS	NS	NS
Linear Ash		NS	**	NS	NS	**	NS	*	NS	**	**	**	**	-	NS	NS	NS
Quad Ash		*	NS	NS	*	NS	NS	NS	NS	NS	NS	*	*	-	NS	NS	NS

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

Table 11. Effect of sludge ash and phosphate fertilizer on the elemental composition of husks 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	-	0.74	0.09	0.51	737	1161	14	19	16	16	24	2.2	3.4	<1.1	<0.4	0.38	0.10
70	Fert.	0.88	0.12	0.62	836	1271	14	21	15	16	21	2.4	3.8	<1.2	<0.4	0.40	0.13
140	Fert.	0.87	0.13	0.64	831	1219	14	22	14	16	17	1.9	3.8	<1.2	0.4	0.43	0.13
280	Fert.	0.84	0.16	0.56	819	1207	12	20	11	16	14	1.0	3.4	<1.2	<0.4	0.37	0.14
70	Ash	0.72	0.10	0.49	734	1138	13	18	13	14	23	1.7	3.3	<1.2	<0.3	0.36	0.10
140	Ash	0.85	0.13	0.63	915	1273	15	23	13	14	30	2.6	3.8	<1.1	<0.4	0.41	0.21
280	Ash	0.74	0.12	0.52	885	1219	13	19	14	12	28	1.6	3.6	<1.1	<0.4	0.42	0.17
Significance		NS	**	NS	*	NS	NS	NS	NS	*	**	**	NS	-	-	NS	**
BLSD (0.05)		-	0.02	-	125	-	-	-	-	3.3	3	0.8	-	-	-	-	0.05
Contrasts																	
Ctrl vs Rest		NS	**	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	*
Fert. vs Ash		*	**	NS	NS	NS	NS	NS	NS	*	**	NS	NS	-	-	NS	NS
Linear Fert.		NS	**	NS	NS	NS	NS	NS	*	NS	**	**	NS	-	-	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	-	-	*	NS
Linear Ash		NS	**	NS	**	NS	NS	NS	NS	**	**	NS	**	-	-	NS	**
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	-	-	NS	*

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

UREA APPLICATION STRATEGIES ON CORN GRAIN YIELDS AND STALK NITRATE-N CONCENTRATIONS

M.A. Schmitt[1/]

ABSTRACT: Urea applications are attractive to corn producers due to their application accuracy, speed and safety. However, volatilization concerns are present when topdress application are made and not incorporated. The urease inhibitor NBPT (N-(n-butyl) thiophosphoric triamide) was evaluated, along with nitrogen rates, times of application and methods of application, on grain yields and postharvest stalk nitrate-N concentrations of corn at two sites in east-central Minnesota. At one of the sites, there was not a grain yield response to N fertilizer, thus there was no effect of the inhibitor. At the N responsive site, the inhibitor was successful in increasing yields compared to the broadcast treatments without an inhibitor when there were conditions present for urea volatilization after application. Nitrate-N concentrations were measured in stalk samples as an indicator of N excess or deficiency during the season. At both sites, relative nitrate-N concentrations were significantly affected by the urea treatments, even when there was not a yield response.

Introduction

The use of urea as a primary N fertilizer product is increasing due to its ease of handling, cost competitiveness and its application options. The primary agronomic liability of urea is its volatilization potential. While incorporation with tillage and injection application systems minimize this volitilization potential, many farmers would like to reduce the necessity of this tillage operation. A urease inhibitor (N-(n-butyl) thiophosphoric triamide) also minimizes volatilization potential by chemically inhibiting the bacteria necessary for the volatilization process to occur. While the inhibitor has been shown to work well in the laboratory, more research is needed from field studies to evaluate its niche in nitrogen (N) management and application strategies.

The objective of this trial is to measure the effect of a urease inhibitor on corn grain yields when urea is the N source. This will be accomplished by evaluating several rates of N to determine overall N response at each site and with different application methods.

Material and Methods

Experimental sites were established on two farmer-cooperator farms in 1990. One was on a Waukegon/Dakota loam soil in Dakota county. Soybeans had been the previous crop and the field has a history of conservation tillage. The second site was in Isanti county on a Alstad fine sandy loam soil. Continuous corn with conservation tillage practices were part of the field history.

All crop management decisions and operations--with the exception of N applications--were conducted by the farmer cooperators according to their individual cropping system programs. Excellent corn stands were obtained and the pest management programs at both sites was excellent.

The N management treatments consisted of a combination of N rates, application methods and inclusion of the urease inhibitor NBPT. Two times of N application were used, an early sidedress application and a late sidedress application. At the early time of application, urea rates of 50, 100 and 150 lbs N/acre were applied as broadcast applications with and without the inclusion of the urease inhibitor NBPT. The second date of application included these treatments and also included urea placed in subsurface bands at 50, 100 and 150 lbs N/acre. There was also a control plot included in this randomized complete block design.

Grain yields and moisture contents were measured after physiological maturity had been attained. Within each plot, two-20 ft sections of row were hand-harvested. At the same time, basal stalk sections, were taken from 12 plants within the harvested area to be analyzed for nitrate-N concentrations. These samples were collected by removing the section of stalk that was between 6 and 14 inches above the soil surface.

[1/] M.A. Schmitt is Extension Soil Scientist in the Department of Soil Science, University of Minnesota.

Results and Discussion

The Isanti county site produced yields that were quite high and contained a great deal of variability both betweeen and among treatments (Table 1). It was also discovered that this site had a high residual nitrate-N amount in the third foot of the soil profile. Therefore, the statistical analysis of the yield data from this site concluded that there was no significant treatment effects and the resulting evaluation of individual main effects, such as urease inhibitors, is unwarranted.

The postharvest stalk nitrate evaluation did indicate statistically significant differences among treatments and between levels of main effects (Table 1). There was an linear response in stalk nitrates at the four N application rates even though the yields were not significantly different. Similarly, the stalk nitrate concentrations were highly correlated to the main effect yields for the urease inhibitor and the time of application.

The Dakota county site soil was coarser-textured than was the Isanti site and had very little residual nitrate-N in its profile. There was a statistically significant response of grain yield to N rates up to the highest N rate applied, 150 lbs N/acre (Table 1). Based on the site location, previous crop and yield history, the optimum N fertilizer rate according to University of Minnesota recommendations would be approximately 150 lbs N/acre.

Two application times were evaluated in this study since many corn producers could conceivably broadcast urea right after emergence or later as a sidedress treatment if volatilization were not a concern. The early urea application at Dakota site was rained upon within 24 hours after the urea was applied and, in the month of June, rainfall amounts were well above average. Thus, the early applications resulted in lower yields than the later applications, most likely due to leaching events.

The urease inhibitor did not have an effect at the early application date due to the beforementioned rainfall event after treatment application. However, the inhibitor did have a positive effect on grain yields with the later urea applications when comparing the broadcast treatments (Table 1). Injection applications of urea, although not an option for most farmers, were still the highest yielding treatments.

Stalk nitrate concentrations at maturity were highly correlated to grain yield and were a function of the urea treatments at the Dakota county site (Table 1). In the overall calibration and correlation of of the stalk nitrate concentrations, there is a distinct linear-plateau response curve at both sites (Figures 1 and 2). This is in good agreement with recent results from Iowa State University (Binford, et al., Agron. J. 82:124-129). Although the Isanti site has more variability in its graph, the variability associated with the yields and the subsurface residual nitrate amounts must be considered. Overall, the stalk nitrate concentrations provided sound relative indication of excess N applications.

Table 1. Corn grain yields and postharvest stalk nitrate-N concentrations as a function of urea application management strategy, Dakota and Isanti counties, Minnesota, 1990.

N Rate	Application Date[1]	Application Method[2]	Chemical	Grain Yield Dakota	Grain Yield Isanti	Stalk Nitrate-N Dakota	Stalk Nitrate-N Isanti
lb N/A				---- bu/A ---		----- %N -----	
0	-	-	-	91.2	148.1	0.0045	0.0286
50	Early	Brd.	-	168.1	161.7	0.0066	0.0239
50	Early	Brd.	NBPT	159.1	167.6	0.0071	0.0333
100	Early	Brd.	-	172.2	146.9	0.0057	0.1314
100	Early	Brd.	NBPT	179.0	171.6	0.1479	0.2961
150	Early	Brd.	-	184.8	167.2	0.0371	0.4290
150	Early	Brd.	NBPT	197.1	168.0	0.1784	0.5409
50	Late	Brd.	-	137.0	145.0	0.0056	0.0424
50	Late	Brd.	NBPT	176.1	124.6	0.0075	0.0367
50	Late	Inj.	-	168.1	147.2	0.0067	0.0541
100	Late	Brd.	-	185.0	154.7	0.1350	0.0250
100	Late	Brd.	NBPT	180.8	150.2	0.0987	0.1676
100	Late	Inj.	-	197.7	160.8	0.0174	0.1193
150	Late	Brd.	-	199.5	140.3	0.2457	0.1177
150	Late	Brd.	NBPT	208.9	153.1	0.3194	0.3086
150	Late	Inj.	-	210.3	162.1	0.3845	0.2116
Pr.>F				0.0001	0.1200	0.0026	0.0001
FLSD (0.10)				23.0	-	0.1341	0.1323
Main Effects							
N rate:			0	91.2	148.1	0.0045	0.0286
			50	156.8	149.8	0.0067	0.0341
			100	182.5	155.9	0.0968	0.1279
			150	197.6	157.1	0.1951	0.2369
N application time:			Early	176.7	163.8	0.0638	0.2425
			Late	181.2	144.7	0.1353	0.1163
Urease Inhibitor			None	174.5	152.6	0.0726	0.1283
			NBPT	183.5	155.9	0.1265	0.2305

[1]-Early application dates were May 22 at both sites and late application dates were June 25 at Dakota and July 2 at Isanti counties.

[2]-Application methods consisted of broadcast (brd.) and injected (inj.) treatments.

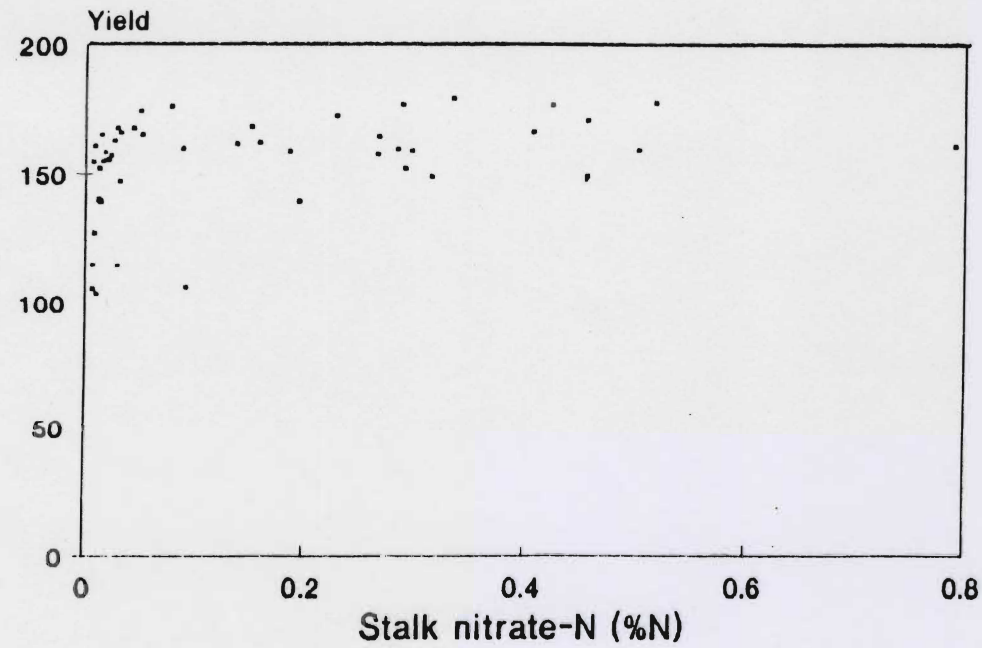

Figure 1. Grain yields regressed as a function of basal stalk nitrate-N concentrations, Isanti County, 1990.

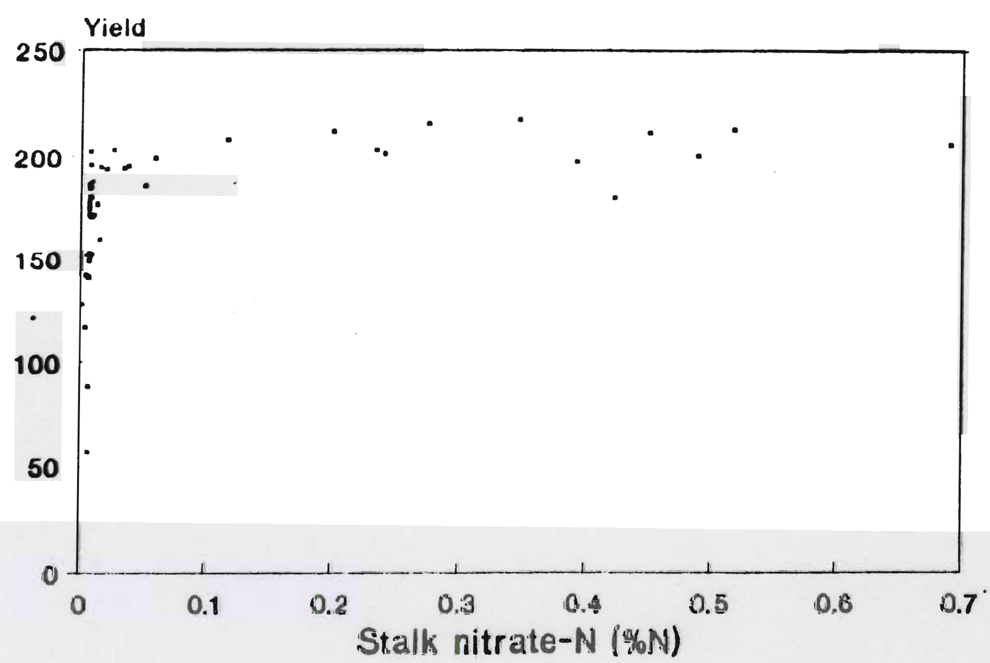

Figure 2. Grain yields regressed as a function of basal stalk nitrate-N concentrations, Dakota County, 1990.

CALIBRATION AND CORRELATION OF SOIL N TESTS FOR CORN'S N RECOMMENDATIONS[1]

M.A. Schmitt, G.W. Randall, G.W. Rehm, G.L. Malzer[2]

Throughout the academic community there is a pressing need to develop a system of analytical testing procedures with correct interpretation that can be used to provide more precise, efficient, and environmentally sound N rate recommendations for corn. Because there is presently not a good predictive tool to assess availability of soil N, application rates of N are often greater than needed by the plant. The potential impacts of this excess N on groundwater quality have created pressure from the farming and non-farming public for refined N recommendations.

Objectives

The primary objective of this project is to develop an N soil test that will enable farmers to apply optimum rates of N for corn under a wide variety of soil, crop, and climatic conditions. Specific objectives include:

1. Evaluate different tests or combination of tests for determining potentially available N before and during the growing season for use in predicting fertilizer N requirements for corn.

2. Determine the optimum time or times that soil samples should be collected to enable an accurate prediction of N needed by corn.

3. Determine the optimum depth of soil sampling that relates best with potentially available soil N.

Methods and Materials

Twenty-nine experimental sites were established in conjunction with participating organizations in 1989 and 1990. The sites were located primarily on farmer-cooperator fields in south-central, southeastern, and east-central Minnesota. Soils in these are derived from glacial till, loess, and glacial outwash, respectively. All sites had well-documented fertilization and manure records and had a range of previous crops.

Two sets of treatments were used at these locations. One set had a series of six preplant fertilizer N rates, four sidedress fertilizer N rates, and three split N rates. The second treatment scheme had four sidedress N rates. Both sets of treatments included a control treatment. The sidedress and split treatments were applied in mid to late June when the corn was in the V5 stage of growth.

Soil samples were collected four times each year: 1) preplant, approximately two weeks before planting, 2) about three weeks after planting, when the corn was in the V2 stage of growth, 3) about 5 weeks after planting, at the V5 growth stage, and 4) after harvest. Only control plots and plots receiving preplant N were sampled before harvest. All plots were sampled after harvest. Soil samples were collected in 1-foot increments to a depth of five feet for the preplant and postharvest samplings and to a depth of three feet for the in-season samplings. The 5-foot samples were collected from two subsamples taken with a hydraulic probe while the in-season samples were collected using hand probes and contained at least six cores per sample.

All soil samples were analyzed for ammonium-N and nitrate-N using a Wescan Autoanalyzer. All samples, except those taken after harvest, were also analyzed for two forms of mineralizable N. The difference in these two methods is the extraction procedure. One method used a phosphate-borate buffer extractant; the other method used a hot potassium chloride extractant. Preplant soil samples were also analyzed for total N and total C for soil characterization purposes.

Stover and grain yields were measured from each plot after physiological maturity. Total Kjeldahl N was measured in the stover and grain, and nitrate-N was measured in the basal stalk section of the corn plants after maturity. Rainfall and temperature records were recorded until the V5 growth stage at each site or taken at a nearby weather reporting station.

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[1] This project has received direct support from Farmland Industries, Tennessee Valley Authority, Southern Experiment Station, and the Garvin Brook Watershed Project.

[2] Schmitt and Rehm are Extension Soil Fertility specialists, St. Paul, Randall is Soil Scientist, Southern Experiment Station, Waseca, and Malzer is Soil Scientist, St. Paul, all with the University of Minnesota.

A randomized complete-block design with four replications was used at all sites. Plot size ranged from 10 to 15 feet wide (all with 30" rows) by 40 to 60 feet long. While data from each site will be subject to descriptive statistical analysis that will assist in interpretation, the pooling of the data across locations and the resulting regressions and analyses of variance will be paramount.

Results and Discussion

Grain yields

Grain yield response to N rates were lower than expected in 1989, with 7 of the 14 locations not responding to additional fertilizer N (Table 1). None of these sites had received manure applications in the year previous to these trials, and since alfalfa was not a previous crop, all of these sites would have had N fertilizer recommended by University of Minnesota guidelines. Only one of the sites not responding to fertilizer N had soybeans as the previous crop, while three of the sites with soybeans as a previous crop had a fertilizer N response up to 60 lb N/acre. This may be important since 1988 was a drought year and no fertilizer N would have been applied to these soybean fields. Therefore, residual N would be of minor significance.

In 1990, four sites did not respond to fertilizer N, although one of these sites had alfalfa as a previous crop (Table 2). Six of the 15 sites had an optimum N response of 60 lb N/acre. Rye, soybeans, and corn were all previous crops for these 60-lb N rate responses. For those five sites that responded to greater than 60 lbs N/acre, the previous crops included oats, soybeans, and corn (3).

Preplant, sidedress, and split N applications were compared at seven sites over the two years,. There were no distinct yield advantages associated with specific application methods in this study. At three of the seven site-years, there was no response to N, so no application method differences are possible.

Preplant N effects on soil N tests

Seven environments that received preplant N applications had nitrate-N and ammonium-N measured on each of the plots when the corn was in the V2 and V5 stage of growth. These measurements are indicative of the recovery of the added N as inorganic N fractions.

Already at the V2 stage of growth, nitrate-N concentrations had increased linearly as the preplant N applications increased at all seven site-years (Tables 3 and 4). Although the majority of the nitrate-N increase is in the top foot of soil, in all cases, the nitrate-N concentrations roughly doubled between the 0 and 180 lbs N/acre rate in the 1-2 foot sample, indicating some downward nitrate movement in this relatively short period of time between application and sampling.

Ammonium-N concentrations also increased significantly as the N application rate increased at the V2 stage of corn growth at all environments except at the Isanti location in both years. Except for the Olmsted site in 1989, the ammonium-N increases occurred primarily in the top foot of soil.

Nitrate-N concentrations at the V5 stage of corn growth were still a function of the preplant N application rate in both the 0-1' and 1-2' samples (Tables 3 and 4). The magnitude of these concentrations were greater than at the V2 sampling stages. This would be expected simply due to nitrification of the urea fertilizer. This is somewhat evident in the decrease in ammonium-N concentrations from the V2 to V5 sampling times and the proportional increase in nitrate-N concentrations. Very little effect of preplant N on ammonium-N concentrations was noticed with any of the V5 samples.

Soil N concentrations in control plots

In plots that received no preplant N additions, the change in N test levels is indicative of the N transformations occurring in each particular soil. Since N processes are dependent on inherent soil properties, the sites are categorized by the soil's parent material.

At the sites where the soil is derived from glacial outwash, there was no distinct pattern regarding the effect of sampling time on soil nitrate-N concentrations (Tables 5 and 6). The nitrate-N is primarily in the top foot of soil except at the Isanti-1, 1989 and Isanti, 1990, locations where a significant amount of nitrate is measured deeper. Ammonium-N concentrations increase at these sites as the sampling time proceeded later into the growing season. The amount of N measured using a phosphate-borate buffer extraction, which includes ammonium-N, also increased slightly with the later sampling dates. The majority of this mineralizable N was in the top foot of soil.

With loess parent material, nitrate-N concentrations exhibited no patterns of increase or decrease with time of sampling. There was a wide range of nitrate concentrations within each site based on sampling time and/or depth as well as between environments. Ammonium-N concentrations were generally greatest in the 0-1' sample and did not show a relationship between quantity and time of sampling. The N measured with the phosphate-borate extractant ranged greatly depending on site and year. There was consistency in this N value between sampling times at all sites in 1990 as well as some of the 1989 sites.

Sampling time had little effect on the nitrate-N concentrations for those sites derived from glacial till. While most of the sites had the majority of the nitrate-N in the top 1', some of the sites had appreciably more nitrate-N in the 1-2' and 2-3' samples. With just a couple of exceptions, the combined ammonium-N and mineralizable N concentrations were consistent among sampling times and, in 1989, were consistent among all of the till locations.

The overall effect of sampling time and sampling depth is summarized for nitrate-N concentrations in Table 7. Within one particular sampling time, the correlations between the depths had strong positive correlations. Thus, if there is a lot of nitrate-N in the 0-1' sample compared to other sites, there is relatively more nitrate-N in the lower depths' samples. Contrarily, when the time of sample changes, regardless of whether the depth is constant or not, there is a poor correlation in the numbers. Hence, knowing what is happening at one sampling date was not very useful in predicting what will happen at another sampling date. The correlation results were consistent in both years of the project.

Summary

Grain yield responses to fertilizer N have been relatively low for the first two years of this project. Some of these lower than predicted responses can be attributed to some relatively high soil N concentrations. However, there has not been good consistency between soil N concentrations and sampling date and N form. Regression equations (not reported here) have been very inconsistent in fitting the data between sites and years. Until more data can be collected to develop better prediction equations, soil N tests should be used only to identify excess N scenarios.

Table 1. Corn grain yields as function of N application rate and timing, 1989.

N Treatment[1/]	Waseca-1 Corn	Olmsted Soybeans	Winona-1 Corn	Isanti-1 Corn	Waseca-2 Soybeans	Waseca-3 Soybeans	Steele Corn	Houston Corn	Winona-2 Corn	Isanti-2 Soybeans	Chisago Corn	Dakota Soybeans	Waseca-5 Oats	Waseca-4 Corn
lb/A								bu/acre[2/]						
PP 0	107.8e	162.7e	185.7	131.6	146.3b	137.6b	178.4	175.4	133.1c	63.7b	98.7bc	150.5	105.6	182.1
30	148.1cd	176.4d	174.5	137.3								141.8	111.4	
60	157.5abc	178.3cd	178.2	141.2								150.8	115.2	
90	160.2abc	187.8abcd	193.6	142.8								151.2	112.8	
120	166.7ab	185.7abcd	180.0	124.4								144.9	110.7	
150	166.1ab	189.5abc	182.4	151.1								159.6	110.4	
180	167.1a	192.3a	177.9	140.2								161.0	113.0	
SD 60	145.1d	183.2abcd	178.6	153.0	166.3a	149.0a	181.9	177.7	143.5bc	88.5a	101.1bc			178.5
90	152.7cd	190.0ab	182.6	133.4	165.0a	152.6a	190.6	175.7	158.1ab	90.4a	80.2c			178.1
120	154.6bcd	187.8abcd	193.3	136.0	166.9a	154.7a	185.1	176.7	168.8a	95.4a	110.0ab			168.9
150	160.4abc	184.2abcd	173.0	152.4	167.1a	150.0a	171.4	175.8	156.4ab	90.9a	123.8a			173.2
60+30	157.7abc	179.0bcd	185.4	127.4										
60+60	158.2abc	179.0bcd	178.5	123.6										
60+90	160.3abc	193.2a	186.1	128.2										
Pr>F	0.000	0.008	0.605	0.114	0.025	0.071	0.278	0.996	0.072	0.006	0.033	0.417	0.897	0.435
LSD(.10)	12.5	11.7			11.2	10.0			15.4	12.7	21.1			

[1/] Nitrogen applications were made a preplant (PP), sidedress (SD) of split (preplant + sidedress) applications.

[2/] Grain yields at each location are statistically similar if the same letter proceeds different treatment yields.

Table 2. Corn grain yields as a function of N application rate and timing, 1990.

	Location and Previous Crop														
N Treatment[1/]	Waseca-1 Corn	Olmsted Corn	Isanti Corn	Waseca-2 Alfalfa	Waseca-3 Soybeans	Watonwan Corn	Goodhue Oats	Wabasha-1 Peas	Wabasha-2 Corn	Winona-1 Corn	Winona-2 Corn	Dakota Soybeans	Sherburne Rye	Chisago Soybean	Waseca-4 Corn
lb/A	bu/acre[2/]														
PP 0	80.1h	88.5i	136.2	160.1	147.1b	106.2b	96.5c	140.0	166.6c	144.7	160.7b	107.1c	80.8b	41.2c	122.5b
30	108.0g	108.7h	131.8												
60	118.1gf	117.9gh	142.7												
90	134.9ed	138.6ef	174.1												
120	144.6abcd	153.7bcd	152.5												
150	149.0abc	161.8abc	132.4												
180	155.5a	170.0a	145.8												
SD 60	130.3ef	127.6fg	135.8	162.1	164.0a	151.2a	140.6b	151.4	174.2cba	151.6	171.6a	160.5b	114.9a	89.9b	156.6a
90	125.8ef	140.0def	152.8	171.9	170.7a	154.0a	160.5a	150.1	172.8cb	151.3	175.4a	183.9a	118.7a	96.7ba	158.4a
120	151.3ab	150.4cde	146.4	159.5	166.3a	149.9a	151.7ba	144.1	175.5ba	153.6	170.9a	192.1a	133.1a	102.2ba	156.1a
150	139.3bcde	153.0bcd	141.1	162.9	164.2a	151.2a	167.3a	150.4	182.3a	152.8	160.8b	197.0a	137.4a	106.9a	162.7a
60+30	136.0cde	141.1def	142.9												
60+60	144.7abcd	155.9bc	145.3												
60+90	148.6abcd	164.9ab	147.0												
Pr>F	0.000	0.000	0.768	0.354	0.104	0.000	0.000	0.356	0.063	0.268	0.049	0.000	0.006	0.000	0.013
LSD(.10)	14.0	14.0			14.5	10.6	16.3		8.2		9.0	18.4	22.7	13.7	18.3

[1/] Nitrogen applications were made a preplant (PP), sidedress (SD) of split (preplant + sidedress) applications.

[2/] Grain yields at each location are statistically similar if the same letter proceeds different treatment yields.

Table 3. Soil inorganic N amounts as affected by rate of preplant N application, time, and depth of sampling, 1989.

Site	Sampling Time	N Form	Depth	Preplant N - lb/A 0	30	60	90	120	150	180
			ft	lb N/acre						
Waseca-1	V_2	NO_3-N	0-1	33.8	72.0	55.9	48.7	93.8	85.2	85.6
			1-2	32.7	41.2	38.9	38.3	49.7	57.2	62.8
	V_2	NH_4-N	0-1	26.9	30.7	33.5	36.7	56.6	59.9	61.6
			1-2	11.1	10.6	15.6	15.1	21.4	24.7	19.6
	V_5	NO_3-N	0-1	27.8	53.0	60.0	63.5	80.1	124.1	176.7
			1-2	27.8	30.5	35.6	20.4	49.9	42.6	46.4
	V_5	NH_4-N	0-1	18.8	25.2	26.7	26.0	27.4	36.6	34.1
			1-2	8.4	6.6	7.7	6.6	9.6	9.9	8.6
Olmsted	V_2	NO_3-N	0-1	44.0	70.1	57.3	78.4	85.1	154.3	220.6
			1-2	24.1	28.0	28.0	37.5	30.3	34.1	45.4
	V_2	NH_4-N	0-1	30.4	33.4	33.6	41.8	59.3	67.4	99.9
			1-2	20.4	23.5	25.2	28.1	30.5	38.2	48.2
	V_5	NO_3-N	0-1	61.2	89.3	109.0	129.6	104.0	148.9	176.0
			1-2	37.7	61.1	69.2	84.8	126.8	103.1	110.9
	V_5	NH_4-N	0-1	35.2	34.7	39.4	43.3	39.4	47.4	45.8
			1-2	25.4	23.5	25.9	39.1	40.1	35.9	42.8
Winona-1	V_2	NO_3-N	0-1	83.3	91.5	96.4	150.6	183.8	197.5	190.9
			1-2	68.9	73.2	65.8	86.2	99.4	92.7	126.7
	V_2	NH_4-N	0-1	28.8	59.8	29.1	26.8	30.2	33.6	57.8
			1-2	20.9	20.6	20.3	17.8	20.3	19.5	24.6
	V_5	NO_3-N	0-1	53.7	79.4	94.3	95.8	164.5	164.9	152.6
			1-2	52.0	95.7	67.4	64.3	69.8	66.2	66.6
	V_5	NH_4-N	0-1	83.0	66.8	72.7	75.7	81.2	73.1	79.6
			1-2	53.8	40.1	40.2	43.8	51.6	42.5	45.5
Isanti-1	V_2	NO_3-N	0-1	60.3	69.2	161.1	106.5	136.8	152.1	165.5
			1-2	66.9	83.1	132.7	100.6	84.7	47.2	128.2
	V_2	NH_4-N	0-1	27.1	15.5	30.5	10.1	16.2	23.6	14.4
			1-2	10.1	10.2	9.1	8.4	6.7	7.9	9.3
	V_5	NO_3-N	0-1	79.3	99.2	130.1	84.0	42.0	121.4	152.5
			1-2	95.7	47.4	65.5	69.2	49.6	67.4	80.6
	V_5	NH_4-N	0-1	54.6	58.9	74.0	83.3	45.0	61.2	58.7
			1-2	48.3	44.9	48.7	44.2	45.1	48.5	35.1

Table 4. Soil inorganic N amounts as affected by rate of preplant N application, time, and depth of sampling, 1990.

Site	Sampling Time	N Form	Depth	Preplant N - lb/A 0	30	60	90	120	150	180
			ft	lb N/acre						
Waseca-1	V_2	NO_3-N	0-1	27.5	50.4	64.4	67.6	132.1	124.6	151.6
			1-2	22.0	28.7	32.4	35.6	58.7	58.6	51.4
	V_2	NH_4-N	0-1	18.5	24.2	28.7	28.0	36.0	42.1	37.8
			1-2	5.5	5.8	5.8	6.3	6.9	6.1	6.6
	V_5	NO_3-N	0-1	17.1	21.2	28.1	44.2	42.2	57.7	52.7
			1-2	14.3	27.6	28.3	39.2	35.6	57.8	52.6
	V_5	NH_4-N	0-1	21.2	23.6	26.3	28.1	26.7	25.5	24.4
			1-2	4.5	5.6	5.3	5.4	4.9	4.2	5.8
Olmsted	V_2	NO_3-N	0-1	21.6	30.4	35.2	60.1	85.8	114.6	142.3
			1-2	17.6	17.1	16.6	30.4	32.6	43.0	43.6
	V_2	NH_4-N	0-1	37.8	33.5	34.0	35.9	34.0	41.1	48.2
			1-2	24.6	17.7	19.9	23.8	17.3	22.9	21.1
	V_5	NO_3-N	0-1	30.2	25.9	27.6	48.6	62.1	127.2	137.6
			1-2	17.6	17.9	19.3	29.4	29.3	55.1	50.4
	V_5	NH_4-N	0-1	28.4	29.4	28.4	30.7	27.6	31.4	31.0
			1-2	21.7	17.5	17.7	19.0	17.3	23.7	20.6
Isanti	V_2	NO_3-N	0-1	34.5	47.0	60.8	97.8	81.1	88.5	84.8
			1-2	41.2	32.1	42.4	46.9	47.5	58.5	59.0
	V_2	NH_4-N	0-1	9.3	3.8	9.0	4.0	8.9	9.0	11.2
			1-2	6.9	3.6	8.6	4.4	7.5	6.2	15.0
	V_5	NO_3-N	0-1	34.7	43.1	57.8	42.6	49.6	52.8	53.3
			1-2	31.2	35.8	52.5	33.7	33.6	35.3	38.8
	V_5	NH_4-N	0-1	19.6	15.8	15.8	19.6	25.2	15.2	32.4
			1-2	22.8	13.8	22.7	21.6	29.1	21.8	26.0

Table 5. Soil N concentrations as a function of sampling depth and time for all plots that received no preplant N, 1989.

Site[1]	Sampling Time[2]	NO_3-N 0-1'	NO_3-N 1-2'	NO_3-N 2-3'	NH_4-N 0-1'	NH_4-N 1-2'	NH_4-N 2-3'	Hydrolyzable N[3] 0-1'	Hydrolyzable N[3] 1-2'	Hydrolyzable N[3] 2-3'
		ppm N								
Outwash										
Isanti-1	Pre	8.1	19.1	2.6	0.8	1.1	1.1	22.2	6.9	5.2
	V_2	15.1	16.7	7.0	6.8	2.5	1.6	32.2	10.7	6.5
	V_5	19.8	23.9	7.3	13.7	12.1	8.6	41.8	17.7	14.0
Isanti-2	Pre	2.1	1.9	2.7	1.3	0.9	0.7	16.6	7.0	3.9
	V_2	2.5	1.5	1.4	11.5	6.5	6.0	32.4	17.4	15.4
	V_5	2.4	1.8	1.4	10.2	7.4	5.9	26.3	14.7	11.3
Chisago	Pre	2.3	4.5	2.8	1.1	1.6	2.6	24.3	6.2	6.3
	V_2	18.4	16.8	13.2	4.4	2.3	4.0	38.7	10.0	9.4
	V_5	10.9	11.8	10.4	12.5	7.2	6.2	48.3	23.0	16.7
Loess										
Olmsted	Pre	7.5	5.7	10.0	6.7	3.4	3.1	57.0	30.2	15.1
	V_2	11.0	6.0	5.3	7.6	5.1	4.4	64.4	35.4	20.3
	V_5	15.3	9.4	8.5	8.8	6.3	4.5	66.6	35.3	18.1
Winona-1	Pre	20.3	24.4	12.2	3.2	2.2	2.0	61.3	32.2	16.8
	V_2	20.8	17.2	9.4	7.2	5.2	4.8	62.3	33.8	18.3
	V_5	13.4	13.0	9.6	20.8	13.5	9.0	89.3	47.2	24.5
Houston	Pre	39.5	31.8	11.6	0.7	1.1	1.1	52.6	27.7	11.7
	V_2	1.4	10.6	7.6	13.2	15.9	7.5	86.9	41.3	21.2
	V_5	36.3	38.6	33.1	9.3	5.6	5.3	79.7	44.6	30.6
Winona-2	Pre	13.3	11.7	5.8	4.1	2.4	2.5	28.1	9.7	8.9
	V_2	19.4	16.3	10.4	6.7	4.5	4.8	43.0	19.3	15.0
	V_5	21.7	14.3	9.4	7.6	5.0	5.1	44.6	20.0	17.9
Dakota	Pre	6.7	10.2	5.6	14.4	11.6	8.4	73.6	48.0	26.1
	V_2	17.1	10.0	7.0	21.6	14.0	9.6	91.9	56.9	35.4
	V_5	7.9	7.0	5.7	10.0	8.0	6.4	72.0	42.4	22.2
Till										
Waseca-1	Pre	11.5	9.2	4.3	4.1	2.1	2.2	51.5	18.2	7.0
	V_2	8.5	8.2	5.1	6.7	2.8	3.8	66.1	28.9	14.9
	V_5	7.0	6.9	5.8	4.7	2.1	2.2	61.9	17.2	13.9
Waseca-2	Pre	8.5	6.0	5.1	3.6	1.3	2.0	37.3	8.4	5.7
	V_2	8.0	6.6	5.5	5.5	2.1	3.4	62.0	15.5	8.8
	V_5	10.9	6.6	5.9	5.6	2.0	2.9	63.1	17.4	15.5
Waseca-3	Pre	12.3	10.3	6.9	4.4	2.7	3.2	51.4	21.7	9.1
	V_2	9.1	6.2	5.7	9.0	4.2	3.3	67.5	28.6	15.7
	V_5	10.5	7.6	6.5	8.2	3.3	2.5	63.7	25.2	17.6
Steele	Pre	13.5	9.6	3.4	1.4	1.4	1.9	40.0	16.3	11.8
	V_2	14.5	13.2	8.3	6.2	4.5	4.5	53.6	27.6	18.6
	V_5	15.1	13.8	8.1	4.7	3.2	3.1	50.9	27.0	20.5
Waseca-4	Pre	19.6	18.8	21.3	7.3	2.5	2.1	51.2	15.4	6.5
	V_2	14.8	15.4	19.4	8.4	2.3	2.9	68.1	20.4	12.0
	V_5	13.4	13.2	16.7	6.6	2.2	2.4	65.8	24.1	15.8

1/ Sites are also categorized by soil's parent material.

2/ Sampling times were before planting (Pre) and at the morphological growth states of V2 and V5.

3/ Includes ammonium-N.

Table 6. Soil N concentrations as a function of sampling depth and time for all plots that received no preplant N, 1990.

Site[1/]	Sampling Time[2/]	NO_3-N 0-1'	NO_3-N 1-2'	NO_3-N 2-3'	NH_4-N 0-1'	NH_4-N 1-2'	NH_4-N 2-3'	Hydrolyzable N[3] 0-1'	Hydrolyzable N[3] 1-2'	Hydrolyzable N[3] 2-3'
		ppm N								
Outwash										
Isanti	Pre	12.1	23.6	11.2	0.5	0.9	1.0	25.5	7.7	4.6
	V_2	8.6	10.3	15.2	2.3	1.7	2.9	28.0	10.2	7.9
	V_5	8.7	7.8	12.5	4.9	5.7	6.9	39.0	13.3	11.4
Dakota	Pre	7.2	3.8	2.0	1.5	1.1	0.7	50.3	26.4	5.1
	V_2	13.1	6.7	4.4	1.4	1.9	0.6	53.7	30.1	11.2
	V_5	11.8	8.7	5.2	2.6	1.5	1.7	58.9	37.3	17.0
Sherburne	Pre	4.1	1.4	1.2	1.3	2.3	1.0	28.3	15.3	4.8
	V_2	4.1	2.0	1.8	1.0	0.6	0.7	24.6	11.0	11.0
	V_5	4.3	0.6	0.1	2.3	2.6	1.0	34.2	18.6	9.6
Chisago	Pre	3.8	1.9	2.4	1.9	0.8	0.9	14.1	2.8	2.8
	V_2	3.8	2.0	2.2	3.3	2.2	1.8	14.3	6.9	5.0
	V_5	2.7	2.0	2.6	5.4	2.8	2.1	21.9	13.0	7.3
Loess										
Olmsted	Pre	3.4	0.4	0.3	6.3	4.3	3.7	72.3	43.3	21.9
	V_2	5.4	4.4	2.4	9.5	6.2	4.5	72.5	55.8	32.3
	V_5	7.6	4.4	2.1	7.1	5.4	4.7	75.8	50.4	28.6
Goodhue	Pre	7.7	4.5	2.5	5.9	3.4	1.8	73.4	27.1	6.8
	V_2	4.9	4.0	3.2	5.9	1.4	1.2	78.8	18.2	6.8
	V_5	7.0	5.0	3.1	8.3	2.6	1.9	88.6	25.5	10.8
Wabasha-1	Pre	6.1	9.5	10.3	2.6	3.1	2.6	41.7	17.4	10.7
	V_2	18.5	11.9	11.5	3.2	3.0	3.6	38.3	17.9	14.3
	V_5	18.4	12.7	11.9	4.8	3.1	4.5	46.1	19.7	17.2
Wabasha-2	Pre	10.0	20.6	10.7	1.7	1.5	1.9	39.3	12.0	8.6
	V_2	17.9	11.4	13.2	1.9	1.1	1.2	39.9	15.4	8.0
	V_5	21.5	11.4	12.9	3.1	4.7	3.8	37.9	16.5	12.4
Winona-1	Pre	14.4	11.0	4.9	2.3	3.5	2.6	37.8	13.2	9.7
	V_2	23.7	10.9	11.3	3.8	2.7	4.1	29.9	13.2	21.3
	V_5	15.6	8.6	11.2	4.6	4.9	6.3	45.0	19.1	19.6
Winona-2	Pre	1.4	5.9	9.2	1.7	1.7	2.2	77.6	24.5	10.6
	V_2	20.1	12.5	15.3	1.5	0.9	0.8	70.0	29.5	13.7
	V_5	14.2	11.2	17.1	5.2	5.2	4.8	78.5	39.4	21.8
Till										
Waseca-1	Pre	5.1	2.5	2.2	4.4	1.9	2.2	47.4	9.3	6.3
	V_2	6.9	5.5	4.4	4.6	1.4	1.8	50.0	12.8	5.3
	V_5	4.3	3.6	3.4	5.3	1.1	1.3	54.0	15.6	9.0
Waseca-2	Pre	13.4	4.8	0.7	8.1	2.2	1.4	83.3	33.2	10.2
	V_2	14.9	13.4	7.4	9.7	1.9	0.8	86.8	27.7	6.5
	V_5	9.5	10.0	8.6	13.6	3.8	2.1	91.1	31.5	13.2
Waseca-3	Pre	8.8	10.2	5.2	8.4	2.7	1.9	89.4	37.1	12.4
	V_2	5.1	7.2	8.5	9.5	3.6	1.8	89.7	37.3	12.5
	V_5	5.2	5.2	7.7	11.7	3.6	2.4	89.1	32.2	13.8
Watonwan	Pre	8.4	8.1	12.3	4.3	1.5	1.5	39.3	8.1	4.8
	V_2	4.6	3.9	6.5	4.3	1.4	1.2	40.7	11.0	5.3
	V_5	5.2	4.1	5.5	4.3	1.5	1.7	44.0	10.2	6.3
Waseca-4	Pre	12.7	10.3	15.9	7.1	2.1	1.7	59.5	17.4	5.6
	V_2	11.1	10.6	12.1	6.5	2.0	2.3	57.6	17.9	8.3
	V_5	5.8	6.8	10.0	9.3	3.0	2.5	64.6	32.8	17.9

[1/] Sites are also categorized by soil's parent material.

[2/] Sampling times were before planting (Pre) and at the morphological growth stages of V_2 and V_5.

[3/] Includes ammonium-N.

Table 7. Selected soil nitrate-N correlations (r) of plots receiving various preplant N applications as a function of soil sampling time and depths in 1989 and 1990.

Soil sampling time and depth comparison			1989	1990
			---- r ----	
Preplant 0-2′	vs.	Preplant 0-3′	0.975	0.999
Preplant 0-3′	vs.	V2 0-1′	0.242	-0.076
Preplant 0-3′	vs.	V6 0-1′	0.139	-0.009
Preplant 0-3′	vs.	V6 0-2′	0.151	0.011
V2 0-1′	vs.	V6 0-1′	0.398	0.415
V6 0-1′	vs.	V6 0-2′	0.904	0.961

EFFECT OF TURKEY MANURE AS A NUTRIENT SOURCE ON CORN YIELDS

P. M. Bongard, R. Hamer[1]

ABSTRACT

Two sites were identified in Rice County to demonstrate nutrient contributions from turkey tom-finish and brood manures to corn. Two rates of each type of manure were applied and compared to a commercial fertilizer treatment and an untreated check. Corn grain yields were measured. There were no significant differences between the low and high rates of either the brood or finish manures at either site. Yields of the manured plots were similar to the commercial fertilizer treatment yields, and significantly better than the check. Average returns over treatment costs were greatest in the plots where low rates of the finish and brood manures had been applied.

Introduction

Animal wastes can contribute substantial amounts of nutrients to crops, as well as enhance soil structure and organic matter contents over time. To date, there has been little research done with turkey manure as a nutrient source in Minnesota. The objective of this study was to demonstrate nutrient contributions from finish and brood turkey manures to corn.

Materials and methods

Two sites which had no history of previous manure applications were selected in Rice County for this demonstration. The primary soil at the Farm 1 site was a Clarion loam; the primary soils at Farm 2 were a Webster clay loam and a Clarion loam. Both sites were soil sampled in early spring (Table 1). The previous crop at Farm 1 was corn; at Farm 2, the previous crop was soybeans. Precipitation was recorded at both sites (Table 2).

Turkey tom-finish and brood manures with wood chip litter were used in this study. The tom-finish barns are cleaned each year after three to four flocks, while the brood barns are cleaned after every flock (every seven weeks). The tom-finish and brood manures for Farm 2 had been taken directly from these barn cleanings, while the manures for Farm 1 had been stored on a pile for approximately four months. The litter and manure in tom-finish and brood barns are tilled regularly.

The two turkey manures were applied at two rates and immediately incorporated in mid-April: 1) Tom-Finish manure at 4 and 8 tons per acre, and 2) Brood manure at 3 and 6 tons per acre. Manure was sampled for nutrient analysis on the day of application (Table 3), and estimates of nutrients available the first year were made (Table 4). An untreated plot and a preplant commercial fertilizer treatment was also included. The fertilizer treatment phosphorus (P) and potassium (K) was applied according to University of Minnesota recommendations based on yield goals and the soil tests; the nitrogen (N) rate was based on previous crop, yield goals, and soil organic matter contents. A randomized complete block was used with three replications at Farm 1 and four replications at Farm 2. Each of the six treatments was sixteen rows wide, and 430 feet long.

Corn grain yields were measured by harvesting and weighing the center eight rows of each plot, and adjusting the moisture contents to 15.5%.

Results

Yields

There were few significant differences in grain yields at either site (Figures 1 and 2). At both sites, the manure and commercial fertilizer treatments yielded significantly better than the untreated plot, representing an average increase of 16 bushels per acre due to manure or fertilizer. The six ton brood manure treatment at Farm 1 is the exception as it was not significantly different from the check. Grain yields in the low rate plots of the finish and brood manures were not significantly different from those in the high application rate plots.

[1]Environmental Agriculture Educator, Cluster 16, and County Extension Agent, Agriculture, Rice County, Minnesota Extension Service

Returns over treatment costs

The net returns over nutrient costs for each treatment were calculated by subtracting the cost of the manure or fertilizer from the projected treatment income (Figures 3 and 4). Returns were based on the following: 1) Corn revenue of $2.00 per bushel; 2) Manure costs of $3.75 per ton tom-finish ($15/4T and $30/8T treatments) and $3.00 per ton brood ($9/3T and $18/6T treatments); and fertilizer costs of $0.20 per pound N and $0.13 per pound K.

Returns over nutrient costs ranged from $247 to $285 per acre at Farm 1, with the highest returns in the low rate finish and brood manure plots. Similar results were obtained at Farm 2, with the addition of the high rate brood manure plots. Returns ranged from $268 to $304 per acre at this site.

Summary and Conclusions

Turkey manure can contribute substantial amounts of nutrients to corn. Grain yields at the two farm sites from the low rates of finish and brood manure were equal to the commercial fertilizer treatment. It may be possible that the above normal precipitation increased N mineralization of the manure and soil, and increased fertilizer N loss.

Since more P and K were applied in the manured treatments at these sites than what was required for this year's corn crop, subsequent crops (particularly legumes) may be able to utilize these nutrients. Future work could focus on refining application rates under different environmental conditions, refining manure handling and sampling techniques, and evaluating yield responses on low testing phosphorus, potassium, and organic matter soils where greater contributions from the manure could be realized in the year of application.

Table 1. Soil test results, 1990.

SITE	ORGANIC MATTER	pH	P	K
	---%---		-----ppm-----	
Farm 1	2.6	5.9	48.7	143.5
Farm 2	4.8	6.2	28.8	136.0

Table 2. Monthly precipitation records and cumulative totals, 1990.

	FARM 1		FARM 2	
MONTH	RAIN	CUM.	RAIN	CUM.
	-------------inches-------------			
May[1]	3.1	3.1	3.9	3.9
June	6.0	9.1	4.9	8.8
July	7.5	16.6	8.8	17.6
August	NA		3.3	20.9

[1]Record beginning May 14.

Table 3. Average turkey manure composition as applied.

MANURE	% SOLIDS	TOTAL N	NH_4^+	ORGANIC N	P_2O_5	K_2O
		TURKEY MANURE COMPOSITION				
		lb/ton				
Tom-finish	62	23.6[1]	10.4	13.2	43.6	28.2
Brood	52	33.0	10.2	22.8	38.6	24.2

[1]Total N for finish manure was lower than average due to a higher than average moisture content. Typical values on a wet basis average 40 pounds N per ton.

Table 4. Estimate of nutrients available first year[1].

NUTRIENT SOURCE	RATE	TOTAL N	NH_4^+	ORGANIC N	P_2O_5	K_2O
		AVAILABLE NUTRIENTS				
	ton/A	pounds/A				
Tom-finish manure	4	57	42	16	148	102
	8	115	83	32	296	203
Brood manure	3	51	31	20	98	65
	6	102	61	41	197	131
Farm 1 fertilizer		180			0	30
Farm 2 fertilizer		130			0	30

[1]Manure availability based on 100% ammonium-N, 30% organic N, 85% P_2O_5, and 90% K_2O; Fertilizer availability based on 100% applied.

Figure 1. Grain yields as affected by nutrient source at Farm 1, 1990.

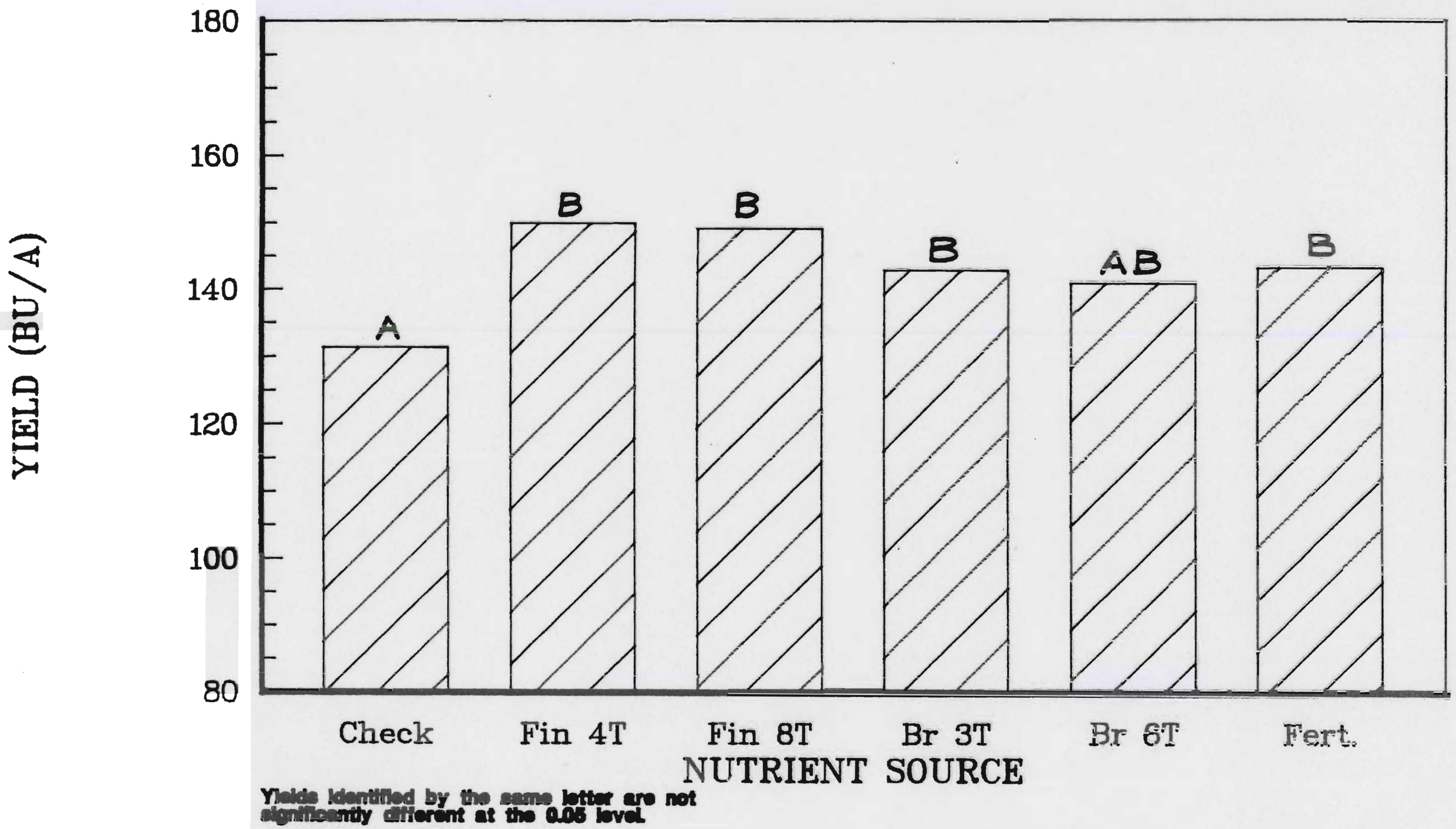
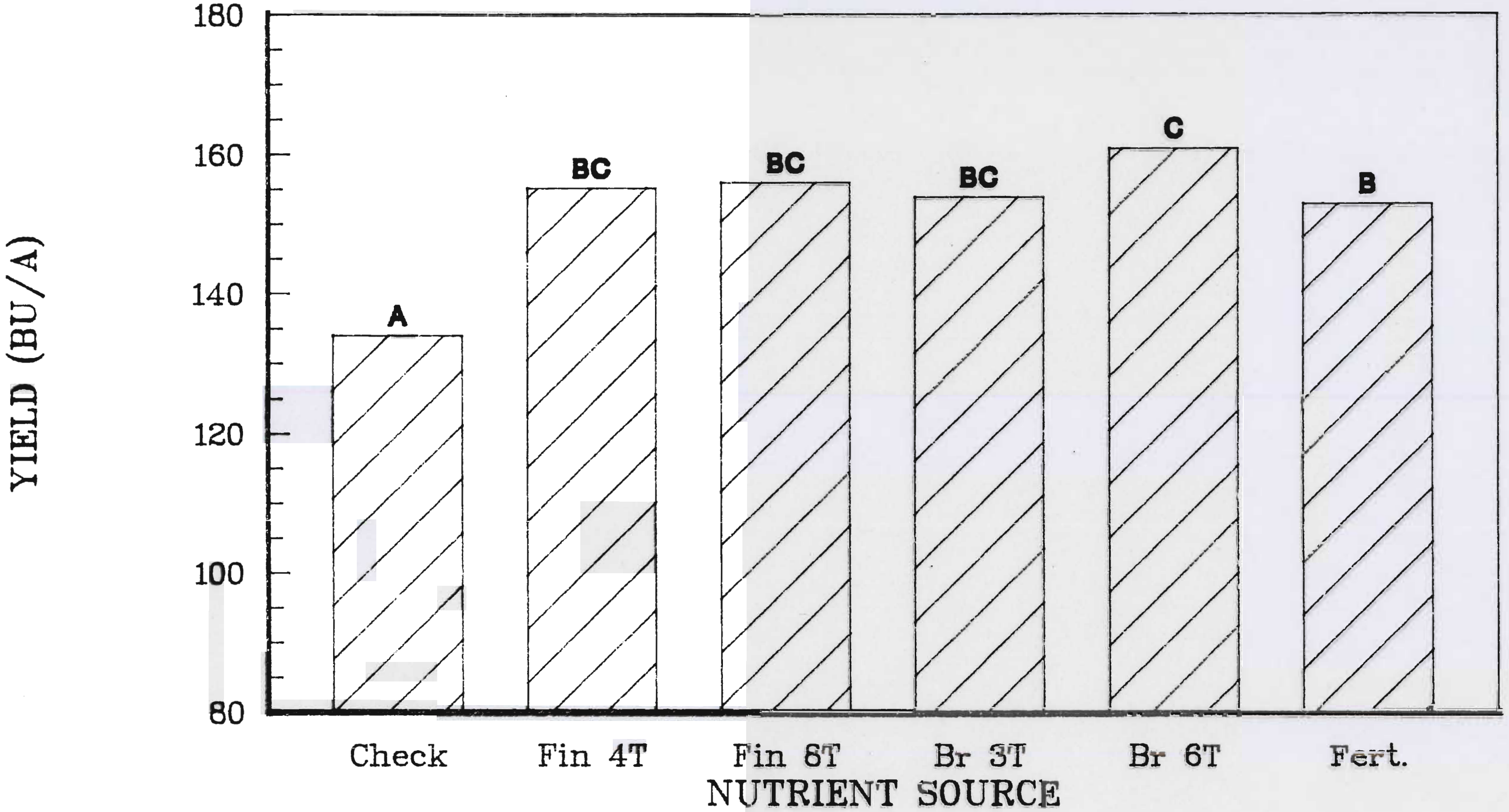


Figure 2. Grain yields as affected by nutrient source at Farm 2, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level.

Figure 3. Returns over nutrient costs ($/A) at Farm 1, 1990

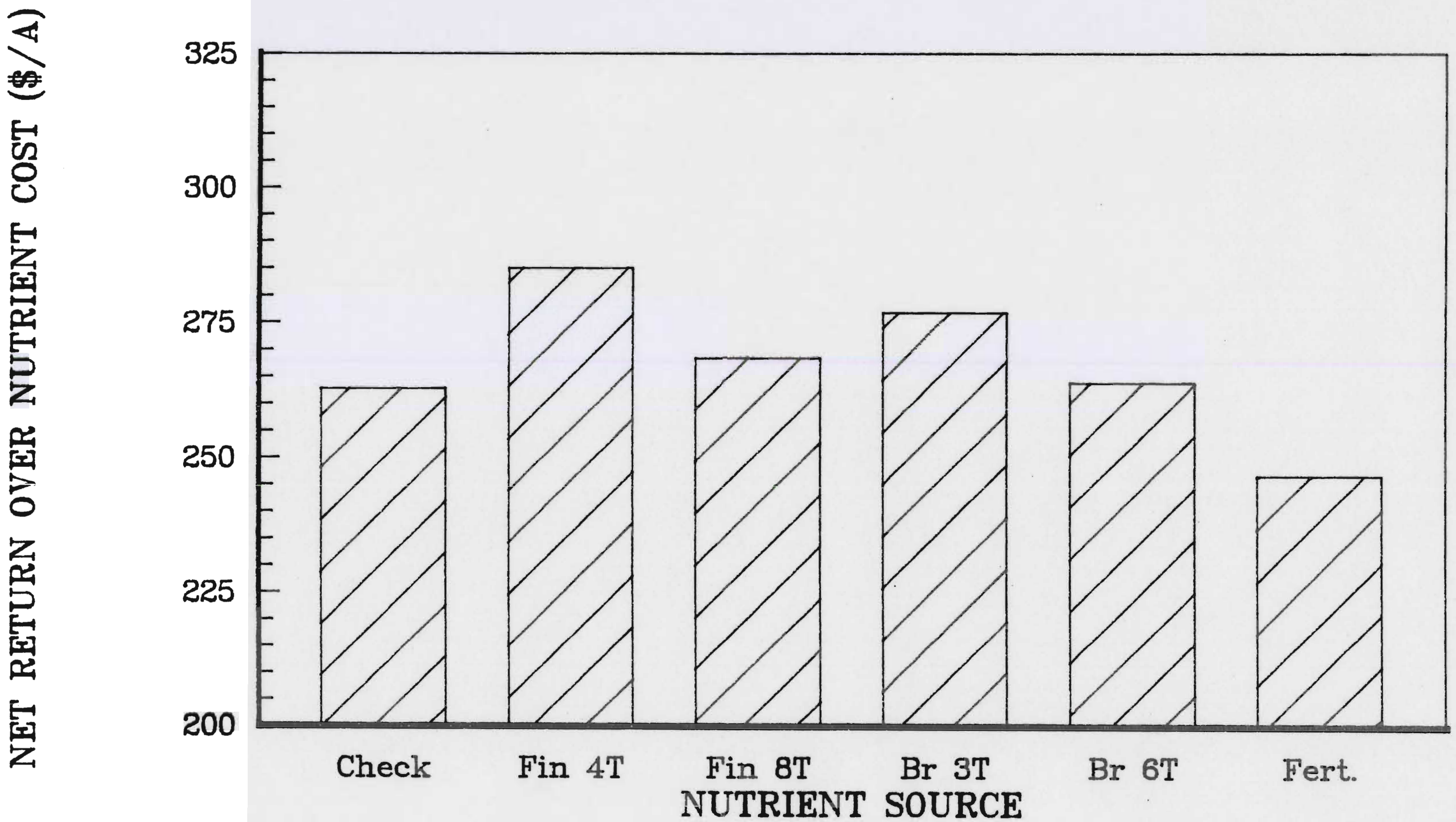
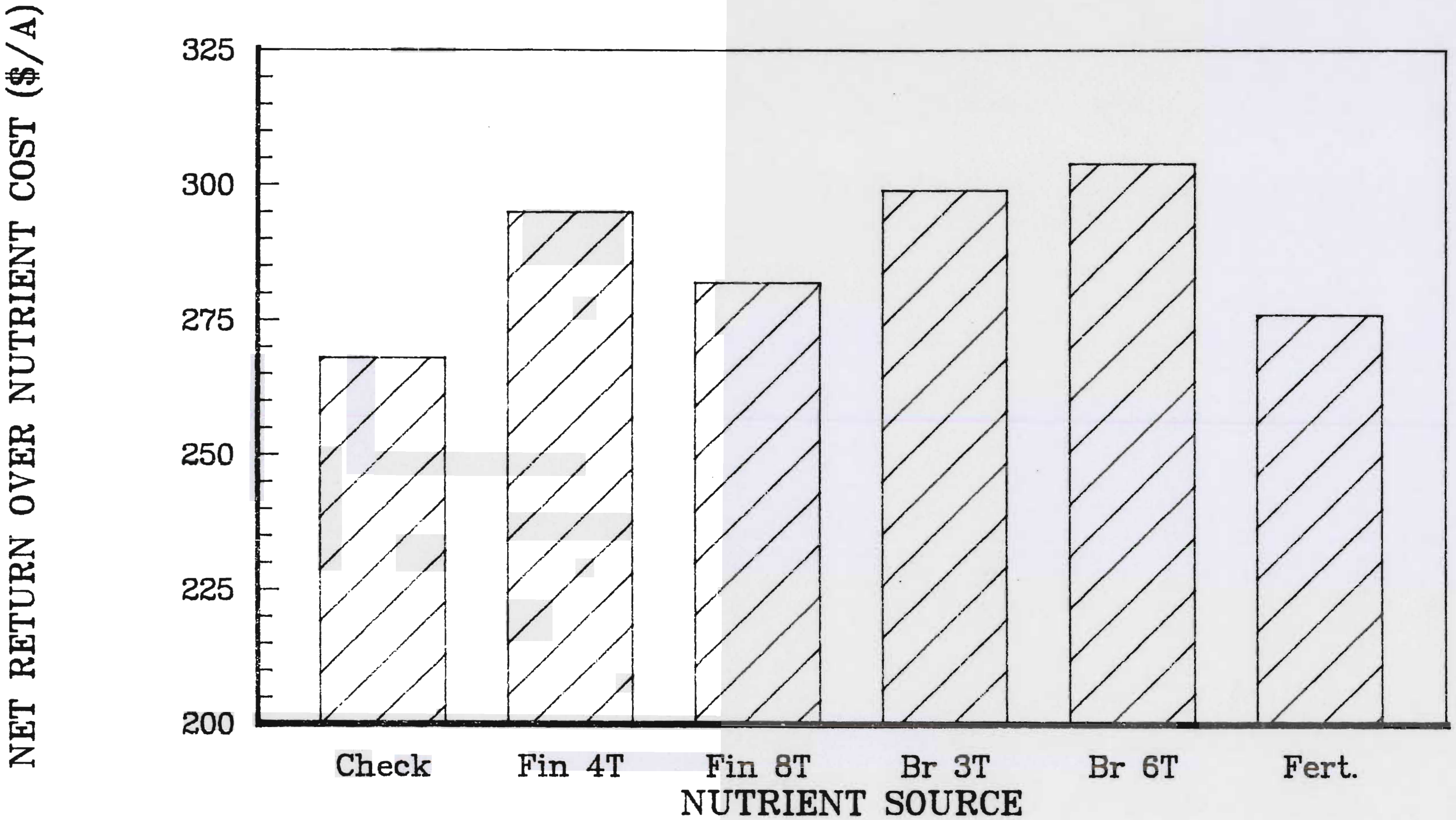


Figure 4. Returns over nutrient cost ($/A) at Farm 2, 1990.



CORN YIELDS AS AFFECTED BY NITROGEN RATE, LEGUME AND MANURE HISTORIES[1]

P. M. Bongard, T. Wager, T. Arlt, and R. Hamer[2]

ABSTRACT

Sites were selected in Freeborn, Mower, Rice, and Steele counties to demonstrate nitrogen (N) contributions from a previous crop of alfalfa or soybeans with and without histories of manure applications. Fertilizer N as urea was applied at five rates (0, 40, 80, 120, and 160 lb. N/acre). Plots were hand harvested after physiological maturity had been attained. There were no yield responses to N at the sites that had histories of alfalfa with or without manure, or soybeans with manure. The average corn grain yields were 147, 184, and 182 bu/acre for these sites, respectively. There was a significant yield response to N up to the 120 pound rate at the soybean with no manure site.

Introduction

It has long been recognized that legumes and manures can contribute substantial amounts of nitrogen (N) to following crops. Sites were chosen in Freeborn, Mower, Rice, and Steele counties to demonstrate N contributions from legumes and/or manure to corn. These demonstrations were part of the Environmental Agriculture Education Program of Cluster 16.

Materials and methods

Each of the county sites was selected based on a different field history (Table 1). Fertilizer N as urea was applied at five rates in a randomized complete block design with four replications. The fertilizer rates were 0, 40, 80, 120, and 160 pounds N per acre.

Nitrogen was applied at the four sites on April 11 or 12 and immediately incorporated. Planting, weed and other pest control, and phosphorus and potassium applications were the responsibilities of each of the farmer cooperators.

Plots were hand harvested in early October after the corn had reached physiological maturity. The corn grain from two, twenty foot plot sections was shelled, weighed, and yields were corrected to 15.5% moisture.

Results

Freeborn County (alfalfa with no manure)

There was no yield response to fertilizer N at this site (Figure 1). As a result, the return over fertilizer N costs (based on $2.00 per bushel corn and $0.20 per lb. N) decreases with added nitrogen (Figure 2). The average overall yield at this site was 184 bushels per acre.

Mower County (soybean with no manure)

At this site, there was a significant response to fertilizer N. The optimum N rate was at 120 pounds per acre, representing a 46 bushel yield increase over the 0 pound per acre N rate. The maximum net economic return based on yields and fertilizer N costs was also at the 120 pound N rate.

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[1]Funding provided by Board of Soil and Water Resources through Environmental Agriculture Education Program Grant of Cluster 16, Minnesota Extension Service.

[2]Environmental Agriculture Educator, Cluster 16; Area Extension Agent, Crops and Soils; County Extension Agent, Agriculture, Steele County; and County Extension Agent, Rice County; Minnesota Extension Service

Rice County (alfalfa with manure)

There was no response to fertilizer N at this site. Similar to the other alfalfa site, the greatest return over fertilizer cost was at the zero N rate. The overall yield for this site was 147 bushels per acre.

Steele County (soybean with manure)

There was no response to fertilizer N at this site, and thus, no financial benefit from applying N. The overall yield at this site was 182 bushels per acre.

Summary

Of the four demonstration sites, the only site where a nitrogen response was obtained was in the field where the previous crop was soybeans, and there was no history of manure applications. There were no yield responses to fertilizer N when alfalfa was the previous crop (with or without a manure history), or when manure had been applied after a soybean crop.

Table 1. Field history and primary soil type of four demonstration sites.

SITE	PREVIOUS CROP HISTORY	MANURE	SOIL TYPE	ORGANIC MATTER
Freeborn	Alfalfa	No	Mayer loam	High
Mower	Soybeans	No	Readlyn silt loam	High
Rice	Alfalfa	Yes	Hayden loam	High
Steele	Soybeans	Yes	Nicollet clay loam	High

Figure 1. Corn grain yields as affected by fertilizer N rates, 1990.

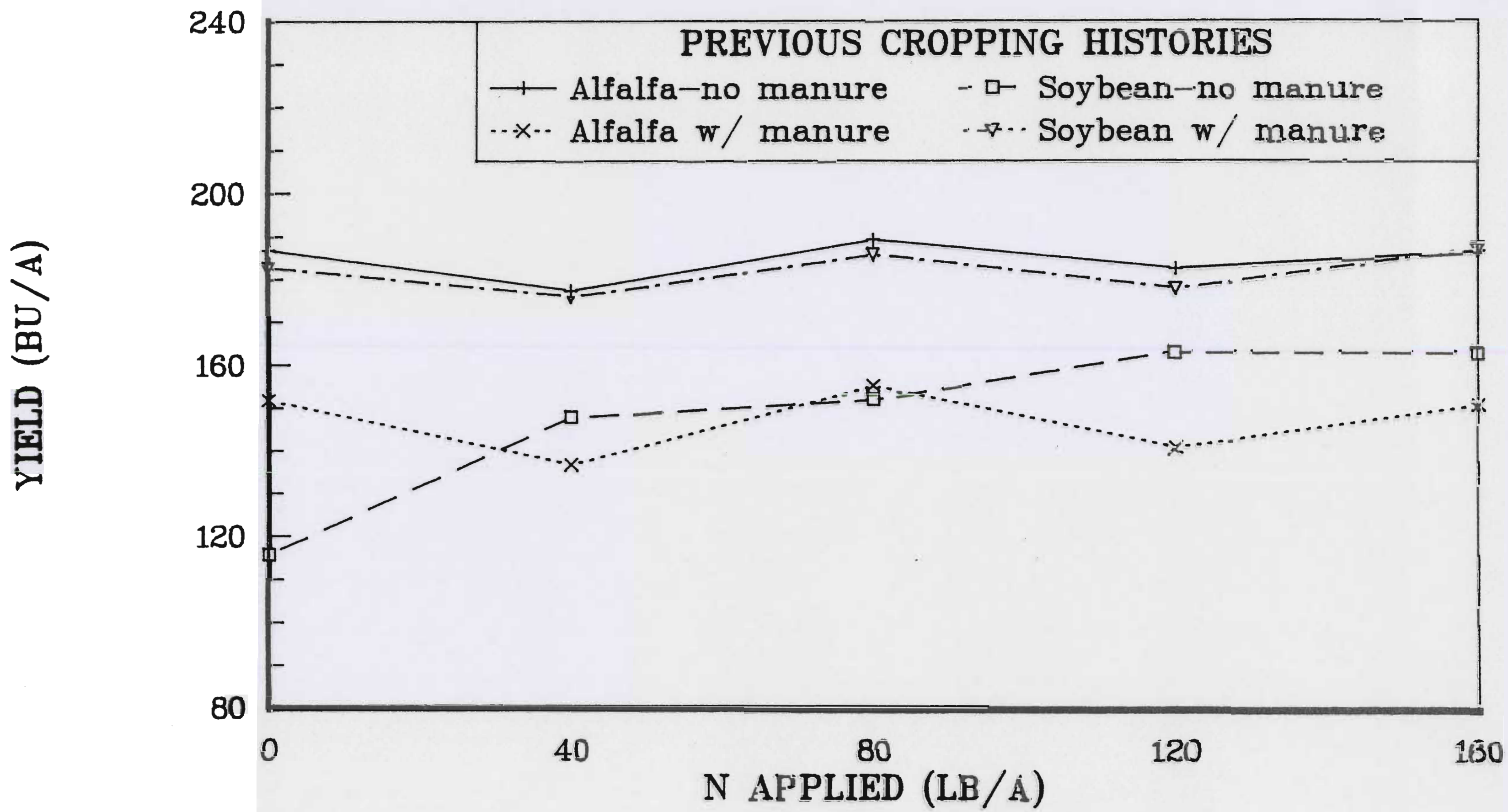
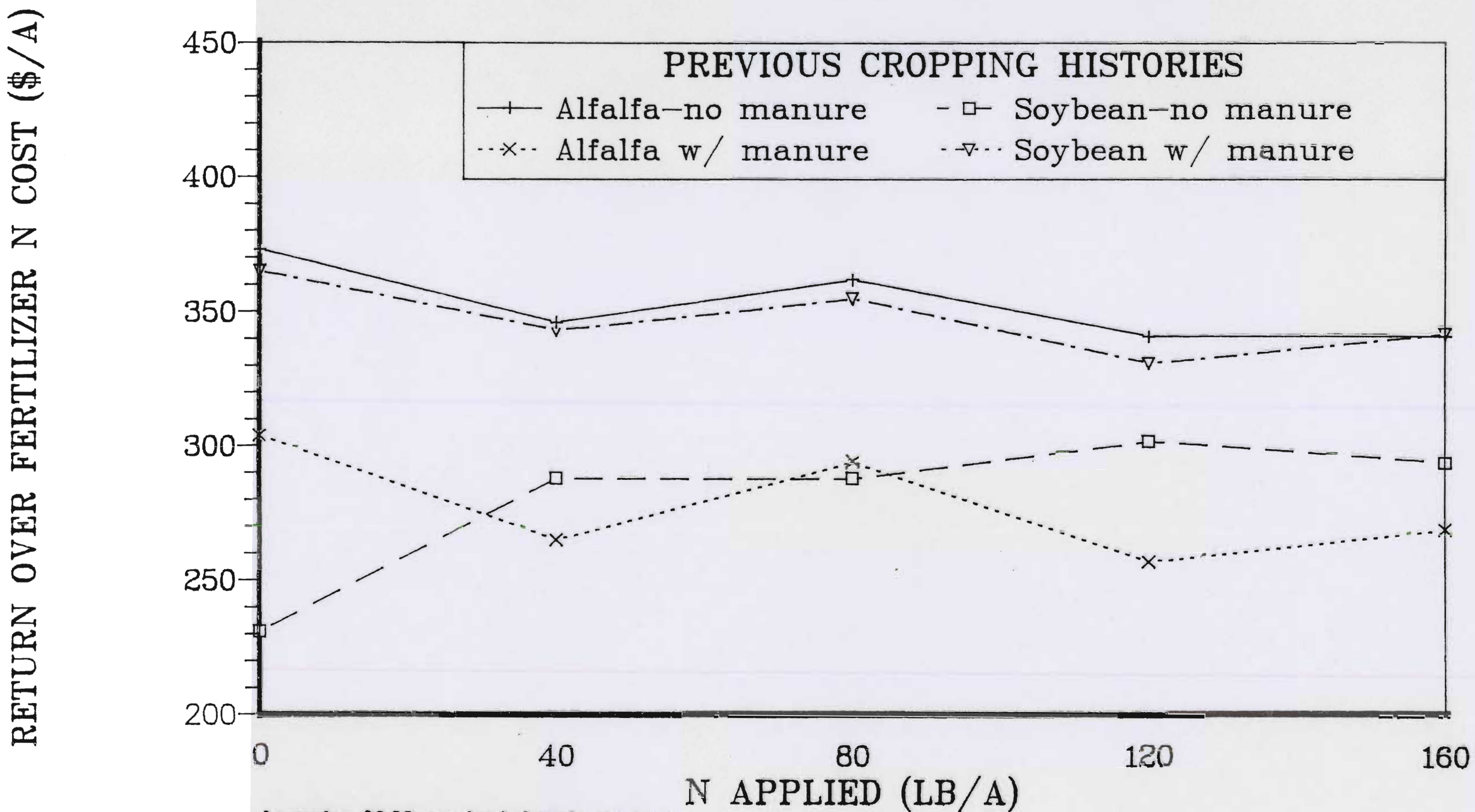


Figure 2. Economic returns as affected by fertilizer N rates and previous crop history, 1990.



Assuming $2.00 per bushel grain revenue and $0.20 per pound N costs.

EVALUATION OF AMMONIUM SULFATE AS A CORRECTIVE TREATMENT FOR IRON CHLOROSIS IN SOYBEANS

George Rehm, Jerome Lensing, Andy Scobbie, and Dan Schmitz[1/]

ABSTRACT: Lime induced iron chlorosis is a major problem for soybean producers in western Minnesota. There were claims that the soil application of ammonium sulfate (21-0-0-24) would correct the problem. This fertilizer material was evaluated at 4 locations in southwestern Minnesota. Both broadcast and row applications were used. There was no consistent effect of the use of this product on yield. Variety selection still remains as the best management practice for reducing yield loss.

Introduction:

Lime induced iron chlorosis has been a persistent problem with soybeans in western Minnesota for several years. Past research has shown that a foliar application of chelated iron materials would help the problem if the plants were sprayed early in the growing season. This treatment, however, is expensive. Recently, there have been claims that the broadcast on banded use of ammonium sulfate 21-0-0-24 would correct the problem.

Objective:

The objective of these field trials was to measure yields of several soybean varieties as affected by either the broadcast or banded application of 21-0-0-24.

Experimental Procedure:

This study was conducted at 4 sites in southwestern Minnesota. Ammonium sulfate (21-0-0) was either broadcast and incorporated before planting or applied in a starter band. The rate of application was 100 lb. per acre for both situations. Two or more varieties were compared at each location. Management practices conducive to the production of high yields were used. Grain yields were measured in late September and corrected to 13.5% moisture.

Results and Discussion:

Grain yields are summarized in the table that follows. The "t" test was used to determine if the use of 21-0-0-24 had an impact on yield for each variety at each site.

Treatment had a significant effect on yield in 4 situations. In 2 situations, the use of 21-0-0-24 produced a significant reduction in yield. However, the 21-0-0-24 increased grain production at 2 other locations. So, the results are inconclusive at best. All sites selected had experienced a serious reduction in yield caused by lime induced iron chlorosis in the past.

The data collected do not substantiate the claim that the use of 21-0-0-24 corrects iron chlorosis problems. The importance of variety selection is illustrated by the yields from the Bussing site. This still remains as the major management tool that can be used for alleviating the problem.

[1/] Extension Specialist; Agronomist, Pioneer Hybrids; Assistant Scientist and Junior Scientist, respectively.

The effect of ammonium sulfate on yield of various soybean varieties of several locations in southwestern Minnesota.

Site Location	Variety	21-0-0-24 Used		21-0-0-24 Not Used
		- - - - - - - bu./acre - - - -		
Schultz	9111	46.5		46.0
	9091	44.3		43.0
Schuller	9181	50.7	*	48.6
	9161	50.7		47.0
	9171	49.2	*	55.4
	9251	45.3	*	49.8
Bussing	9091	49.3		51.9
	9061	3.8		4.1
Burns	9202	43.8	*	38.6
	9091	38.7		37.5

* There is a significant difference between the 2 averages at the .05 confidence level. Treatment means are averages of 4 replications.

THE EVALUATION OF BANDED APPLICATIONS OF POTASH FERTILIZER FOR IMPROVED CORN AND SOYBEAN PRODUCTION IN A RIDGE-TILL PLANTING SYSTEM

George Rehm, Andy Scobbie, Dan Schmitz[1/]

ABSTRACT: Banded application of K_2O in the center of existing ridges has increased corn yields. This study was designed to evaluate the frequency of banded K_2O applications on yields in a corn/soybean rotation. In 1990, the test crop was soybeans. Soybean yields were increased by the rate of K_2O applied in a band in the fall of 1988 as well as rate of K_2O applied in a band in the fall of both 1988 and 1989.

Background and Justification:

During the mid-1980's farmers who were growing corn in ridge-till planting systems observed potassium (K) deficiency symptoms with certain corn hybrids. These symptoms appeared even though soil test values for K were considered to be high or very high. The frequency of these observations increased substantially during the very dry 1988 growing season. Observations were not limited to one soil type or one localized area in Minnesota. This was a situation that appeared in all parts of the state.

It was also apparent from the reports that the severity of the deficiency symptoms varied with hybrid. The most acute symptoms were reported where Pioneer 3732 was the hybrid of choice. Using only visual symptoms as a guide, there appeared to be no problem with Pioneer 3737. In Minnesota, Pioneer hybrids are used on a large number of acres where the ridge-till planting system is used. So, this apparent K deficiency became a very real problem that had to be addressed.

There's general agreement that K uptake by corn is reduced in ridge-till planting systems regardless of hybrid. To help overcome this problem, Dr. Barber of Purdue University has suggested a banded application of potash fertilizer. His suggestions evolve from a root growth model developed from laboratory and greenhouse data. He also suggested that banding of immobile plant nutrients be further evaluated in field situations. Reports of consultants who worked closely with farmers who used ridge-till planting systems suggested that banded applications of potash fertilizer in the center of the ridge in the previous fall could help to overcome K deficiency symptoms and subsequent yield reductions.

It was obvious that there was a pressing need to evaluate the impact of banded potash fertilizer in ridge-till planting systems. This was especially true when soil test values for K are in the high and/or very high range.

Objective:

Based on the situation just described, the overall objective of this study is to evaluate the effect of rate and frequency of potash application in the center of existing ridges on both corn and soybean production. The impact of this method of fertilizer application on soil test values will also be measured.

Experimental Procedure:

This project was initiated in Murray County in the fall of 1988. The site had a history of creating K deficiency symptoms in corn. Prior to fertilizer application, detailed soil samples were collected from several locations in the plot area. The sample collection pattern was designed to measure the amount of extractable K at various positions in the ridge. When results of the analysis were averaged, the K concentration was 145 ppm.

The study initiated in 1988 was a factorial combining 4 rates of K_2O (0, 40, 80, 160 lb/acre) with 3 hybrids (Pioneer 3902, Pioneer 3732, Pioneer 3737) using 4 replications. In the fall of 1989, the design was changed so that the impact of both K_2O rate and frequency of application could be measured. Three frequencies (1 in 3 years, 2 in 3 years, 3 in 3 years) were combined with 4 rates of K_2O (0, 40, 80, 160 lb K_2O/acre) in a complete factorial with 4 replications.

The second application of K_2O (supplied as 0-0-60) was made in the fall of 1989. For all treatments in both years, a coulter system set to operate at a depth of approximately 5 inches placed the 0-0-60 at a depth of about 3 to 3.5 inches below the soil surface.

[1/] Extension Specialist, Assistant Scientist, Junior Scientist, respectively.

Soybeans were grown as the test crop in 1990. They were planted on May 25 at a population of about 10 seeds in a linear foot. The most recently mature leaflets were collected at early to mid-bloom. These tissue samples were dried, ground, and analyzed for K. Soybean grain yields were measured in October and corrected to 13.5% moisture.

Yield

Results and Discussion:

Soybean yield was affected by both frequency and rate of K_2O applied (Table 1). There was no residual effect from the application of 40 and 80 lb K_2O per acre in the fall of 1988. There was, however, some residual effect from the 160 lb K_2O per acre applied at that time.

The yield data also suggest that the annual application of K_2O is most beneficial. When the K_2O was applied in both 1988 and 1989, there was a significant increase in yield with each rate of K_2O applied.

These data also show that the banded application of K_2O has a positive effect on the yield of both corn and soybeans. It is possible that the potassium problem could have limited yields of soybeans grown in a ridge-till planting system in previous years.

Table 1. Effect of frequency of application and rate of K_2O used on soybean yield. Murray County. 1990.

K_2O Applied	Rate of K_2O Used	Yield
	lb./acre	bu./acre
1988 only	0	49.6
	40	49.6
	80	49.7
	160	52.5
1988 and 1989	0	49.5
	40	51.0
	80	51.5
	160	54.3

K in Plant Tissue

In contrast to yields, neither frequency of application nor rate of K_2O used had a significant effect on the concentration of K in the soybean leaflets at early to mid-bloom (Table 2). There's general agreement that the critical concentration of K in soybean leaf tissue is 2.0%. The K concentration for all treatments was higher than this value indicating that, under conventional planting systems a response to K_2O use would not be expected. It's obvious that K concentration in leaf tissue is not indicative of response to K_2O for soybean production in ridge-till planting systems.

Table 2. Effect of frequency of application and rate of K_2O used on K concentration in soybean tissue at early to mid-bloom. Murray County. 1990.

K_2O Applied	Rate of K_2O Used	K Conc.
	lb./acre	%K
1988 only	0	2.11
	40	2.17
	80	2.22
	160	2.21
1988 and 1989	0	2.12
	40	2.21
	80	2.12
	160	2.34

MECHANICAL AND CHEMICAL WEED CONTROL DEMONSTRATIONS IN CORN AND SOYBEANS[1]

P. M. Bongard, F. Breitenbach, T. Arlt, and R. Hamer[2]

Introduction

Timely cultural weed control practices may reduce reliance on chemical measures, and thus reduce the inherent risk of pesticide contamination to groundwater. The objective of this demonstration was to show different combinations of herbicide applications and mechanical practices for optimum weed control in corn and soybeans. This demonstration is part of the Environmental Agriculture Education Program of Cluster 16.

Materials and methods

Two corn and two soybean demonstration sites were selected in the Cluster 16 area. The corn sites were located in Freeborn and Rice counties; the soybean sites were located in Mower and Steele counties. All sites were located on medium textured soils which were high in natural fertility and organic matter contents (Table 1).

A split-plot arrangement with four replications was used at each site. Three herbicide treatments (main plots) were used: 1) No herbicide; 2) a pre-plant incorporated herbicide; and 3) a pre-emergence herbicide in corn and a post-emergence herbicide in soybeans. Within each of the main herbicide plots, there were four mechanical weed control treatments (sub-plots): 1) Rotary hoe (5-7 and 10-14 days after planting); 2) Cultivation (four weeks after planting and again by lay-by); 3) Combination of rotary hoe and cultivation; and 4) No mechanical practices. Sub-plots were six or eight rows wide (dependant upon cooperators' equipment), and 100 feet long.

Corn demonstration

Dual 8E at 3 pints/acre (3 lb a.i./acre) was used for both the pre-plant incorporated and pre-emergence herbicide applications. At Freeborn County, the pre-plant incorporation, planting, and the pre-emergence application was completed on May 8. At Rice County, the pre-plant application was made on May 15, but incorporation was delayed twelve days due to rain. Planting and the pre-emergence application was completed by May 29. Pioneer 3751 was planted at both locations. Farmer cooperators followed the mechanical control schedule described above as closely as was possible (Table 2).

Early season weed control was evaluated visually on a scale of 1 to 10 (1=poor, 10=excellent) approximately six weeks after planting. Plots were harvested with the farmers' equipment, weighed, and yields adjusted to 15.5% moisture.

Soybean demonstration

The herbicides selected for the soybean demonstrations were Treflan (pre-plant incorporated treatment) and Pursuit (post-emergence treatment). Treflan 4E was applied at 2 pt./acre (1 lb. a.i./acre) and incorporated at the Mower and Steele county sites on May 31. Hardin soybeans were planted within 24 hours of the pre-plant treatment at both sites. Pursuit was applied on June 22 at the 4 oz./acre rate (0.063 lb. a.i./acre). Cooperators followed the mechanical weed control schedule described above as closely as possible (Table 2).

Early season weed control was visually evaluated approximately six weeks after planting. Plots were harvested with the farmers' equipment, weighed, and yields adjusted to 12.0% moisture.

Results and discussion

Nineteen-ninety was an interesting year to conduct weed control trials. After three dry years, the unusually wet and cool 1990 season provided different weed control challenges. A late flush of weeds seemed to result in greater overall weed competition.

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[1]Funding provided by Board of Soil and Water Resources through Environmental Agriculture Education Program Grant of Cluster 16, Minnesota Extension Service.

[2]Environmental Agriculture Educator, Cluster 16; Area Extension Agent, Crop Pest Management; County Extension Agent, Agriculture, Steele County; and County Extension Agent, Rice County; Minnesota Extension Service.

Late season weed pressure varied greatly between demonstration sites. Weed pressure was high at the Freeborn County corn and Steele County soybean sites, while pressure was low at the Rice and Mower county demonstration sites. Due to differences in weed pressure, analyses for each site were kept separate.

Corn demonstration

Early season weed control in the pre-plant and pre-emergence application plots was very good at both sites (Table 3). Mechanical measures had the greatest impact in the plots where no herbicide had been applied. This was quite evident at the Freeborn site where weed pressure was high. Rotary hoeing at this site was only slightly better than using no mechanical measures, and much less effective than cultivation. A late flush of weeds emerged after plots could be rotary hoed, but while cultivation was still a viable control option. The primary weed species at both sites was giant foxtail.

Differences in weed pressure had an interesting effect on yields and returns over weed control costs. At the high weed pressure site (Freeborn County), there were no statistical yield differences between any of the pre-plant or pre-emergence treatments. However, yields in the no herbicide plots were severely reduced (Figure 1). Since there was no yield advantage to mechanical control in the herbicide plots, the highest returns over weed control costs was in these no mechanical, pre-plant or pre-emergence herbicide plots (Figure 2). At the low weed pressure site in Rice County, no herbicide plots that had been rotary hoed + cultivated or cultivated only yielded as well as the plots where herbicide had been applied (Figure 3). As a result, the highest returns were from these cultivated no herbicide plots (Figure 4). The low weed pressure encountered at this site may have been a function of the later than average planting date.

Soybean demonstration

Early season weed control at the Mower County site, where weed pressure was low, was excellent (Table 3). At Steele County, early season control was best in the Pursuit and cultivated Treflan plots. (Since cultivation and the rotary hoe + cultivation treatments performed similarly, they will be referred to collectively as cultivated plots.) Similar to the Freeborn County corn site, the rotary hoe only treatment missed a late flush of weeds in the no herbicide and Treflan plots. Treflan lost some effectiveness in the unusually wet and cool conditions, resulting in higher weed pressure in the rotary hoe and no mechanical treatment plots. At Steele County, giant foxtail and giant ragweed were the predominant weed species. The slight weed pressure at Mower County was primarily from giant foxtail.

These differences in weed pressure were reflected in yield and return differences between the two sites. At the Mower County site, yields were not significantly different between the Pursuit plots and the cultivated Treflan and no herbicide plots (Figure 5). Highest returns over weed control costs were realized in the Pursuit, no mechanical control plots (Figure 6). At the high weed pressure site, yields were equally good among the Pursuit plots and the cultivated Treflan plots (Figure 7). Soybean yields were severely reduced in the no herbicide and rotary hoed Treflan and no mechanical control plots, as the late weed flush had transformed these plots into giant ragweed and giant foxtail forests. It is no suprise that the greatest returns were obtained in the Pursuit and cultivated Treflan plots (Figure 8).

Summary

These demonstrations reinforce the need for producers to be familiar with weed species and pressures of individual fields. At low weed pressure sites, yields in the cultivated no herbicide plots were as good as herbicide treated plots, suggesting that mechanical control measures can be more heavily relied on under certain conditions. If, on the other hand, no herbicide had been used on a whole field basis at the high weed pressure sites, losses to the producer would have been substantial. Risks of contaminating groundwater with pesticides may be reduced by carefully selecting and applying herbicides when needed, and relying on mechanical measures to a greater extent when appropriate.

Table 1. Soil types and histories of demonstration sites, 1990.

County	Demonstration crop	Primary soil	O.M. content	Previous crop
Freeborn	Corn	Spicer silt loam	High	Corn
Rice	Corn	Clarion loam	High	Corn
Mower	Soybeans	Readlyn silt loam	High	Corn
Steele	Soybeans	Clarion loam	High	Sweet corn

Table 2. Mechanical weed control practice schedule, 1990

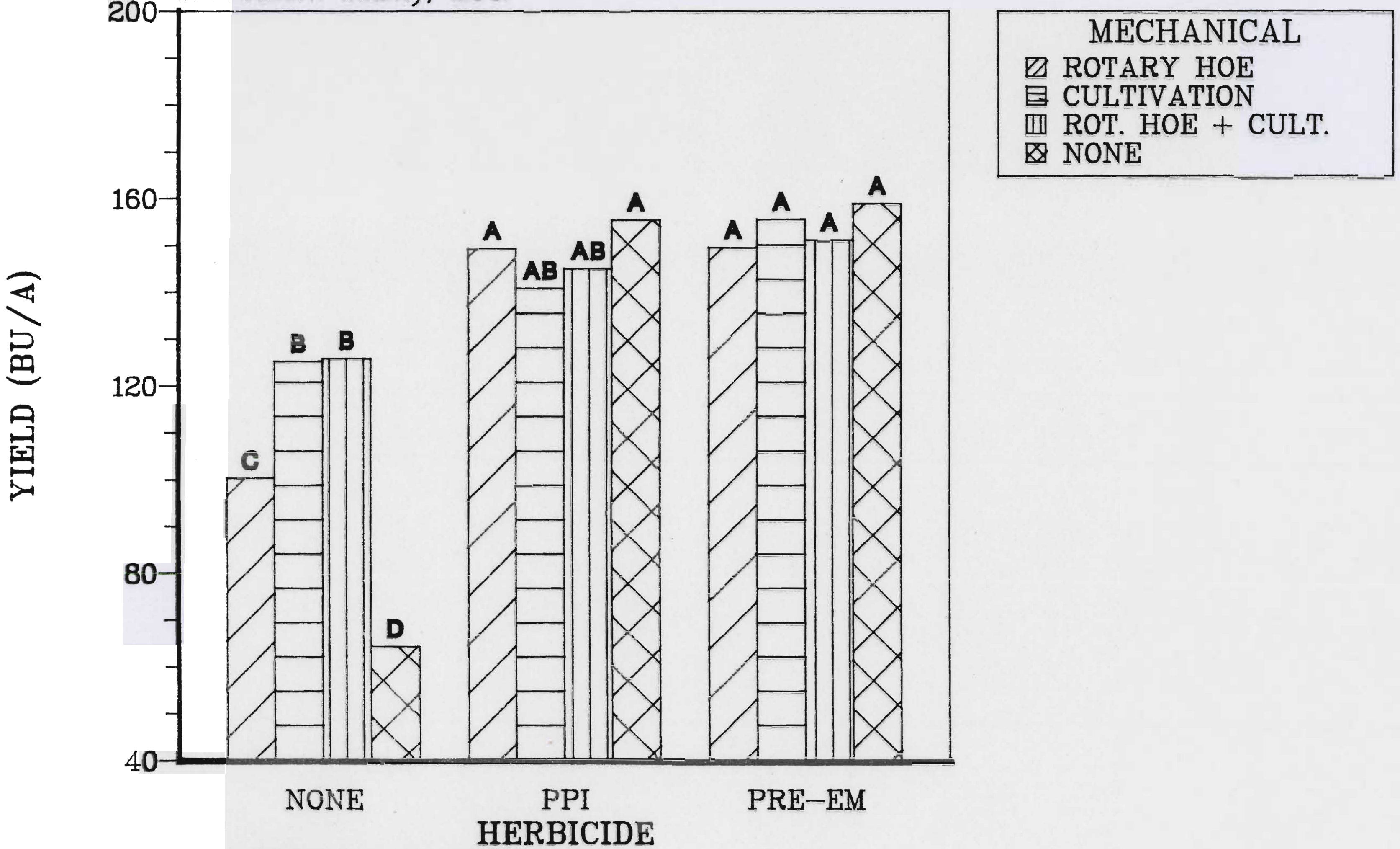
County	Crop	1st rot. hoe	2nd rot. hoe	1st cult.	2nd cult.
		DAP[1]		WAP[2]	
Freeborn	Corn	20	-	3	6
Rice	Corn	10	17	4	6
Mower	Soybeans	6	-	4	6
Steele	Soybeans	7	14	4	6

[1]DAP = days after planting
[2]WAP = weeks after planting

Table 3. Visual weed control evaluations (1=poor to 10=excellent). Scores followed by the same letter in the same column are not significantly different at the 0.05 level.

Herbicide	Mech. control	Corn: Freeborn	Corn: Rice	Soybeans: Mower	Soybeans: Steele
None	Rot.hoe	2.5 f	6.2 cd	7.8 cd	1.2 f
	Cult.	4.8 e	7.2 bc	9.5 a	7.2 d
	R.H. + cult.	5.8 d	8.5 ab	9.0 ab	7.2 d
	None	1.2 g	4.8 d	7.0 d	1.2 f
PPI	Rot. hoe	9.2 abc	9.5 a	9.0 ab	6.5 d
	Cult.	9.0 bc	9.8 a	9.8 a	9.2 abc
	R.H. + cult.	10.0 a	9.8 a	10.0 a	9.5 abc
	None	8.5 c	8.8 ab	8.2 bc	5.0 e
Pre-em	Rot. hoe	9.5 ab	9.2 a	9.5 a	8.8 bc
or	Cult.	9.5 ab	9.0 a	10.0 a	10.0 a
Post	R.H. + cult.	10.0 a	9.8 a	9.8 a	9.8 ab
	None	9.0 bc	8.2 ab	9.2 ab	8.5 c

Figure 1. Corn yields as affected by mechanical and chemical weed control practices in Freeborn County, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level

Figure 2. Returns over weed control costs at Freeborn County, 1990.

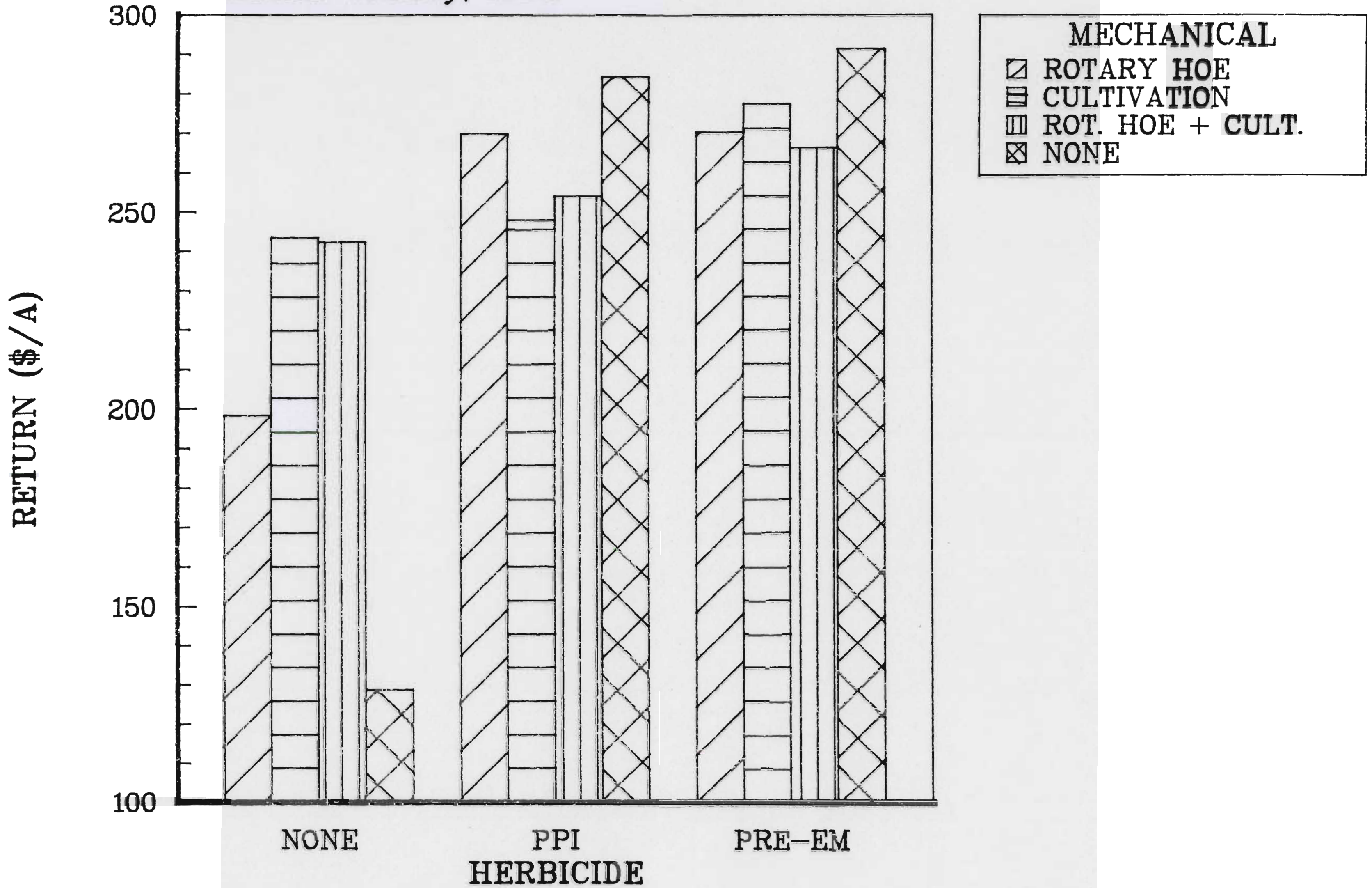
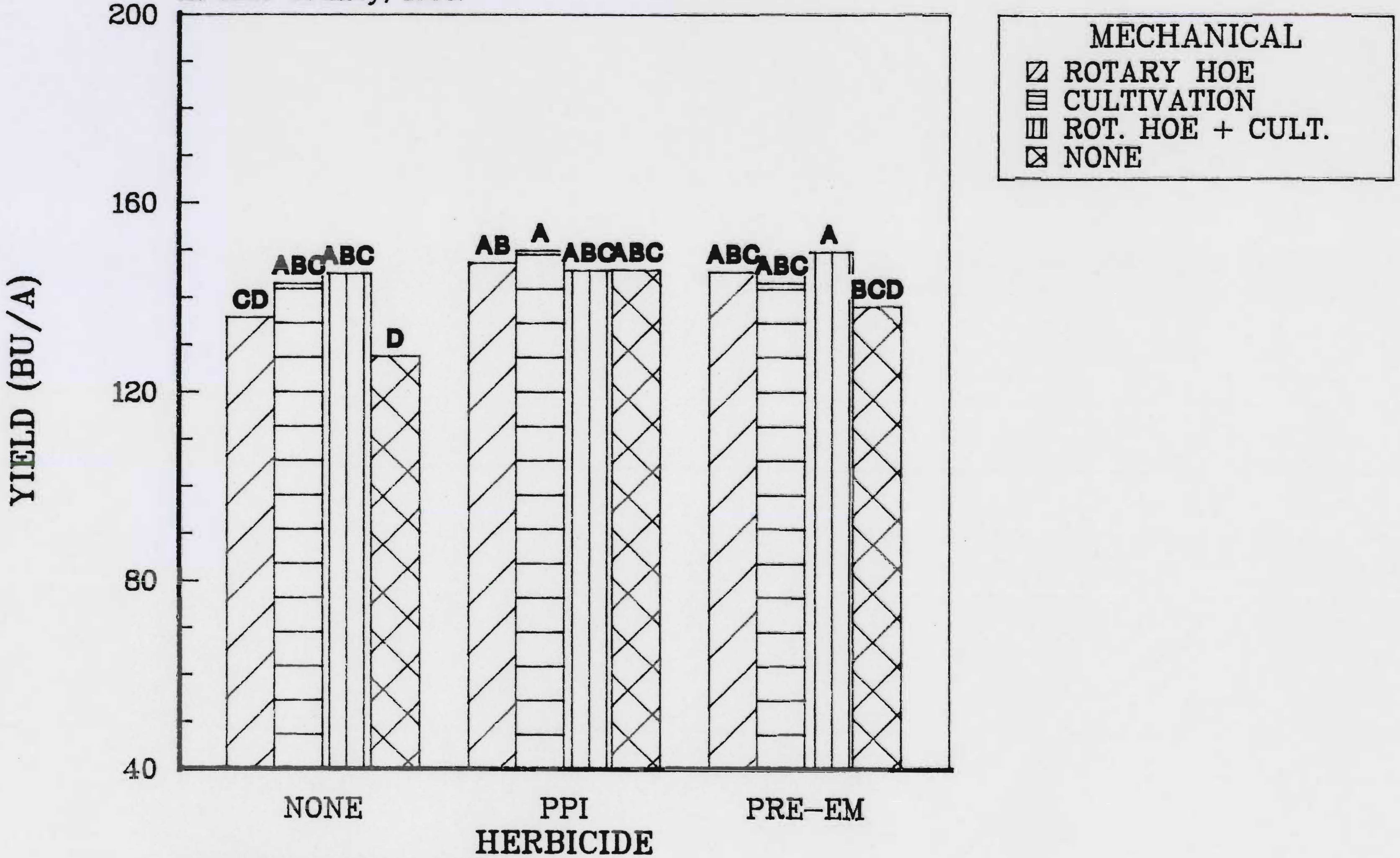


Figure 3. Corn grain yields as affected by mechanical and chemical weed control practices in Rice County, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level.

Figure 4. Returns over weed control costs at Rice County, 1990.

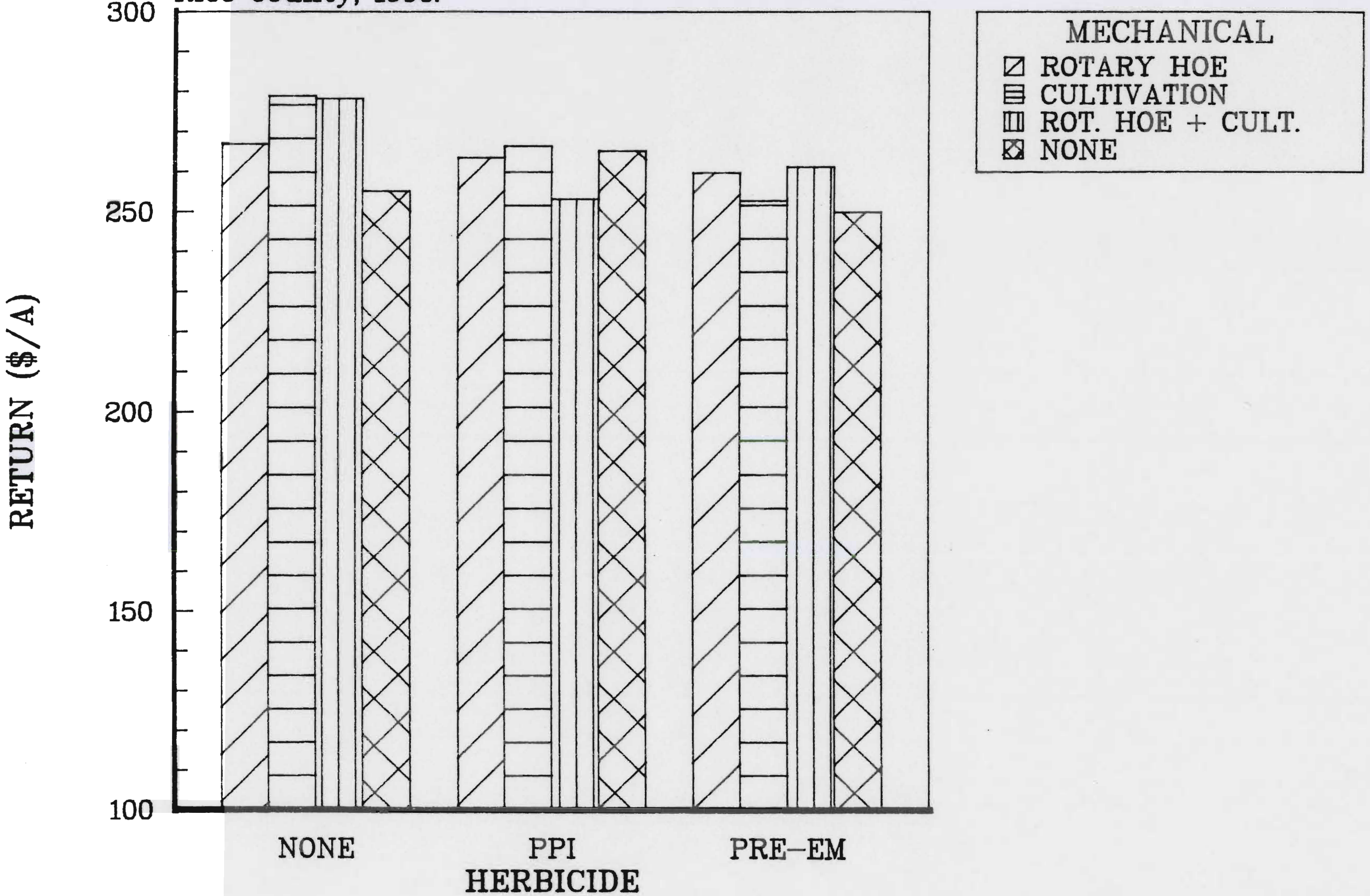


Figure 5. Soybean yields as affected by mechanical and chemical weed control practices in Mower County, 1990.

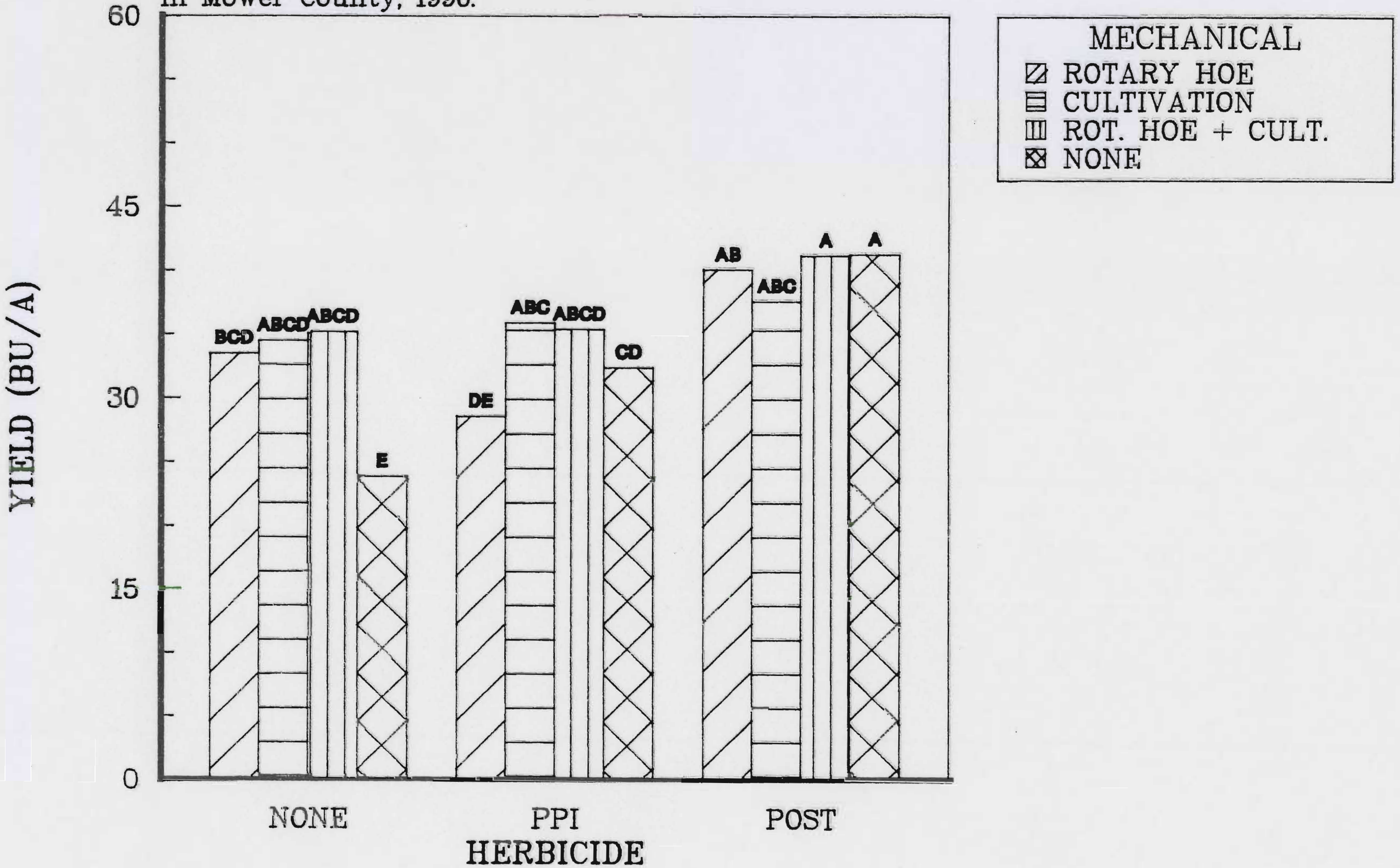


Figure 6. Returns over weed control costs at Mower County, 1990.

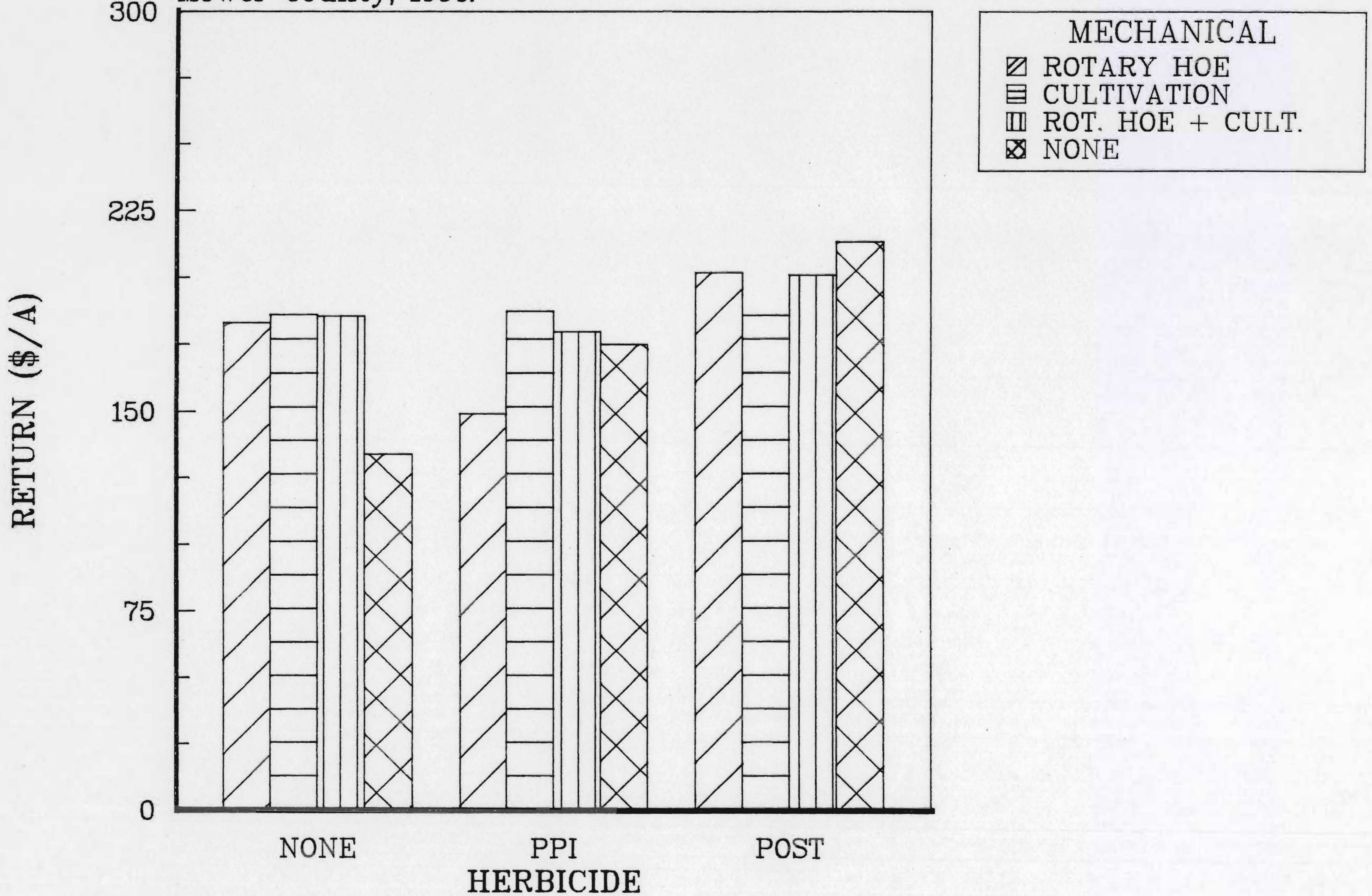
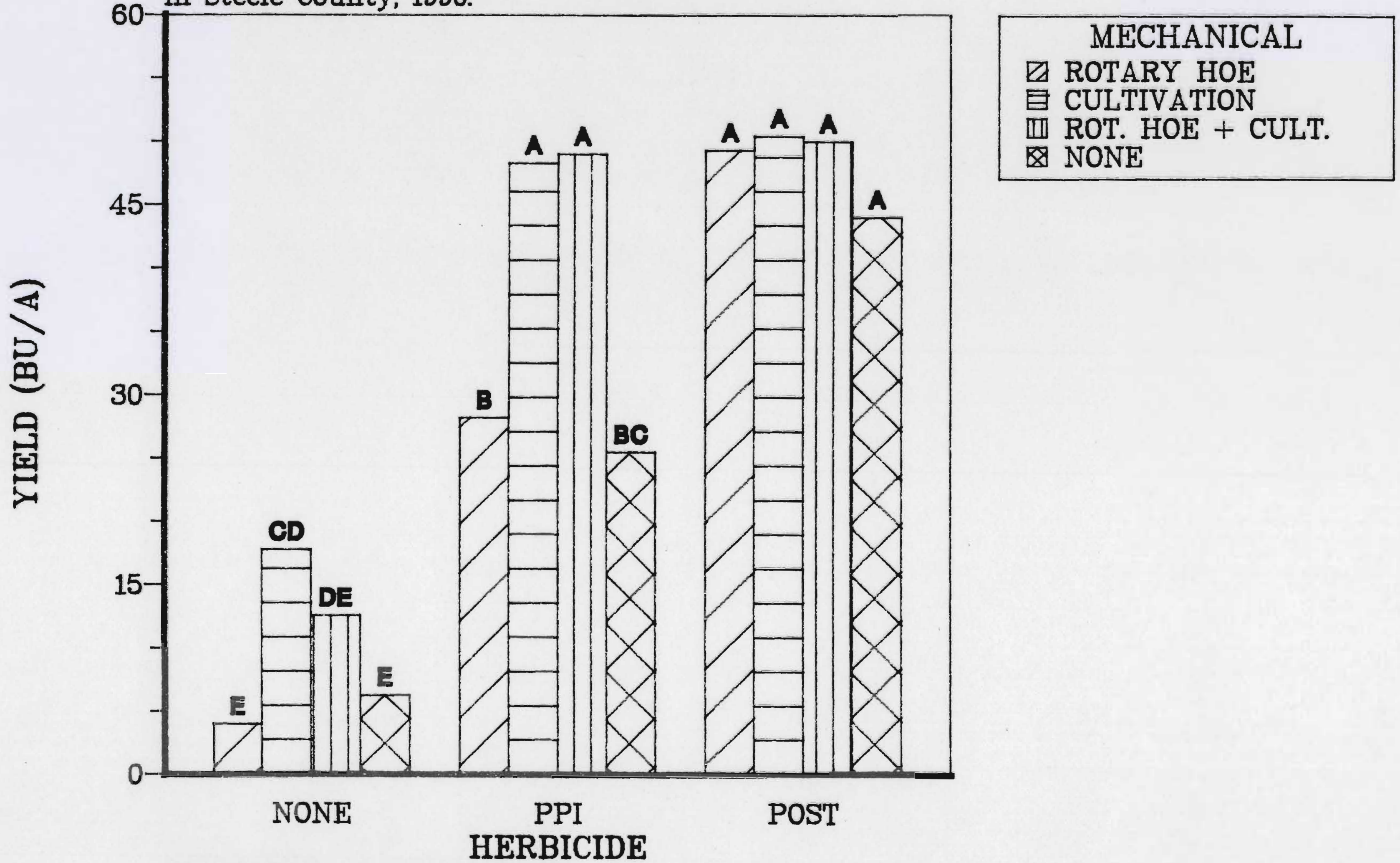
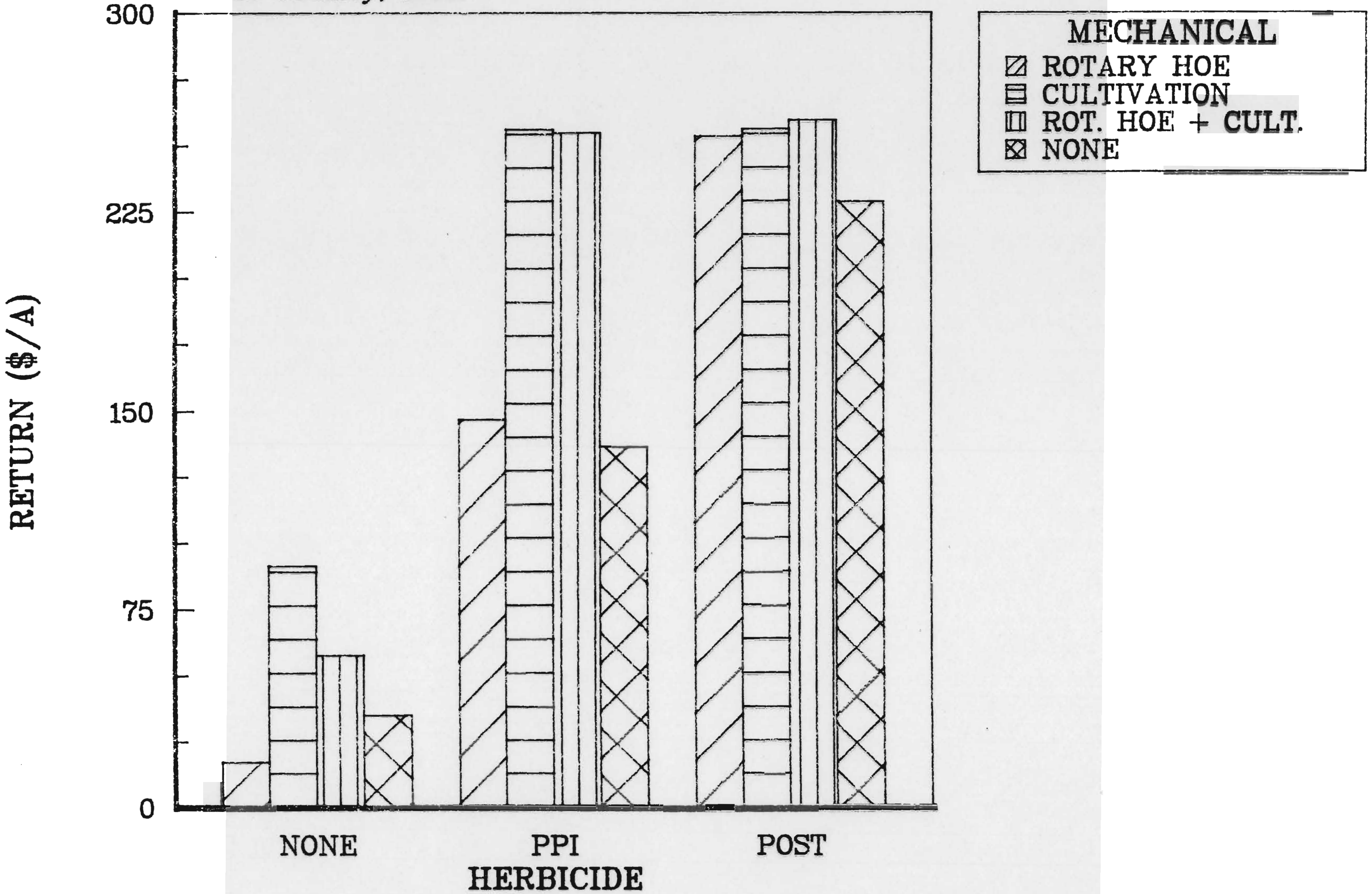


Figure 7. Soybean yields as affected by mechanical and chemical weed control practices in Steele County, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level.

Figure 8. Returns over weed control costs at Steele County, 1990.



SOIL NITRATE MOVEMENT IN IRRIGATED POTATO/CORN ROTATIONS[1]

Carl Rosen, Dave Birong, and Louise America

ABSTRACT. Soil samples from 10 irrigated fields were collected to a depth of three feet during the 1990 growing season. Fields sampled included: 6 potato fields, 3 sweet corn fields, and, 1 field corn field. Soil nitrate-N and ammonium-N were determined in KCl extracts. In addition, soil water from all fields was collected weekly from suction tubes and analyzed for nitrate-N. Rainfall during the 1990 season was well above average with over 6 inches occurring during a one week span in mid-June. Significant nitrogen movement beyond the root zone corrsponding to the June rainfall was detected in all fields. Nitrogen distribution during the season in potato and corn fields differed due to differences in placement. At mid-season nitrate and ammonium were higher between the row in corn and higher within the row for potato. Dry matter and nitrogen accumulation in roots, vines, and tubers through the season for early harvested and late harvested potatoes are presented.

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 nitrate-N 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 fields under conditions defined by growers. The ultimate goal is to help improve N management practices for irrigated crops.

Experimental Procedures. Six potato fields, three sweet corn fields, one field corn field, one tomato field, and one gladiolus 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 flowering for the gladiolus 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. All soil samples were placed in plastic bags and kept moist at 40°F until analyzed (usually less than 3 days). 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 Sept. samples, total nitrate-N and ammonium-N in the 3' profile were calculated by assuming half the field was 'within row' and the other half was 'between row'.

In five of the six potato fields, recently mature leaf (leaflet plus petiole) and petiole alone samples were collected on June 29. Samples were dried and ground to pass through a 30 mesh seive. Water soluble nitrate-N was determined using conductimetric procedures. Other elements were determined in ashed samples dissolved in 1 N HCl using ICP methodology. In two potato fields, 3, 5 ft sections were harvested at 10 day intervals and seperated into roots, vines, and tubers and then dried and weighed. Nitrogen was determined using the salicylic acid method for total nitrogen. Suction tubes were installed in the rows of five of the six potato fields and all other fields at 2.5 and 4.5 foot depths. There were two tubes at each depth in each field. Nitrate in soil water was determined in samples collected weekly during the growing season and at 2-3 week intervals after harvest through mid-November.

Results and Interpretations. Rainfall during the 1990 growing season was excessive. There were at least 3 dates between June and August where more than 3 inches of rain fell over a 24 hour period (Fig. 1). Most growers attempted to supplement rainfall, when needed, to provide about 1.5" - 2" of water per week from June through mid-August. Potato yields varied from approximately 260 cwt/A to 530 cwt/A, and N fertilizer applications ranged from 180 lb N/A to 300 lb N/A. Sweet corn yields ranged from 5.5 T/A to 7.5 T/A, and N fertilizer applications ranged from 160 lb N/A to 200 lb N/A. The field corn yield was 156 bu/A with 250 lb N/A applied.

[1] Partial support for this project was provided by the Sherburne County Farm Bureau and the East Central Irrigators Association.

[2] Extension Soil Scientist, Junior Scientist, Research 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 29 lb/A nitrate-N in the top 3 feet before planting and fertilizer application, with a range of 18 to 34 lb/A. There was a gradual decrease in nitrate from the top foot to the bottom 2-3 foot depth. In contrast to previous years, the residual nitrate level in the soil was low, possibly due to higher amounts of fall and winter precipitation. The practice of hilling and placing fertilizer N in the row affected N distribution in the field. Levels of nitrate-N in the rows were over 2 times greater than levels between rows. The amount of nitrate-N in the top 3' in July was about 20 lbs lower than in previous years due to leaching rainfall that occurred in June and July. At harvest, the level of nitrate-N in the top 3 feet was about 10 lbs higher than the level recorded before planting.

Ammonium-N levels during the growing season over all potato fields are summarized in Table 2. One field had unusually high ammonium-N levels. This particular field had field corn as a previous crop where anhydrous ammonia was used as the N source. 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 most potato fields, large flushes of nitrate were detected at about day 175. This corresponds to a leaching rain on June 18-19 (calendar day 169-170). In most cases nitrate-N rapidy declined at the 2.5' depth after this date followed by a more gradual decline at the 4.5' depth. Management practices did have some influence on the relative levels of nitrate in the soil water. For example, late planted, low yielding potatoes (Figure 2) and potatoes receiving higher rates of N (Figures 3 and 4) generally had higher soil water nitrate concentrations during the season and after harvest compared to potatoes with higher yields and where lower nitrogen rates were used. Dry matter accumulation and nitrogen accumulation in roots, vines, and tubers through the season for early and late harvested potatoes are presented in Figures 11 and 12. For half the season, most of the dry matter and N accumulation was attributed to the vines. Tubers accounted for most of the dry matter and nitrogen during the latter part of the season. Roots were relatively minor contributors to dry matter and N accumulation. Early harvested potatoes accumulated a total of 100 lb N/A by the end of the season while late harvested potatoes accumulated 125 lb N/A.

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. Because of the later planting date, field 1 had higher levels of tissue N than the other fields. Based on established critical values for that sampling date, fields 2, 3, and 4 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, 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-N and ammonium-N were generally similar to those found in fields to be planted in potatoes. 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. At mid season there was significantly more ammonium-N in the corn than in the potato fields. Except for one field, most of the N fertilizer was applied after the heavy rainfall in June. Residual nitrate was higher in corn than in potato fields.

Soil water nitrate in the corn fields is presented in Figures 7 to 10. The early planted sweet corn (Fig. 10) had the highest nitrate-N concentrations in the soil water at both sampling depths following the leaching rain in June. The other corn fields sampled had relatively low nitrate-N concentrations. The lower concentrations were due to the later planting dates and delay in applying N fertilizer until later in the season.

In summary, the 6 inch rainfall occurring in June caused leaching in all fields. From a potato production standpoint, this rain occurred at a time when the potential for nitrate leaching was very high. All the sidedress N had been applied, any ammonium-N applied would have been nitrified, and plant growth was just begining the exponential phase. Therefore, 1990 would probably represent a worst case leaching potential for potatoes. This survey has also shown that N distribution during the growing season in potato and corn fields differed. Most N was within the row for potato and between the row for corn. Because of the later planting and N fertilizer application dates for corn, more nitrate moved beyond the root zone in potato than corn. Based on nitrate samples from suction tubes, timing of application, N rate, and final yield had an effect on nitrate-N movement through the soil profile for both crops.

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: 180 - 300 lb N/A
Ranges in total yield: 260 - 530 cwt/A

April 1990

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	11.1	5.7 - 15.0
1 - 2	10.6	6.9 - 14.1
2 - 3	7.3	5.7 - 8.8
Total	28.9	18.2 - 34.3

July 1990

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/half acre[1]			
0 - 1	13.8	3.0 - 33.8	5.3	3.3 - 8.4
1 - 2	14.4	2.2 - 27.1	4.1	2.2 - 5.8
2 - 3	7.3	1.8 - 12.7	2.9	1.3 - 4.8
Total	35.4	6.9 - 64.2	12.3	8.3 - 17.2
Total lbs NO_3-N/A in field[2]			48.1	17.9 - 81.0

September 1990

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/half acre[1]			
0 - 1	12.1	7.0 - 16.4	8.0	3.8 - 13.2
1 - 2	7.0	2.6 - 11.6	4.8	2.0 - 9.4
2 - 3	3.7	1.5 - 7.3	2.6	1.4 - 4.3
Total	22.8	11.0 - 30.2	15.3	8.3 - 21.7
Total lbs NO_3-N/A in field[2]			38.1	25.7 - 45.8

[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 1990

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	13.8	1.9 - 52.5
1 - 2	4.2	0.7 - 9.1
2 - 3	1.7	0.1 - 2.5
Total	19.5	5.2 - 63.2

July 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	7.6	3.7 - 20.5	3.1	1.2 - 9.3
1 - 2	5.7	1.9 - 14.4	3.2	1.3 - 6.8
2 - 3	3.9	1.3 - 13.2	2.3	1.4 - 3.5
Total	17.1	7.5 - 34.8	8.7	4.0 - 19.6
Total lbs NH_4-N/A in field[2]			26.2	14.4 - 45.5

September 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	1.6	0.5 - 2.5	1.1	0.4 - 2.9
1 - 2	1.2	0.2 - 2.4	1.3	0.4 - 2.3
2 - 3	1.0	0.2 - 2.9	0.7	0.2 - 1.3
Total	3.8	1.3 - 7.8	3.1	1.6 - 6.1
Total lbs NH_4-N/A in field[2]			6.9	2.9 - 11.2

[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. Nutrient concentrations of potato leaves sampled from N-Survey grower fields on June 29, 1990 (Means of 4 samples from each field).

Field Number	NO_3-N Leaf	NO_3-N Petiole	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Al	Na
	%						ppm						
1	0.87	2.68	0.51	5.18	0.48	0.27	388	269	38	7	41	454	103
2	0.32	1.46	0.63	3.58	0.62	0.53	84	271	17	5	24	54	26
3	0.37	1.45	0.40	5.07	0.34	0.31	114	487	46	27	31	82	76
4	0.73	1.98	0.44	5.59	0.73	0.30	88	598	31	6	32	55	26
5	0.10	0.57	0.54	4.97	0.66	0.42	101	273	31	7	30	79	40

Table 4 Summary of soil nitrate-N levels in irrigated corn/sweet corn fields over the growing season. Means and ranges of four commercial corn/sweet corn fields.

Ranges in total N fertilizer applied: 160 - 250 lb N/A
Ranges in total yield (sweet corn): 5.5 - 7.5 T/A
(field corn): 156 bu/A

April 1990

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	15.9	14.6 - 16.9
1 - 2	10.7	5.1 - 16.7
2 - 3	8.5	4.1 - 15.8
Total	33.6	23.7 - 49.5

July 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	4.0	2.4 - 5.8	19.5	15.0 - 23.4
1 - 2	2.4	1.9 - 2.9	16.1	10.0 - 24.6
2 - 3	2.9	1.0 - 5.3	7.0	4.9 - 9.6
Total	9.3	8.2 - 10.2	42.4	33.6 - 52.5
Total lbs NO_3-N/A in field[2]			51.7	41.7 - 62.7

September 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	3.5	1.0 - 6.6	11.8	1.1 - 19.5
1 - 2	1.9	0.6 - 5.1	17.4	1.1 - 50.2
2 - 3	1.5	0.6 - 2.5	8.4	0.7 - 19.8
Total	6.9	3.2 - 14.2	37.5	3.0 - 89.2
Total lbs NO_3-N/A in field[2]			44.4	6.1 - 103.4

[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 fields.

April 1990

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	3.6	1.1 - 6.7
1 - 2	2.7	2.0 - 3.3
2 - 3	2.5	1.8 - 3.3
Total	8.7	4.9 - 12.9

July 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	2.3	0.7 - 4.0	80.4	16.7 - 234.1
1 - 2	2.1	0.4 - 3.3	16.6	1.3 - 44.0
2 - 3	2.0	0.4 - 3.4	4.5	0.8 - 9.3
Total	6.4	1.5 - 10.6	99.5	32.2 - 281.3
Total lbs NH_4-N/A in field[2]			105.9	39.4 - 291.9

September 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	0.9	0.4 - 1.2	7.3	0.7 - 23.9
1 - 2	1.0	0.6 - 1.4	5.7	0.3 - 19.5
2 - 3	0.8	0.4 - 1.6	1.4	0.6 - 2.5
Total	2.7	1.8 - 4.2	14.2	2.8 - 45.0
Total lbs NH_4-N/A in field[2]			16.9	4.6 - 47.7

[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.

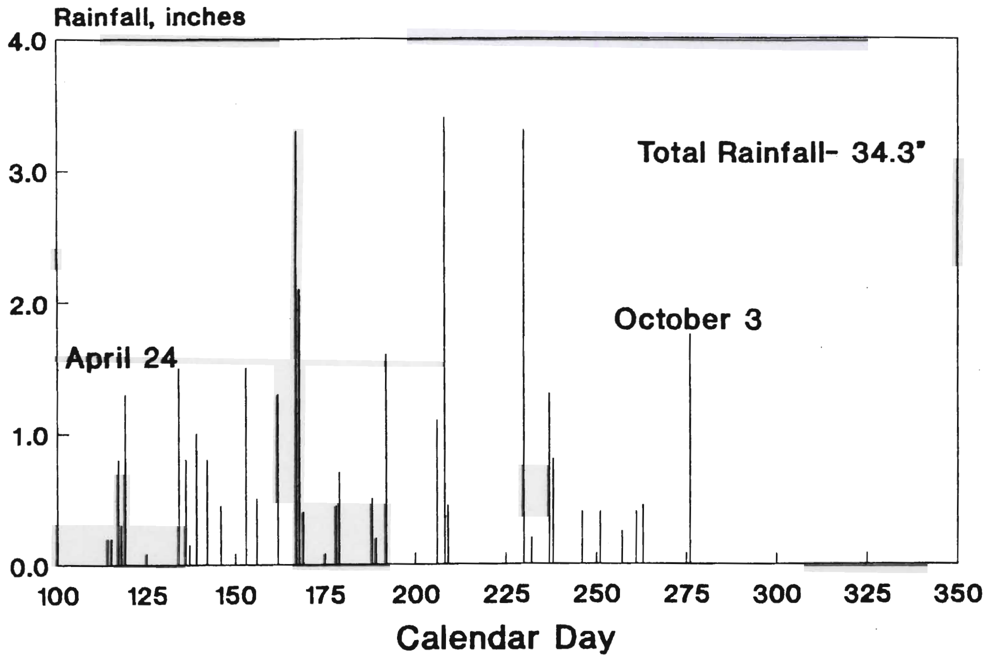
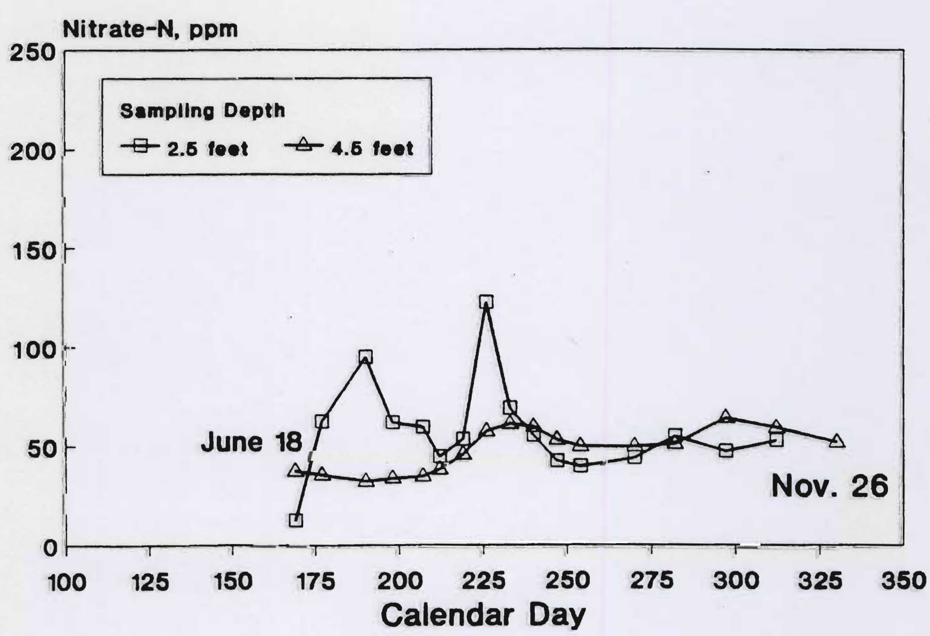


Figure 1. Rainfall distribution during the 1990 growing season at Big Lake, MN. This location was within a 15 mile radius of all fields sampled. April 24 indicates beginning of rainfall measurements, Oct. 3 indicates final rainfall measurement.

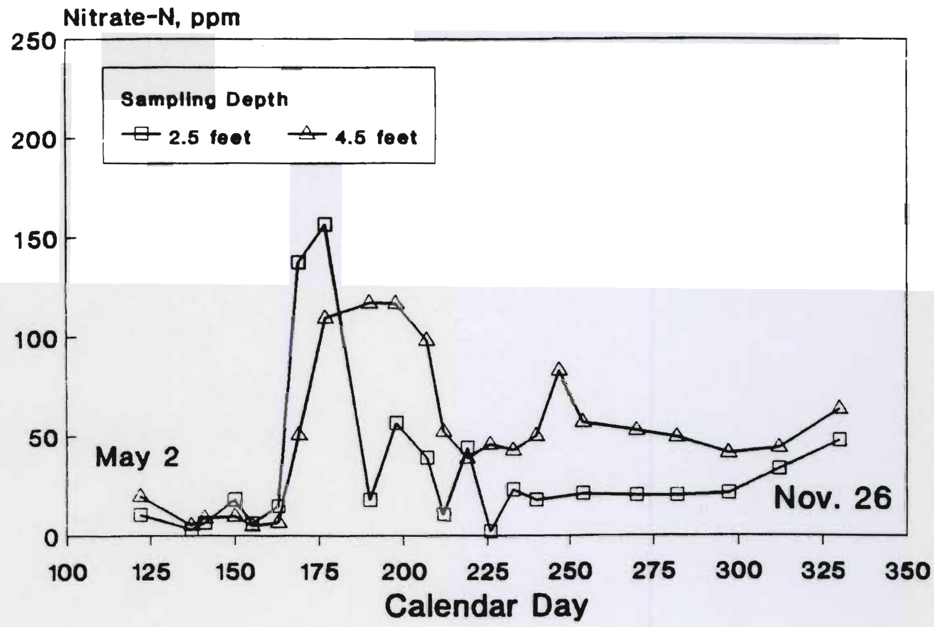


Cultivar - Norkota
Planting Date - May 29
Harvest Date - Sept. 20

N rate and mgmt. -
80 lb N/A starter
60 lb N/A June 15
60 lb N/A July 5
30 lb N/A late July
Total 230 lb N/A

Total Yield - 260 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. June 18 indicates the first sampling date and Nov. 26 indicates the last sampling date.

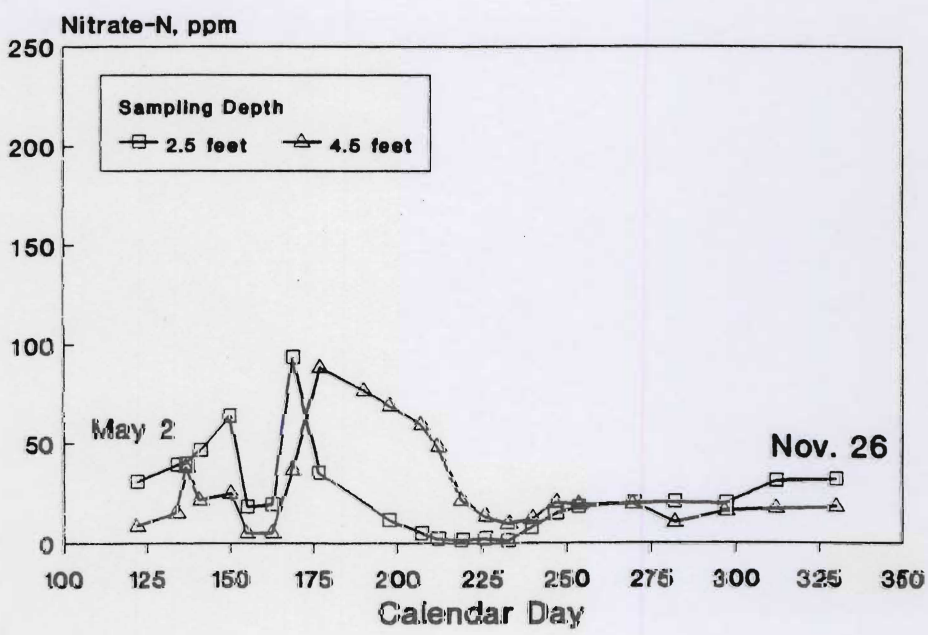


Cultivar - Russet Burbank
Planting Date - April 16
Harvest Date - Sept. 20

N rate and mgmt. -
70 lb N/A starter
180 lb N/A emergence
(82-0-0)
50 lb N/A hilling
Total 300 lb N/A

Total Yield - 480 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 2 indicates the first sampling date and Nov. 26 indicates the last sampling date.

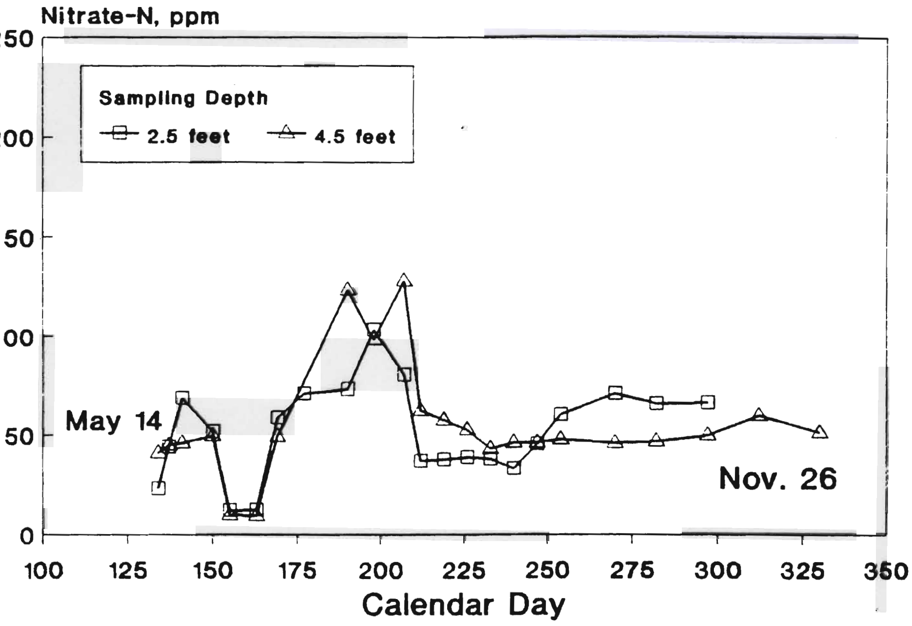


Cultivar - Russet Burbank
Planting Date - April 20
Harvest Date - Sept. 25

N rate and mgmt. -
80 lb N/A starter
46 lb N/A May 7
33 lb N/A May 25
46 lb N/A June 1
15 lb N/A June 15
15 lb N/A July 1
15 lb N/A July 15
Total 250 lb N/A

Total Yield - 530 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 2 indicates the first sampling date and Nov. 26 indicates the last sampling date.

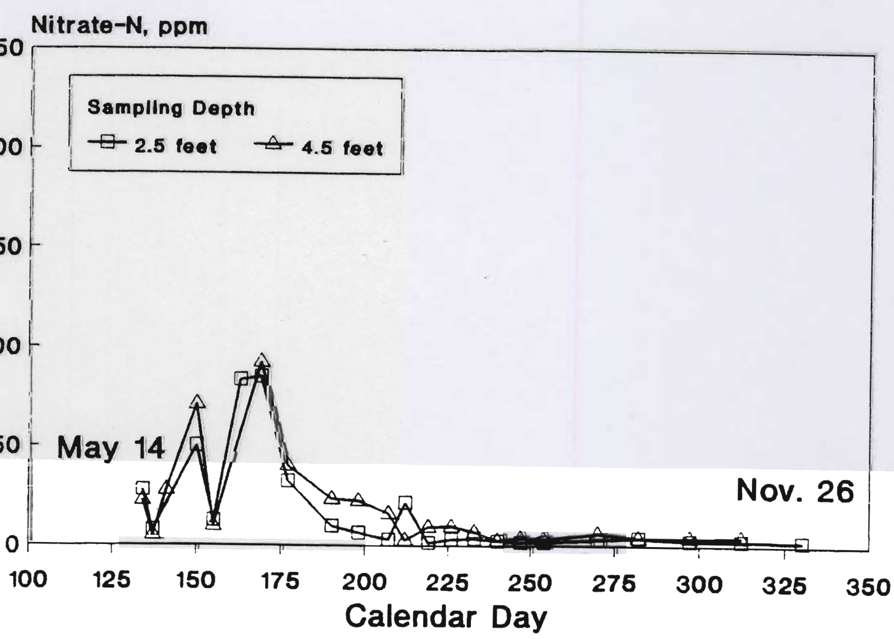


Cultivar - Norland
Planting Date - April 15
Harvest Date - August 25

N rate and mgmt. -
60 lb N/A starter
90 lb N/A emergence
110 lb N/A hilling
Total 270 lb N/A

Total Yield - 350 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 14 indicates the first sampling date and Nov. 26 indicates the last sampling date.

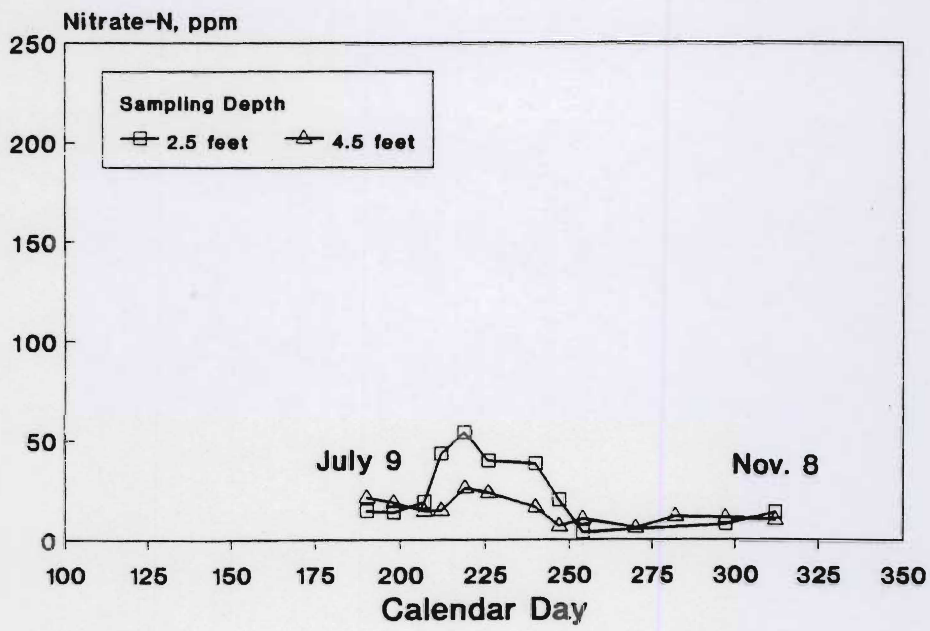


Cultivar - Norchip
Planting Date - April 13
Harvest Date - August 29

N rate and mgmt. -
84 lb N/A starter
100 lb N/A emergence
Total 184 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. May 14 indicates the first sampling date and Nov. 26 indicates the last sampling date.

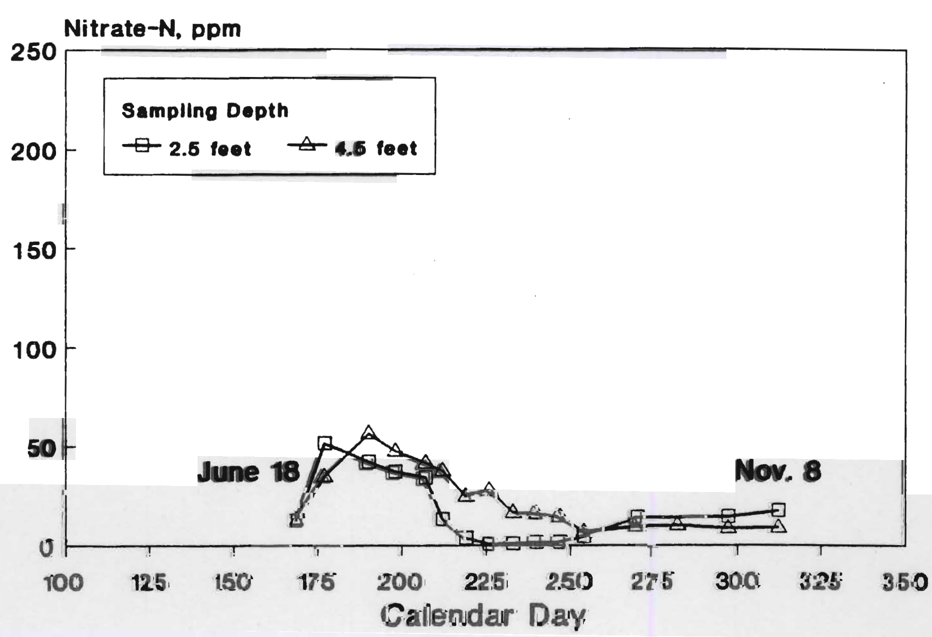


Hybrid - Sweet Jubilee
Planting Date - June 18
Harvest Date - August 25

N rate and mgmt. -
10 lb N/A starter
160 lb N/A July 4
Total 170 lb N/A

Total Yield - 4.5 T/A

Figure 7. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 6 (Sweet Corn). July 9 indicates the first sampling date and Nov. 8 indicates the last sampling date.

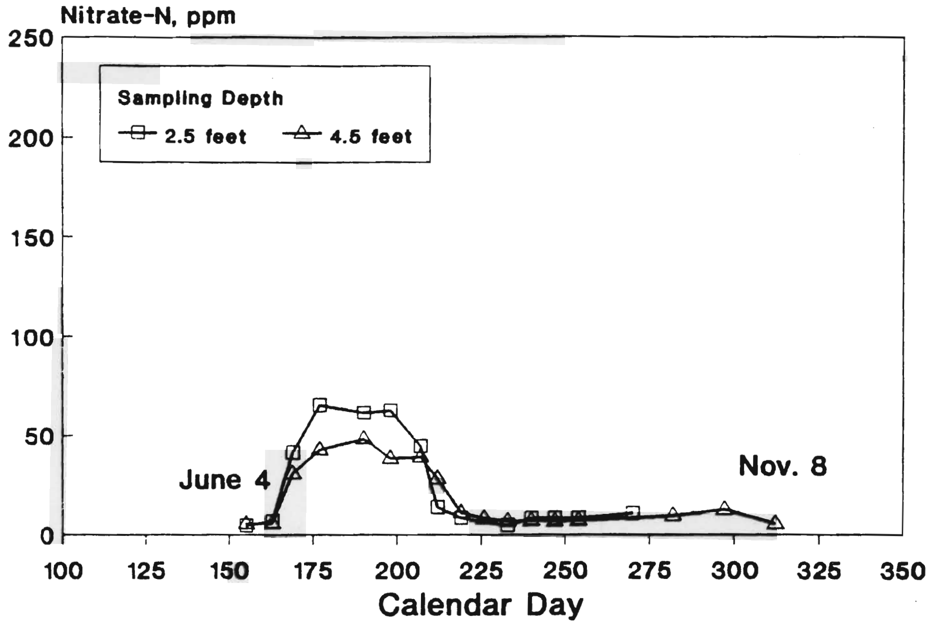


Hybrid - Silver Queen
Planting Date - June 4
Harvest Date - August 15

N rate and mgmt. -
30 lb N/A starter
140 lb N/A June 26
30 lb N/A late July
30 lb N/A early August
Total 230 lb N/A

Total Yield - 7.5 T/A

Figure 8. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 7 (Sweet Corn). June 18 indicates the first sampling date and Nov. 8 indicates the last sampling date.

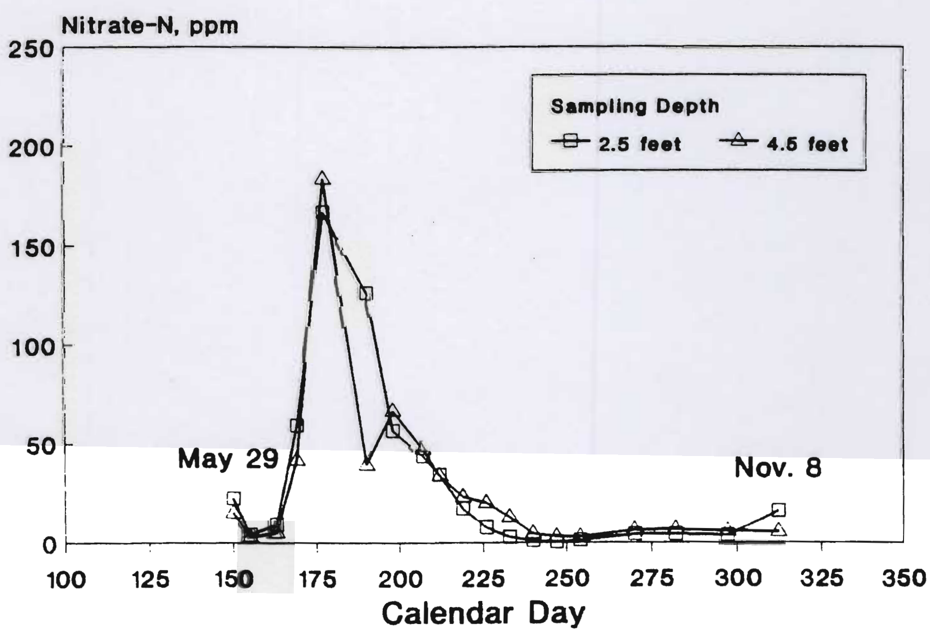


Hybrid - Field Corn
Planting Date - May 2
Harvest Date - Sept. 30

N rate and mgmt. -
18 lb N/A starter
32 lb N/A June 8
200 lb N/A June 19
Total 250 lb N/A

Total Yield - 156 bu/A

Figure 9. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 8 (Field Corn). June 4 indicates the first sampling date and Nov. 8 indicates the last sampling date.



Hybrid - Yukon
Planting Date - May 2
Harvest Date - July 30

N rate and mgmt. -
20 lb N/A starter
140 lb N/A June 7
Total 160 lb N/A

Total Yield - 7.0 T/A

Figure 10. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 9 (Sweet Corn). May 29 indicates the first sampling date and Nov. 8 indicates the last sampling date.

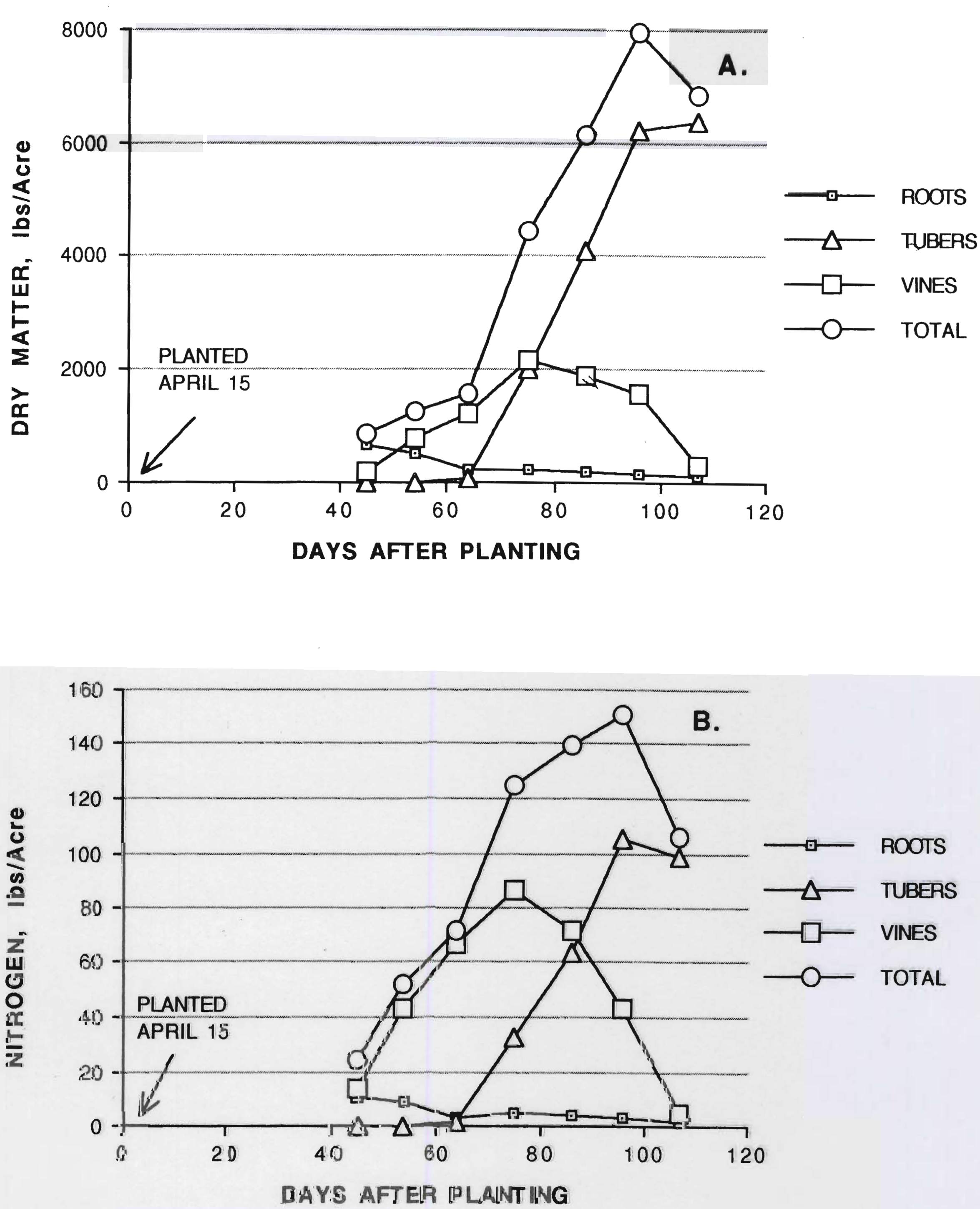


Figure 11. Dry Matter (A) and Nitrogen (B) accumulation in potato root vines and tubers through the season for early harvest Norland. Management practices for this field are presented in Figure 5.

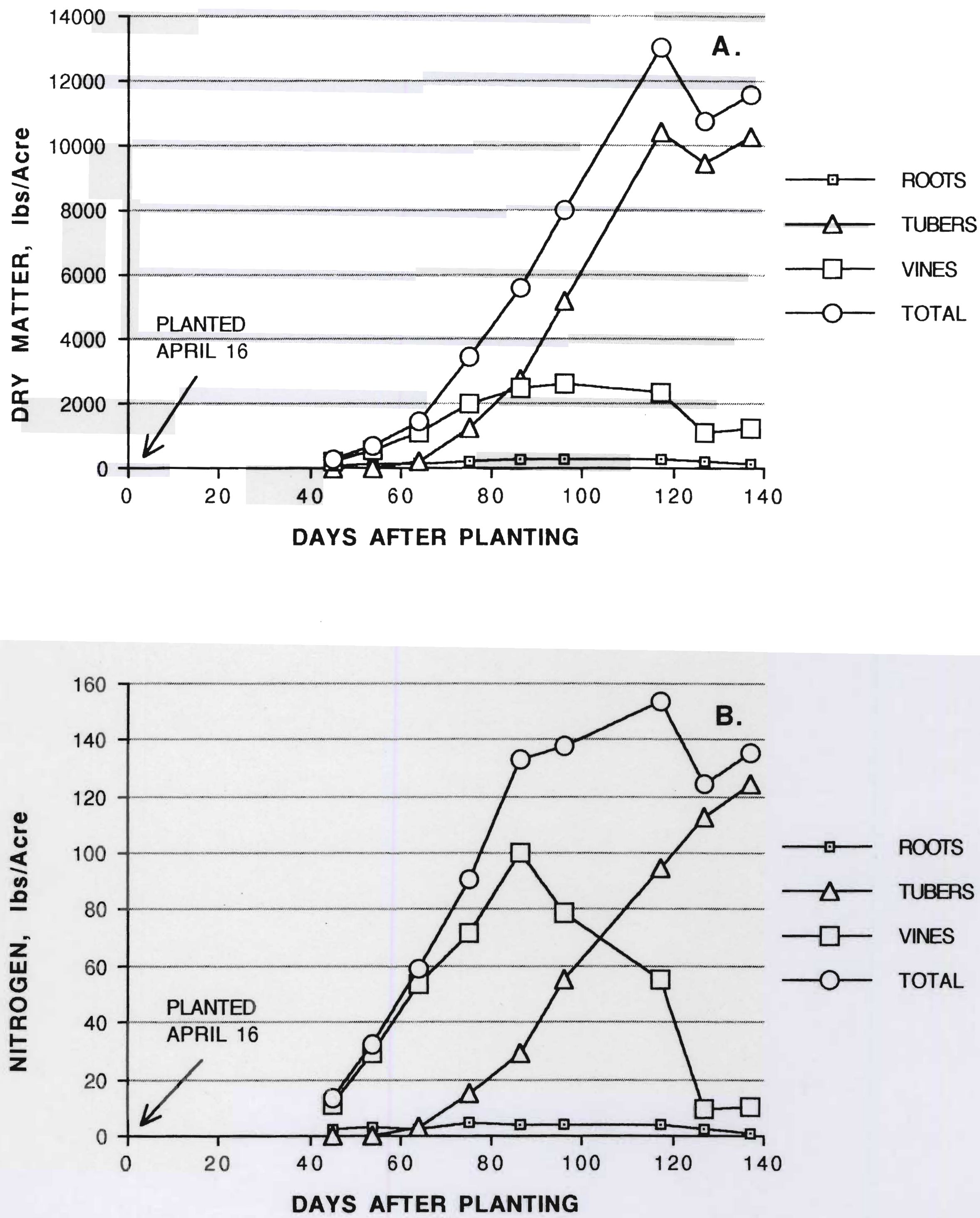


Figure 12. Dry Matter (A) and Nitrogen (B) accumulation in potato root vines and tubers through the season for late harvest Russet Burbank. Management practices for this field are presented in Figure 3.

EFFECT OF N-HIB AND N-FIX ON POTATO YIELD[1]

Carl Rosen, John Lamb, Duane Preston, and Roger Hanson[2]

Objective: To determine the effects of N-hib (Stoller Chemical, Houston, TX) and N-fix (BioCorp Global, Inc., Springfield, MO) on potato yield and quality and to compare the effects with standard fertilizer practices.

Location: Potato Research Farm, Grand Forks, ND

Cultivars: Norchip for the N-Hib trial - Planted 5/10/90, Russet Burbank for the N-Fix trial - Planted 6/1/90

Treatments:
N-hib trial:
1. Control, no fertilizer applied
2. Conventional, 25 lbs N/A as urea broadcast and incorporated prior to 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 prior to emergence banded near the row
5. Conventional plus 70 lbs N/A plus 30 lbs Ca/A as N-Hib prior to 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 30 lb P_2O_5/A as a broadcast application prior to planting. The experimental design was a randomized complete block with 6 replications.

N-Fix trial:
1. Control, No fertilizer applied
2. Conventional fertilizer, 44 lb N/A and 44 lb P_2O_5/A
3. N-Fix at the rate of 0.1 gal/A applied 6/90
4. Conventional fertilizer plus N-fix

Results: As in 1989, yields were low due to the extremely dry weather conditions (Tables 1 and 2). There was a significant yield response in the N-hib trial to applied fertilizer either from the conventional source or from N-hib. There was no difference due to source of fertilizer (ie. N-hib was the same as conventional fertilizer) indicating that the cheapest source would be the most economical to use. There were no significant differences in the N-Fix trial due to applied fertilizer and/or N-fix. Yields were extremely low due to the dry weather and the late planting date.

Table 1. Effect of N-hib, supplemental N, and foliar B on Norchip tuber yield and specific gravity.

Treatment	Tuber Size					
	<1.5"	1.5-2.5"	2.5-3.5"	>3.5"	TOTAL	SPECIFIC GRAVITY
	cwt/A					
Control	1.5	42.8	79.7	8.4	132.4	1.093
Conventional	1.6	47.7	83.4	9.0	141.7	1.093
Conventional + Urea	1.7	48.7	89.9	12.0	152.3	1.094
Conventional + N-hib	1.3	49.6	81.5	7.0	139.3	1.093
Conventional + N-hib + B	1.5	52.9	79.4	7.5	141.2	1.092
Significance	NS	*	NS	NS	*	NS
LSD (5% level)	--	6.2	--	--	13.9	--

NS = Not significant, * = significant at the 5% level.

Table 2. Effect of N-fix and fertilizer on Russet Burbank tuber yield and specific gravity.

Treatment	Tuber Size				
	<1.5"	1.5-2.5"	2.5-3.5"	TOTAL	SPECIFIC GRAVITY
	cwt/A				
Control	1.9	41.8	30.6	74.3	1.093
Fertilizer alone	4.6	41.5	24.4	70.2	1.093
N-Fix alone	2.2	43.1	24.4	69.8	1.094
Fertilizer + N-Fix	2.3	43.2	32.6	78.3	1.093
Significance	NS	NS	NS	NS	NS

NS = Not significant.

[1]Supported by the Grand Forks Potato Research Station and the U of M Agricultural Experiment Station.
[2]Extension Soil Scientist, Associate Professor, Dept. Soil Sci., U of M, Area Agent and Potato Research Station Supervisor, Grand Forks, ND.

IMPACT OF AG-LIME ON SOYBEAN AND POTATO PRODUCTION ON IRRIGATED SANDY SOILS[1]

George Rehm and Carl Rosen[2]

Abstract: The sandy soils of the Anoka Sand Plain typically have an acid pH. This is satisfactory for potato production, but may limit yields of soybean in the rotation. This study was conducted to evaluate the effect of ag-lime on the production of soybeans and potatoes. In 1989, soybean yield was not affected by the ag-lime use at rates of 1, 2, and 3 ton per acre. In 1990, potato yield was not affected by ag-lime application; however, scab incidence increased significantly with ag-lime application.

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. Little data in Minnesota could be found that examined the effect of lime on the incidence of scab in potatoes. The objective of this study, therefore, was to determine the effects of ag-lime applications in a soybean/potato rotation.

Experimental Procedure:

The study was conducted at Big Lake, Minnesota on a Hubbard loamy sand soil. Agricultural limestone was broadcast and incorporated before planting in 1989 at the rates of 0, 1, 2 and 3 tons per acre. Each treatment was replicated 4 times in a randomized complete block design. The potato cultivar used was the scab sensitive, Norkota Russet. Soil pH (1:1 soil:water) was determined in samples collected from the top six inches in the row at harvest. Potato yields were determined by measuring 2, 10 ft rows from each plot. Twenty-five tubers from each plot were washed and evaluated for total scab incidence and deep scab incidence.

Results:

Soil pH, potato yield, and scab incidence are presented in Table 1. Soil pH increased with increasing rate of lime application. All plots dropped in pH from 1989 to 1990. The reasons for this drop are not clear, but may be due to the heavy rainfall occurring in 1990 compared to 1989. Because of the frequent rains in 1990, little high pH irrigation water was applied in that year. Potato yields were not significantly affected by lime application; however, scab incidence increased with lime application. Deep pitted scab increased with lime indicating a decrease in marketable potatoes. These results suggest that lime should be used cautiously in a potato/soybean rotation. If lime is used, then a scab resistent potato cultivar should be selected for the rotation. An additional experiment should be conducted on a soil with an initial pH of less than 5.0 to see if low rates of lime might be more beneficial than in this study where initial pH was already higher than needed for potato/soybean production.

Table 1. Effect of ag-lime on soil pH in 1989 and 1990, potato yield, and potato scab incidence.

Treatment	Soil pH 1989	Soil pH 1990	Potato Yield	Total Scab Incidence	Deep Pitted Scab Incidence
Tons lime/A			cwt/A	%	%
0	6.3	5.8	410	22	4
1	6.4	5.9	389	47	19
2	6.4	6.2	355	45	14
3	6.5	6.3	360	39	17
Significance	NS	*	NS	*	*

[1]This project was supported in part by the Minnesota Lime Producers Association.
[2]Extension Soil Scientists, Department of Soil Science.

EVALUATION OF LIMING MATERIALS AND RATE OF APPLICATION FOR ALFALFA PRODUCTION ON IRRIGATED SANDY SOILS

George Rehm, Dan Schmitz, and Andy Scobbie[1/]

ABSTRACT:

There are several liming materials that can be used for alfalfa production on acid soils. For this study, 4 liming materials were applied at 3 rates. All materials were broadcast and incorporated before the alfalfa was seeded. In the first year of production, yield was not affected by either lime source or rate of application. Soil pH was not influenced by lime source but increased curvilinearly with rate of application.

Introduction:

The cost of lime needed for profitable alfalfa production is substantial in many parts of Minnesota. There are some alternatives to the use of what is usually described as "normal ag lime". These alternatives, however, need to be evaluated in field situations. Therefore, this study was conducted to measure the effect of liming materials and rate of application on alfalfa yield and soil pH.

Experimental Procedures:

This study was established in an irrigated field in Wadena County in the spring of 1990. Four liming materials (normal ag lime, finely ground ag lime, sugarbeet lime, Pel Lime) were applied at 3 rates (4,321; 8,640; 12,960 lb. ECCE/acre). Treatments in the complete factorial were arranged in a randomized complete block design with 4 replications. To provide another comparison, Pel Lime was applied at a rate of 2,160 lb. ECCE per acre. A control treatment was established, but it was not part of the complete factorial design.

The liming materials as well as adequate rates of phosphate, potash, and sulfur were broadcast and incorporated before planting. Alfalfa was seeded in late April without a companion crop at a rate of 16 lb./acre. Irrigation water was applied as needed throughout the growing season.

Soil samples (0-6 in.) were collected prior to treatment application and the results are listed in Table 1. Two cuttings were harvested. Soil samples (0-6 inches) were collected from each plot at the end of the growing season.

Results and Discussion:

In 1990, alfalfa yields were quite variable and this is to be expected in the seeding year. An excellent stand was established and yield differences due to treatment are anticipated in 1991 and succeeding years. In the first year of production, however, neither rate nor material had a significant effect on yield (Table 2).

Soil pH at the end of the 1990 growing season was affected by both lime source and rate of application. When averaged over all rates, pH values were high when the sugarbeet lime and finely ground ag lime were used. The use of "normal ag lime" and Pel Lime produced lower and equal values. When averaged over all sources, the pH increased as rate of application increased.

Summary:

An excellent stand of alfalfa was established at this experimental site. The treatments used had no significant on yield in the first year of production, but this is to be expected. Major differences due to lime use are anticipated for 1991.

[1/] Extension Specialist, Junior Scientist, Assistant Scientist, respectively.

Table 1. Soil properties (0-6 inches) at the experimental site.

pH	5.4
phosphorus (Bray #1), ppm	66
potassium (1 N $NH_4C_2H_3O_2$), ppm	144
exchangeable calcium, ppm	995
exchangeable magnesium, ppm	128
sulfur, ppm	5.8
organic matter, %	3.0

Table 2. The effect of lime source and rate of application on yield of irrigated alfalfa and soil pH in the fall of 1990.

Lime Source	Effective Calcium Carbonate Equivalent Applied	Yield	Soil pH
	lb./acre	ton D.M./acre	
control	-	1.45	5.6
normal ag lime	4,321	1.62	6.0
	8,640	1.62	6.1
	12,960	1.47	6.1
finely ground ag lime	4,321	1.75	6.2
	8,640	1.76	6.2
	12,960	1.39	6.5
sugarbeet lime	4,321	1.71	6.2
	8,640	1.54	6.4
	12,960	1.56	6.6
Pel Lime	2,160	1.39	5.8
	4,321	1.54	5.9
	8,640	1.53	6.2
	12,960	1.40	6.2

APPLICATION OF LIMING MATERIALS FOR ESTABLISHED ALFALFA

George Rehm, Andy Scobbie, Dan Schmitz[1/]

ABSTRACT: There have been many instances where alfalfa growers plant alfalfa and then realize that lime should have been applied before seeding. This project in Goodhue County is designed to evaluate liming materials and placement of these materials for established alfalfa on soils where pH values are low. Treatments used had variable effects on individual cuttings but none increased total yield for the growing season.

Introduction:

There is general agreement that lime, when needed, should be broadcast and incorporated before alfalfa is seeded. There are, however, situations where alfalfa is planted and, because soil samples were not collected, lime is not applied as needed. This study is designed to evaluate liming materials and methods of application that might be appropriate for alfalfa that has been established on acid soils.

Experimental Procedure:

This study was established in Goodhue County in August of 1989. Alfalfa had been seeded in the spring of 1989 in a field where the soil pH averaged 5.7. Seven treatments were applied and compared to a control (see Table 1).

For the treatments where the knife application was used, coulters were spaced 12 inches apart and knives designed to apply either dry or fluid materials were placed behind the coulters. The depth of application was approximately 5 inches. Rate of application was limited with this equipment. Consequently, there was no attempt to apply equal rates of all materials. Since the calcium carbonate equivalent varies with material, the pounds of effective calcium carbonate equivalent (ECCE) are reported. With the new Minnesota Lime Law, this will be reported at ENP (Effective Neutralizing Power).

Three cuttings were taken during the growing season. Alfalfa was in the bud to 1/10 bloom stage at each cutting. Soil samples (0-6 inches) were collected from each plot in September.

Results and Discussion:

The total alfalfa yield for the growing season as well as the pH values measured in September are summarized in Table 1. Statistical analysis of the yield data showed no significant differences among the treatments that were applied. There was some variability in the yields. This variability, however, was due to the growth of alfalfa in the field and not the treatment that was applied. It's also important to note that the use of coulters on 12 inch centers in an established alfalfa stand had no negative effect on yield.

Soil pH was increased by the broadcast application of the high rates of both ag lime and fluid lime. Otherwise, there was no change in soil pH when compared to the control.

Table 1. Effect of lime source and rate of application on the yield of established alfalfa and soil pH at the end of the growing season.

Lime Source	Placement	Rate Applied	Alfalfa* Yield	Soil pH
		lb. ECCE/acre	ton D.M/acre	
control	-	-	4.24 a	6.0 bc
Pel lime	knife	724	4.44 a	5.9 c
ag lime	broadcast	972	4.25 a	6.0 b
ag lime	broadcast	2.916	4.30 a	6.2 a
fluid lime	broadcast	2,000	4.72 a	6.1 b
fluid lime	broadcast	6,000	4.38 a	6.4 a
fluid lime	knife	681	4.17 a	6.1 b
fluid lime	knife	2,082	3.91 a	6.0 bc

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

[1/] Extension Specialist, Assistant Scientist, Junior Scientist, respectively.

Summary:

The data collected during the 1990 growing season would indicate that yield of established alfalfa was not affected by in-season application of limestone materials either topdressed or knifed in to the established stand. It is possible that the treatments used may have a significant effect on alfalfa production in the years ahead. This study will be continued in 1991 to monitor changes that might occur.

RECYCLING OF NITROGEN FROM TURFGRASS CLIPPINGS[1]

Carl Rosen, Paul Johnson, Dave Birong, Don White, and Karl Ruser[2]

ABSTRACT: Turfgrass managed during a typical Minnesota growing season produced 147 lbs/1000 sq. ft. of clippings on a fresh weight basis and 44 lbs/1000 sq. ft. on a dry weight basis. The nitrogen content of the clippings was approximately 1.4 lbs/1000 sq. ft.

During the summer months about 30% of the waste stream can be made up of grass clippings. Recent legislation banning the dumping of organic yard waste in landfills has led to the need for finding alternatives to collecting the clippings. An acceptable means of managing turfgrass clippings is simply to return them to the lawn to decompose. Leaving the clippings on the lawn will recycle most nutrients, particularly nitrogen. The objective of this study was to quantify the amount of clippings produced and the amount of nitrogen contained in clippings during a 'typical' Minnesota growing season. These data will provide background information on how best to manage nitrogen for Minnesota lawns.

Procedures:

Established turf plots located on the St. Paul Campus were used for this study. The soil is classified as a Waukigen silt loam and the turf was predominantly Kentucky blue grass with some fescue and perennial ryegrass. On May 17, 1990, KCl extractable nitrate-N and ammonium-N in the top foot was 2.5 ppm and 2.4 ppm, respectively. Four, 15 X 30 ft. plots were measured and Scotts Turf Builder Plus (nitrogen plus pendimethalin) was applied at the rate of 1 lb N/1000 sq. ft. on May 24, 1990. On the same day, Trimec (2,4-D + dicamba, + mecoprop) was also applied at recommended rates to control broadleaf weeds. From May 30, 1990 through October 19, 1990, turfgrass was cut every 7-14 days to a height of 2 inches. On July 12, 1990, an additional 0.5 lb N/1000 sq. ft. was applied as ammonium nitrate. Plots were set up for irrigation; however, because of the timely and, on occasion, heavy rains during 1990, no irrigation was needed. Clippings were collected with a rear bag mower, weighed, and placed in a 55 gallon barrel compost bin (one bin for each plot). A small subsample of clippings was taken to determine moisture and Kjeldahl nitrogen content each time the turf was cut.

Results and Discussion:

An assumption made in this study was that clippings obtained for sampling were similar to those returned to a lawn where clippings were not removed. Since these plots had all clippings removed, the nutrients that would have been supplied by their degradation were not accounted for. Therefore, the data probably underestimates the amount of nutrient recycling that actually occurred.

Turfgrass fresh and dry weight, and nitrogen concentration and content at each mowing date and totals for the season are presented in Table 1. Nitrogen concentration in the clippings declined steadily until July and then increased with the July 12 nitrogen fertilizer application. Water extractable nitrate in the clippings was also determined; however, concentrations were less than 200 ppm nitrate-N (data not presented).

The total amount of clippings removed from the plots was equivalent to 147 lbs per 1000 sq. ft. on a fresh weight basis and 44 lbs per 1000 sq. ft. on a dry weight basis. The nitrogen content of the clippings was 1.4 lb N/1000 sq. ft. Thus, the clippings contained approximately the same amount of nitrogen that was applied. Had the clippings been left on the lawn, some of the nitrogen in the clippings would have been available for growth of the turfgrass. The exact amount of nitrogen available from the decaying clippings is not known, but the high nitrogen concentration of the clippings would render them susceptible to rapid microbial degradation. The amount of nitrogen found in the clippings in this study is about twice that reported in the literature from other areas of the country. Further studies need to be conducted to resolve these differences.

According the state demographers, there are approximately 1.3 millon residences in Minnesota. Assuming that each residence is about 0.2 acres in size, then there would be roughly 260,000 acres of lawn in the state. Based on these figures and the data obtained in this study, approximately 830,000 tons of fresh clippings and 249,000 tons of dry clippings are produced on home lawns each year in the state. Assuming a nitrogen content similar to that obtained in this study, the clippings would contain 8,100 tons of nitrogen. Based on these calculations, leaving clippings on the lawn can lead to significant nitrogen inputs into lawn fertilization in Minnesota.

[1]Funding for this study was provided by the Minnesota Extension Service and the Agricultural Experiment Station.

[2]Extension Soil Scientist, Research Assistant, Junior Scientist, Professor of Horticulture, and Associate

Table 1. Fresh weight, dry weight, nitrogen concentration, and nitrogen accumulation in turfgrass clippings. Mean ± one standard deviation.

DATE	FRESH WEIGHT	DRY WEIGHT	NITROGEN CONCENTRATION	NITROGEN CONTENT
	lbs/1000 sq ft	lbs/1000 sq ft	%	lbs N/1000 sq ft
MAY 30	10.5 ± 2.5	3.2 ± 0.8	3.32 ± 0.11	0.11 ± 0.03
JUNE 6	13.0 ± 2.5	3.8 ± 0.7	3.16 ± 0.15	0.12 ± 0.03
JUNE 12	9.4 ± 2.1	2.7 ± 0.6	3.08 ± 0.10	0.08 ± 0.02
JUNE 21	12.7 ± 2.7	3.9 ± 0.8	2.91 ± 0.15	0.11 ± 0.03
JUNE 29	8.5 ± 1.9	2.5 ± 0.6	2.98 ± 0.17	0.07 ± 0.02
JULY 5	3.6 ± 0.8	1.3 ± 0.2	2.74 ± 0.13	0.03 ± 0.01
JULY 13	5.3 ± 1.0	1.7 ± 0.3	3.14 ± 0.23	0.05 ± 0.01
JULY 23	10.0 ± 1.5	3.3 ± 0.5	3.30 ± 0.12	0.11 ± 0.02
JULY 27	6.0 ± 1.3	1.7 ± 0.3	3.33 ± 0.10	0.06 ± 0.01
AUG 3	8.7 ± 1.1	2.5 ± 0.3	3.30 ± 0.21	0.08 ± 0.01
AUG 10	6.7 ± 1.1	1.8 ± 0.3	3.40 ± 0.14	0.06 ± 0.01
AUG 17	4.0 ± 1.0	1.3 ± 0.3	3.26 ± 0.17	0.04 ± 0.01
AUG 30	14.4 ± 2.4	3.9 ± 0.5	3.46 ± 0.14	0.14 ± 0.02
SEPT 11	17.5 ± 0.8	4.9 ± 0.3	3.59 ± 0.09	0.18 ± 0.01
SEPT 21	7.2 ± 1.1	2.3 ± 0.3	3.28 ± 0.03	0.08 ± 0.01
SEPT 28	5.4 ± 0.4	1.8 ± 0.1	3.12 ± 0.08	0.06 ± 0.00
OCT 19	4.5 ± 0.7	1.5 ± 0.2	3.09 ± 0.01	0.05 ± 0.01
TOTAL	147.3 ± 19.0	44.0 ± 5.7	---	1.43 ± 0.19

EFFECT OF TILLAGE AND FREQUENCY OF LIQUID DAIRY MANURE APPLICATION ON CORN PRODUCTION: A LONG TERM SUMMARY[1]

J. R. Joshi, J. B. Swan, J. F. Moncrief, and P. Burford[2]

Abstract: A summary of a long term study on tillage and liquid dairy manure for corn production are presented in this report. Liquid dairy manure was injected either annually, biennially or triennially on chisel-plowed treatments and annually or biennially on no-till treatments. Additional treatments included an annual application of chemical fertilizer, and a check.

The liquid dairy manure applied from an anaerobic pit during the study period (1982-90) contained an average of 0.33% N, 0.07% P, 0.23% K and 7.8% solids, and the variability over the years was small. Soil cover by corn residue was adequate (above 30%) in no tillage and marginal (around 30% or below) in chisel plowing systems across the treatments. Manure injection reduced residue by about half in no tillage but had little effect on chisel plowing. Yield obtained with fertilizer application were comparable to those of manure in the year of application. Tillage did not affect yield when manure was applied; however, chisel plowing did better in the years following manure application. Manure affected grain yields up to the third year after its application.

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 Seaton (Typic hapludalf, fine-silty, mixed, mesic) 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 and 1990, the fertilized check received anhydrous ammonia , instead of ammonium nitrate, injected at the rate of 175 lbs N/A.

Between 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.

A long term (1982-90) summary of the data available on manure analysis, surface residue cover, and yield characteristics for fertilizer, triennial and biennial manure treatments is presented in this report. The cultural practices for individual years can be found in this and earlier issues of the 'bluebook'.

RESULTS AND DISCUSSION

Manure Composition. The amounts of liquid dairy manure applied and its nutrient composition during 1982-90 is given in Table 1. On an average, the manure contained 0.331% N, 0.069% P, 0.231% K, and 7.8% solids. About 56% of the total N was in mineral form. Standard deviation for the concentration of most elements from year to year was within 10% of the mean values. Actual amounts of the nutrients applied each year are given in Table 2.

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[2] Graduate Research Assistant, Soil Sci. Dept., Univ. of Minnesota; Professor of Agronomy at Iowa State Univ.; and Assoc. Professor at Soil Sci. Dept., Univ. of Minnesota, St. Paul, MN, 55108; and former graduate research assistant currently working at Minnesota Pollution Control Agency, respectively.

Residue Cover. Soil cover by corn residue left on the surface after planting in both tillages is summarized in Table 3.

Under no tillage conditions, the greatest amount of residue was left in the treatments which did not receive tillage associated with manure. These include fertilizer, check, and the second year of biennial manure treatments. The injection of manure reduced the residue by about half 'in' and 'between' the rows. Soil Conservation Service recommends at least 30% of residue cover to control erosion in conservation tillage practices. From that criteria, most treatments under no tillage had adequate amount of soil cover. Exception to this was treatment that received manure injection where the amount of residue was marginal.

Chisel plowing reduced the soil cover to below 30% in most treatments. The injection of manure did not cause any further reduction in soil cover.

Triennial Manure Study (1988-90). A table of significance of analysis of variance of various yield characteristics to evaluate the effects of N from manure applied triennially on chisel plowed corn for the period 1988-90 is given in Table 4. The year when N was applied during the triennial cycle had a significant effect on grain yield, stover yield, and N uptake characteristics in all three years. The response to the residual K from previous years was variable from year to year.

Compared to the manure application year, the grain and stover yield, on an average, declined by 16% in the second year and 35-38% in the third year of application (Table 5). The third year yields in this period were similar to the check plots. The response in terms of grain moisture, stover moisture, harvest index, and final stand at harvest was variable from year to year (Table 6 and 7). Nitrogen uptake as grain and stover N, and total N removal varied greatly depending upon when the manure applied (Table 7 and 8). Total N removal reduced by 26% in the second year and by 49% in the third year following the application of manure. The amount of N removed in the third year was similar to those of the check treatments.

Triennial Manure Study (1983-90). A summary of grain yields in fertilizer, manure (annual and triennial), and check treatments during a longer duration (1983-1990) is given in Table 9 and 10. As the effect of additional potassium has been variable during this period, the tables are prepared to compare fertilizer and check treatments (both 200 lb K_2O/A) with the average of manure treatments that received 0 and 200 lbs K_2O/A (Table 9) and with the manure treatments with 0 lb K_2O/A only (Table 10).

The long term averages reflect the following: (a) yields obtained with fertilizer and annual manure treatments were similar, (b) yield difference in the application year of manure on annual and triennial cycle was small (about 5%), (c) yield reduction in year following manure application was about 16-18%, (d) yield reduction in the third year after manure was applied is about 29 to 33%, the greater reduction when no K was added, and (e) there was a yield advantage of about 13-18 bu/A in the third year of triennial manure over check.

Biennial Manure Study (1983-90). A summary of grain yields in fertilizer, manure (annual and biennial), and check treatments on a longer term basis (1983-1990) is given in Table 11 and 12. Once again as the effect of additional potassium has been variable during this period, the tables are prepared to compare fertilizer and check treatments (both 200 lb K_2O/A) with the average of manure treatments that received 0 and 200 lbs K_2O/A (Table 11) and with the manure treatments with 0 lb K_2O/A only (Table 12).

The long term averages reflect the following: (a) tillage did not affect yields in the application year of N regardless of its source but chisel plowing was advantageous in the non-application year including check, (b) yield reduction in the year following manure application was 17% in no tillage and 10% in chisel plowing, and (c) yield after two years following manure application was higher than check by 82% under no tillage and 52% under chisel plowing.

Table 1. Rate of application and nutrient composition of liquid dairy manure (1982-1990)

NUTRIENT	1982S[1]	1983S	1983F	1985S	1986S	1987S	1988S	1989S	1990S	**MEAN**	**STD**
TOTAL-N (%)	.365	.306	.348	.34	.292	.398	.303	.298	.325	**.331**	**.033**
AMMON-N (%)	.185	.174	.177	.161	.237	.177	.205	.183	.156	**.184**	**.023**
P (%)	.062	.072	.067	.066	.062	.083	.	.	.	**.0 69**	**.007**
K (%)	. 190	.244	.244	.235	.197	.297	.219	.219	.	**.231**	**.315**
SOLIDS (%)	7.21	6.99	7.35	8.86	.	9.15	7.6	7.6	.	**7.8**	**.78**
RATE(GAL/A)	12700	9100	10700	9200	9200	9200	8600	8300	8500	**9500**	**1306**

[1] S= spring-applied, F= fall-applied.

Table 2. The amounts in lbs/acre of nutrients applied as liquid dairy manure (1982-90)

NUTRIENT	1982S[1]	1983S	1983F	1985S	1986S	1987S	1988S	1989S	1990S	**MEAN**	**STD**
TOTAL-N	379	228	304	256	219	299	213	202	226	**258**	**55**
AMMON-N	192	129	155	121	178	133	144	124	108	**143**	**26**
P_2O_5	148	122	135	114	106	143	.	.	.	**128**	**15**
K_2O	236	218	256	212	178	268	184	178	.	**216**	**33**
SOLIDS (%)	7.2	7.0	7.4	8.9	.	9.2	7.6	7.6	.	**7.8**	**.8**

[1] S= spring-applied, F= fall-applied.

Table 3. Surface residue cover as affected by N source and frequency in Goodhue Co., MN.

NO TILL

N Source and Frequency	Surface Residue (%)										**Mean**	
	1984		1985		1988		1989		1990			
	IN	BET	IN	BET	IN	BET	IN	BET	IN	BET	**IN**	**BET**
Fertilizer	42	74	55	63	.	.	75	66	35	72	**52**	**69**
Manure (annual)	22	40	17	22	.	.	27	40	46	51	**28**	**38**
Manure (1st year)	30	33	21	20	5	18	27	34	24	41	**21**	**29**
Manure (2nd year)	31	66	49	60	67	60	44	56	57	62	**50**	**61**
Check	25	57	23	62	.	.	33	41	37	59	**30**	**55**

CHISEL PLOW

N Source and Frequency	Surface Residue (%)										**Mean**	
	1984		1985		1988		1989		1990			
	IN	BET	IN	BET	IN	BET	IN	BET	IN	BET	**IN**	**BET**
Fertilizer	17	24	13	23	.	.	24	44	20	36	**19**	**32**
Manure (annual)	13	14	22	21	.	.	40	42	20	50	**24**	**32**
Manure (1st year)	13	13	13	20	9	7	28	39	16	37	**16**	**23**
Manure (2nd year)	17	18	17	14	38	22	15	35	13	40	**20**	**26**
Check	16	16	6	15	.	.	35	36	20	25	**19**	**23**

Table 4. A table of significance of analysis of variance on various dependent variables on the effects of N from manure applied triennially on chisel-plowed corn in Goodhue Co., MN.

DEPENDABLE VARIABLE	1988			1989			1990		
	Year(Y)	K Rate(K)	Y*K	Year(Y)	K Rate(K)	Y*K	Year(Y)	K Rate(K)	Y*K
Grain Yield	**.000**	.173	.254	**.000**	.973	.792	**.000**	.514	.955
Plant Stand	**.007**	.192	**.082**	.377	.470	.318	.990	.978	.113
Grain Moisture	**.036**	.359	.556	.128	.507	.396	**.000**	.194	.877
Grain N	**.002**	**.080**	.762	**.000**	.304	.586	**.000**	.329	.183
Grain N Uptake	**.000**	**.065**	.203	**.000**	.128	.458	**.000**	.936	.919
Stover Yield	**.042**	.698	.373	.584	.876	**.084**	**.037**	.222	.663
Stover Moisture	.408	.431	.789	**.002**	.368	**.094**	**.019**	.589	.731
Total Dry Matter	**.005**	.440	.464	**.004**	.732	**.069**	**.006**	.414	.737
Harvest Index	.750	.567	.716	.151	.557	.218	.364	**.050**	.543
Stover N	**.009**	**.009**	.598	**.004**	.400	.323	**.000**	.123	**.079**
Stover N Uptake	**.000**	.300	.556	**.017**	.612	.104	**.000**	**.039**	.271
Total N Uptake	**.000**	**.065**	.195	**.000**	.365	.145	**.000**	.475	.682

Table 5. Effects of N from manure applied triennially to chisel-plowed corn on grain yield, stover yield, and total dry matter yield in Goodhue Co., MN.

Year of Application	K_2O (lbs/A)	GRAIN YIELD (bu/A)				STOVER YIELD (t/A)				TOTAL DRY MATTER (t/A)			
		1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**
First Yr	0	127	148	153	**143**	1.54	1.87	2.65	**2.02**	4.53	5.18	6.38	**5.36**
	200	134	148	158	**147**	1.81	2.77	3.36	**2.65**	4.97	6.38	7.25	**6.20**
	MEAN	**130**	**148**	**155**	**144**	**1.67**	**2.39**	**2.95**	**2.34**	**4.75**	**5.87**	**6.76**	**5.79**
Second Yr	0	120	125	117	**121**	1.40	1.98	2.34	**2.10**	4.24	5.10	5.24	**4.86**
	200	120	119	123	**121**	1.43	1.97	2.62	**2.01**	4.26	5.17	5.79	**5.07**
	MEAN	**120**	**122**	**120**	**121**	**1.42**	**1.97**	**2.48**	**2.06**	**4.25**	**5.12**	**5.52**	**4.96**
Third Yr	0	86	92	95	**91**	1.00	2.52	1.89	**1.80**	3.03	4.56	4.27	**3.95**
	200	69	97	96	**87**	1.06	1.48	1.96	**1.50**	2.69	3.62	4.14	**3.48**
	MEAN	**77**	**95**	**96**	**89**	**1.03**	**2.00**	**1.92**	**1.65**	**2.86**	**4.16**	**4.21**	**3.74**
Check	**200**	**79**	**82**	**87**	**83**	**1.08**	**2.04**	**1.77**	**1.69**	**2.95**	**4.20**	**3.84**	**3.66**

Table 6. Effects of N from manure applied triennially to chisel-plowed corn on grain moisture, stover moisture, and final stand count in Goodhue Co., MN.

Year of Application	K_2O (lbs/A)	GRAIN MOISTURE (%)				STOVER MOISTURE (%)				PLANT POPULATION			
		1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**
First Year	0	19.0	23.2	29.6	**23.9**	50.1	54.9	39.6	**48.2**	26.2	26.1	28.7	**27.0**
	200	19.3	21.4	28.7	**23.1**	48.1	52.8	41.3	**47.4**	27.6	24.6	30.6	**27.6**
	MEAN	**19.1**	**22.2**	**29.2**	**23.5**	**49.1**	**53.7**	**40.3**	**47.7**	**26.9**	**25.3**	**29.5**	**27.2**
Second Year	0	19.3	25.7	31.7	**25.6**	46.1	45.7	42.8	**44.9**	28.6	24.7	29.4	**27.6**
	200	18.4	23.6	30.2	**24.1**	45.5	50.4	41.4	**45.8**	27.9	22.1	29.5	**26.5**
	MEAN	**18.9**	**24.6**	**30.8**	**24.8**	**45.8**	**48.0**	**42.1**	**45.3**	**28.3**	**23.4**	**29.4**	**27.0**
Third Year	0	20.8	24.1	33.8	**26.2**	48.7	53.3	48.5	**50.2**	26.1	24.0	30.5	**26.9**
	200	20.0	25.5	33.2	**26.2**	45.6	54.4	52.5	**50.8**	25.2	25.5	28.2	**26.3**
	MEAN	**20.4**	**24.7**	**33.5**	**26.2**	**47.2**	**53.8**	**50.5**	**50.6**	**25.6**	**24.7**	**29.4**	**26.6**
Check	200	**20.6**	**23.2**	**32.3**	**25.4**	**46.3**	**54.4**	**47.5**	**49.4**	**28.2**	**25.4**	**30.7**	**28.1**

Table 7. Effects N of from manure applied triennially to chisel-plowed corn on harvest index, grain N, and stover N in Goodhue Co., MN.

Year of Applica-tion	K_2O (lbs/A)	HARVEST INDEX				GRAIN N (%)				STOVER N (%)			
		1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**
First Yr	0	0.66	0.64	0.60	**0.63**	1.44	1.27	1.30	**1.34**	0.61	0.65	0.45	**0.57**
	200	0.64	0.58	0.54	**0.59**	1.41	1.34	1.27	**1.34**	0.52	0.54	0.48	**0.51**
	MEAN	**0.65**	**0.60**	**0.57**	**0.61**	**1.42**	**1.31**	**1.28**	**1.34**	**0.56**	**0.59**	**0.46**	**0.54**
Second Yr	0	0.68	0.61	0.56	**0.62**	1.35	1.14	1.23	**1.24**	0.47	0.42	0.40	**0.43**
	200	0.66	0.62	0.54	**0.61**	1.26	1.18	1.05	**1.16**	0.42	0.47	0.38	**0.42**
	MEAN	**0.67**	**0.62**	**0.55**	**0.61**	**1.30**	**1.16**	**1.08**	**1.18**	**0.44**	**0.44**	**0.39**	**0.42**
Third Yr	0	0.66	0.46	0.56	**0.56**	1.30	1.04	1.03	**1.12**	0.53	0.42	0.33	**0.43**
	200	0.60	0.59	0.53	**0.57**	1.25	1.03	1.07	**1.12**	0.40	0.38	0.38	**0.39**
	MEAN	**0.63**	**0.52**	**0.54**	**0.56**	**1.28**	**1.03**	**1.05**	**1.12**	**0.47**	**0.40**	**0.36**	**0.41**
Check	200	**0.62**	**0.51**	**0.54**	**0.56**	**1.16**	**1.09**	**1.06**	**1.10**	**0.39**	**0.37**	**0.34**	**0.37**

Table 8. Effects of N from manure applied triennially to chisel-plowed corn on grain uptake, stover uptake, and N uptake in Goodhue Co., MN.

Year of Application	K_2O (lb/A)	GRAIN N UPTAKE (lbs/A)				STOVER N UPTAKE (lbs/A)				TOTAL N UPTAKE (lbs/A)			
		1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**
First Yr	0	86.5	84.3	93.9	**88.2**	18.2	24.1	24.0	**22.1**	104.7	108.4	118.0	**110.4**
	200	89.3	97.2	94.7	**93.7**	18.7	28.6	32.5	**26.6**	108.0	125.9	127.3	**120.4**
	MEAN	**87.9**	**91.7**	**94.3**	**91.3**	**18.5**	**26.7**	**27.7**	**24.3**	**106.4**	**118.4**	**121.9**	**115.6**
Second Yr	0	76.8	70.3	62.8	**70.0**	12.7	16.7	19.6	**16.3**	89.5	86.9	82.4	**86.3**
	200	71.2	75.3	60.8	**69.1**	12.2	18.3	20.8	**17.1**	83.4	93.6	80.1	**85.7**
	MEAN	**74.0**	**72.8**	**61.8**	**69.5**	**12.5**	**17.5**	**20.3**	**16.7**	**86.5**	**90.3**	**81.3**	**86.0**
3rd Yr	0	53.1	42.3	46.7	**47.4**	10.1	21.1	12.4	14.5	63.2	63.4	59.1	**61.9**
	200	40.8	43.3	48.7	**44.3**	8.3	11.0	15.1	11.5	49.0	54.3	63.8	**55.7**
	MEAN	**46.9**	**42.7**	**47.7**	**45.8**	**9.2**	**16.0**	**13.8**	**13.0**	**56.1**	**59.5**	**61.5**	**59.0**
Check	**200**	**43.5**	**48.7**	**43.7**	**45.3**	**8.4**	**14.7**	**12.0**	**11.7**	**51.9**	**63.4**	**55.8**	**57.0**

Table 9. Corn grain yields as affected by N from manure applied annually and triennially, and fertilizer applied annually in chisel plowing system in Goodhue Co., MN.

N Source and Frequency	Grain Yield (bu/A)								1984-90	
	1983	1984	1985	1986	1987	1988	1989	1990	**MEAN**	**ST.DEV.**
Fertilizer, 200 lbs K_2O/A	127	165	155	149	164	144	167	153	**157**	**8**
Manure (annual)[1]	132	165	151	150	162	136	163	166	**156**	**10**
Manure (1st year)	.	148	138	146	164	130	148	155	**147**	**10**
Manure (2nd year)	.	125	117	114	129	120	122	120	**121**	**5**
Manure (3rd year)	.	128	91	103	100	77	95	96	**99**	**14**
Check, 200 lbs K_2O/A	91	85	78	89	103	79	82	87	**86**	**8**

[1] Manure treatments were averaged over 0 and 200 lb K_2O/A treatments.

Table 10. Corn grain yields as affected by N from manure applied annually and triennially, and fertilizer applied annually in chisel plowing system in Goodhue Co., MN.

N Source and Frequency	Grain Yield (bu/A)								1984-90	
	1983	1984	1985	1986	1987	1988	1989	1990	**MEAN**	**ST DEV.**
Fertilizer, 200 lb K_2O/A	127	165	155	149	164	144	167	153	**157**	**8**
Manure (annual)	132	163	150	150	155	133	159	171	**154**	**11**
Manure (1st year)	.	149	139	147	158	127	148	153	**146**	**9**
Manure (2nd year)	.	129	108	120	137	120	125	117	**122**	**9**
Manure (3rd year)	.	132	102	113	109	86	92	95	**104**	**14**
Check, 200 lb K_2O/A	91	85	78	89	103	79	82	87	**86**	**8**

[2] Manure treatments with 0 lb K_2O/A only.

Table 11. Corn grain yields as affected by tillage, and N source and frequency of application in Goodhue Co., MN.

N Source and Frequency	GRAIN YIELDS (bu/A)																**Mean**	
	1983		1984		1985		1986		1987		1988		1989		1990		**1983-90**	
	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	**NT**	**CH**
Fertilizer[1]	119	127	159	165	134	155	151	149	160	164	145	144	163	167	164	153	**149**	**153**
Manure (annual)	129	132	145	165	145	151	147	150	164	162	151	136	170	163	170	166	**153**	**153**
Manure (1st year)	114	112	156	160	138	150	147	151	169	163	144	137	154	150	144	153	**146**	**147**
Manure (2nd year)	108	122	101	134	109	117	106	122	133	140	125	126	143	135	140	144	**121**	**130**
Check	55	91	66	85	62	78	55	89	62	103	67	79	79	82	78	87	**66**	**87**

[1] Fertilizer and check treatments with 200 lb K_2O/A. Manure treatments were averaged over 0 and 200 lb K_2O/A treatments.

Table 12. Corn grain yields as affected by tillage, and N source and frequency of application in Goodhue Co., MN.

N Source and Frequency	GRAIN YIELDS (bu/A)																**Mean**	
	1983		1984		1985		1986		1987		1988		1989		1990		**1983-90**	
	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	**NT**	**CH**
Fertilizer[1]	119	127	159	165	134	155	151	149	160	164	145	144	163	167	164	153	**149**	**153**
Manure (annual)	127	134	144	163	148	150	154	150	166	155	145	133	160	159	166	171	**151**	**152**
Manure (1st year)	125	114	155	153	132	146	146	154	168	159	149	131	141	155	146	155	**145**	**146**
Manure (2nd year)	104	125	98	138	115	121	104	134	150	145	111	126	151	136	128	129	**120**	**132**
Check	55	91	66	85	62	78	55	89	62	103	67	79	79	82	78	87	**66**	**87**

[1] Fertilizer and check treatments with 200 lb K_2O/A and manure treatments with 0 lb K_2O/A only.

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]

J. R. Joshi, J. B. Swan, J. F. Moncrief, and G. L. Malzer[2]

Abstract: A summary of the results of the 1990 season of the study to determine the effects of tillage and frequency of liquid manure application on corn yield, N uptake, and soil N distribution initiated in 1982 is presented in this report. Despite late planting by about two weeks due to wet spring, the yields obtained in this season were comparable to those in the previous year. Annual application of manure produced greater grain yields and stover dry matter than anhydrous ammonia receiving equivalent amounts of N or biennial manure treatments receiving half as much N. The effects were not significant with respects to tillage treatments (no till and chisel plowing). The residual effect of additional K was reflected in higher plant stand at harvest, and lower grain moisture in manure treatments.

A significant amount of precipitation fell in April and May to raise the soil moisture levels to 22-26% by weight. The soil was uniformly wet throughout the profile. The amount of N in the soil profile dropped by 30 to 60 lbs/A from the levels in the previous fall. At the same time, soil water N at 5 ft. depth increased considerably suggesting the downward movement of water and N in the spring. The overall trends in soil water nitrate were similar in 1989 and 1990: no till yielded lower nitrate in soil water than chisel plowing, and there was more nitrate in soil water in anhydrous ammonia treatment than any of the manure treatments applied with equivalent or half the amount of N.

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 Seaton (Typic hapludalf, fine-silty, mixed, mesic) 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 and 1990, the fertilized check received anhydrous ammonia , instead of ammonium nitrate, injected at the rate of 175 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 analysis on yield and soil characteristics done for 1990 are included in this report.

RESULTS AND DISCUSSION

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 18, 1990. A table of significance of treatment effects on residue cover is given in Table 2. There was about 18% more residue in between the rows than in the rows (Table 3). The difference in the amount of residue due to row position was small in no till when manure was applied but the amount increased in between rows by 17% in biennial manure treatment in the year following manure application, and by 37% in anhydrous ammonia treatments. In chisel plowed treatments, the amount of residue in between the rows exceeded the amount of residue in rows by 17-30% in all N treatments.

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[2] Graduate Research Assistant, Soil Sci. Dept., Univ. of Minnesota; Professor of Agronomy at Iowa State Univ.; and Associate Professor and Professor at Soil Sci. Dept., Univ. of Minnesota, St. Paul, MN, 55108, respectively.

Plant Population and Stover Yield. The effects of various treatments on plant population, stover dry matter, and stover moisture are given in Table 4. Although the plant population at harvest was not affected significantly by tillage or N treatments, no tillage had slightly lower population than chisel plowing. Previous K addition resulted in an increased stand (Table 5). Both stover dry matter yield and stover moisture at harvest were not affected significantly by treatments. The stover dry matter production response to N treatments was similar to grain yields: annual manure yielding highest followed by fertilizer, biennial manure in the year of application and biennial manure in the year following application. The stover moisture at harvest was lower in biennial manure in the year of application compared to the other N treatments (Table 6). Additional K in the previous years did not show any effect on stover yield or stover moisture content.

Grain Yields, Grain Moisture and Total Dry Matter. The treatment effects on grain yield, grain moisture, and total dry matter are summarized in Table 7. Tillage had no significant effect on grain yield, grain moisture, and total dry matter production at harvest. The source and frequency of N applied did have a significant effect on total grain yields, grain moisture, and total dry matter production at maturity. The grain yields ranged from an average high of 169 bu/A in treatments with manure applied annually to a low of 142 bu/A in the second year of biennial manure application. Grain yields were 10 bu/A lower with anhydrous ammonia treatment as compared to annual application of manure. A change from annual application of manure to biennial application resulted in a decrease in the yield by 20 bu/A in the year of application and by 26 bu/A in the year following the application of manure. The grain moisture content was generally 1-2% lower in manure applied treatments compared to the fertilizer treatment. The total dry matter yield at harvest ranged between 5.9 to 7.2 tons/A and showed similar response to N treatments as in grain yield: the highest yield associated with annual manure followed by anhydrous ammonia, biennial manure in the year of application and biennial manure in the year after application, respectively. The application of additional 200 lb/A of potassium in the previous years resulted in lower grain moisture in no till and higher grain moisture in chisel plowing compared to no addition of K (Table 8). Additional K also increased grain yields and decreased grain moisture at maturity at lower rates of N (Table 9).

Harvest Index. The harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover), was not affected by any tillage, N or K treatments (Table 10). The value of the index ranged from 0.52 to 0.57.

Soil Profile Moisture: Fall 1989. Gravimetric soil moisture determination were also made on soil samples taken to a depth of 5 ft. in the fall of 1989 during Oct. 24- Nov. 2. The soil samples were taken from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. The soil moisture was fairly uniform throughout the soil profile (Table 12): about 18% by weight in the upper 0-2 ft layer and about 17% in the depth below. The soil moisture was about 1% higher in between the rows than in the rows (Table 13). No till treatment had higher moisture in between the rows in all N treatments (Table 14); whereas, in chisel plowing, manure applied treatments had fairly uniform moisture in and between the rows while fertilizer and check treatments had higher moisture in between the rows than in the rows.

Soil Profile Nitrogen: Fall 1989. The soil samples taken in the fall were analyzed for total inorganic N and ammonium-N. A table of significance values using general linear means procedure of SAS is given in Table 11.

Of the N treatments sampled, anhydrous ammonia treatment had the highest total of 300 lbs N/A in the 5 ft. soil profile followed by 182 lb N/A in annual manure, 126 lb N/A in biennial manure in the year of application and 94 lb N/A in check treatments (Table 15). Of the total mineral N, the amount of ammonium N ranged from 60 to 75 lb N/A with a maximum difference of about 15 lb N/A among the N treatments. The major difference was in the amount of nitrate-N making up the difference in the amount of total mineral N. Most of the N in the profile was concentrated in the top 0-3 ft. layers (Table 16). Check treatments had fairly equal amount of N in and between the rows while N treatments had greater N in between the rows than in the rows (Table 17).

The amount of ammonium-N in the two row positions was more uniform in no till as compared to chisel plowed treatments (Table 18). In no till, most of the N in ammonium form was concentrated in the top 0-1 ft. depth segment; whereas, it was concentrated more in 1-2 ft. depth segment in chisel plowed treatments (Table 19). Most of the N in the nitrate form was still in the top 0-1 ft. depth segment in biennial manure and check treatments while a significant portion of nitrate N had moved down below up to 3 ft. depth in higher N treatments such as annual manure and fertilizer (Table 20). The amount of nitrate N was higher in between the rows than in the rows in all depth segments down to 3 ft. depth. In no till, the amount of nitrate-N was greatest in the top 1 ft. depth segment and decreased gradually down the profile; whereas, in chisel plowing most nitrate-N was concentrated in the 1-2 ft. depth segment of the profile.

Soil Profile Moisture: Spring 1990. Gravimetric soil moisture determination were made on soil samples taken to a depth of 5 ft. in the spring of 1990 on the 2nd of May. The soil samples were taken from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. A summary of significance for treatment effects on soil moisture is given in Table 21. The soil moisture ranged from 22% to 26% by weight, and was higher in manure applied treatments than the fertilizer and check treatments (Table 22). There was slightly higher moisture in the rows than in between the rows in biennial manure and check treatments; whereas, annual manure and fertilizer treatments had higher moisture in between the rows than in the rows. The 2-4 ft. depth segments were wetter than the depths above and below (Table 23). No till treatments were wetter in the top 4 ft. depth than the chisel-plowed treatments. The check was drier throughout the soil profile than any of the N treatments (Table 24).

Soil Profile Nitrogen:Spring 1990. Soil samples were taken to a depth of 5 ft. in 1 ft. increment were analyzed for total inorganic N and ammonium-N. A table of significance values using general linear means procedure of SAS is given in Table 21.

There was a decrease of about 30 to 60 lb N/A in total mineral N in the profile from the previous fall (Table 25). However, anhydrous ammonia treatments still contained highest amount of total mineral N in the top 5 ft. soil profile followed by annual manure, biennial manure and check treatments, respectively. The range in the amount of N among various treatments was between 45 to 53 lbs/A, and the most of the difference in the total amount of the mineral N was in the form of nitrate-N. Most of the ammonium N was in the surface 0-1 ft. layer while most of the nitrate-N was concentrated in the 2-4 ft. layer (Table 26). The nitrate-N was mostly concentrated to upper 2 ft. layer of the profile in biennial and check treatments showing little movement down below the profile (Table 27). In case of high N treatments such as annual manure and anhydrous ammonia, nitrate-N had moved down to 5 ft. depth.

Soil Water N. Suction water samplers were established on manure (annual and biennial) and fertilizer treatments to monitor nitrate-N in soil water at 5 ft. depth. Three samplers per plot were installed in corn row in two replications for each treatment. Water samples were drawn from each samplers at a weekly interval and were analyzed for nitrate-N in the laboratory.

The amount of N leached through the profile depends on the amount of water available in soil and the amount of recharge provided through precipitation after evapotranspiration and runoff losses. A summary of the monthly precipitation during 1988-90 growing seasons is illustrated in Fig. 1. The total amount of precipitation during April-September period was about 13 inches in 1988, 16 inches in 1989, and 31 inches in 1990. The soil profile was dry in a dry season of 1988, and hence there was difficulty in obtaining enough samples for nitrate analysis. In 1989, there was slightly higher precipitation and soil was recharged enough to obtain the water samples. Most significant rain fell in the spring of 1990 and the soil was fairly wet to cause the downward leaching of water and chemicals.

The effects of tillage treatments on soil water N at 5 ft. depth for the years 1989-90 are presented in Figure 2. In 1989 following a dry 1988 growing season, the initial concentration of nitrate-N in soil water for chisel plowed treatments was almost 80 ppm, about 4 times higher than the no till treatments. While the initial concentration dropped initially, and fluctuated in response to the precipitation events, the average concentration was fairly constant at about 70 ppm for chisel plowing and about 25 ppm for no tillage through the end of 1989 growing season.

In 1990, the concentration of nitrate-N in no till treatments increased to slightly below the level of chisel plowed treatments in May and June while the concentration of nitrate-N in chisel-plowed treatment remained at the level of previous year. There was a fluctuation in the concentration of nitrate-N in water in response to precipitation events in the succeeding weeks. However, the concentration of nitrate in water started declining with no tillage and started increasing towards the end of the season. The overall trends in water nitrate were similar: no till yielding lower nitrate at 5' depth as compared to chisel plowing.

The effects of N treatments on soil water N at 5 ft. depth are illustrated in Fig. 3. The concentration of nitrates in water was fairly constant for anhydrous ammonia, annual manure, and biennial manure treatments throughout the 1989 season. The average nitrate content in water in anhydrous ammonia treatment was about 60 ppm followed by about 35 ppm in annual application of manure and less than 10 ppm in biennial application of manure.

The nitrate levels in 1990 increased in all the N treatments by about 5 to 35 ppm. There were fluctuations in nitrate levels in response to the precipitation events; however, overall nitrate levels remained fairly constant through the end of the season. The overall trend in 1989 and 1990 were similar: the fertilizer applied treatments yielding higher nitrate at 5 ft. depth followed by annual manure application and biennial manure application.

Table 1. Cultural practices at the Flueger Farm in Goodhue County, MN in 1990.

Tillage	**Cropping History**
No Till	Corn since 1981-P 3906
Chisel Plowed and field cultivated on May 26, 1990.	1989 Corn Pioneer 3737
	1990 Corn Pioneer 3751

Manure Application

Injected liquid dairy manure at the following rate and analysis on May 5, 1990.

		1990 rate	
		Mean	Std. Dev.
Manure	(gal/A)	8500	300
Total-N	(lbs/A)	240	14
NH_4-N	(lbs/A)	108	23

Planting Information

A four row 38 inch John Deere Maxemerge planter with 2" fluted coulters.

Planting Date	Rate	Harvested
May 28, 1990	32,500 plants/A	October 13, 1990

Fertilizer

Material Analysis	Tillage	Amount	Actual N -lbs/A-	Date Applied	Method of Application
82-0-0	Both		175	June 25, 1990	Injected after planting
9-23-30	Both	111 lbs/A		May 28, 1990	As a starter

(From 1982-88, no till and chisel plowed plots received 210 lbs N/A and 170 lbs N/A, as ammonium nitrate, respectively, and 170 lbs N/A for both tillages in 1989.)

Soil

Seaton silt loam (Typic hapludalfs, fine-silty, mixed, mesic), 2 to 12% slope. Soil is well drained.

Insect Control

10.5 lbs/A Lorsban applied in furrow on May 28, 1990.

Weed Control

3 pt./A Prowl, 2.5 lb/A 90 DF Bladex applied in 20 lb/A water as carrier on May 23, 1990. Cultivated all treatments on June 25, 1990.

Table 2. Significance table for surface residue cover in Goodhue Co., MN on 6/18/1990.

Till (T)	N Freq (F)	T*F	K (K)	T*K	F*K	T*F*K	Row (R)	T*R	F*R	K*R	T*F*R	F*K*R	T*F*K*R
.064	.426	.441	.113	.666	.169	.425	.000	.132	.836	.283	.029	.595	.418

Table 3. Surface residue cover as affected by tillage, N source and row position in Goodhue Co.,MN on 6/18/90.

N SOURCE AND FREQUENCY	ROW POSITION	RESIDUE (%)	
		NO TILL	CHISEL
MANURE (YEAR OF)	IN	24.3	16.3
	BET	41.3	36.7
MANURE (YEAR AFTER)	IN	56.7	12.7
	BET	62.3	40.3
MANURE (ANNUAL)	IN	46.2	20.4
	BET	50.6	50.4
ANHYDROUS AMMONIA	IN	35.0	20.0
	BET	72.3	36.3
Pr>F		.029	

Table 4. Corn plant population, stover yield, and stover moisture at harvest as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1990.

Frequency & Source of N	K_2O lb/A	PLANT POPULATION No Till	Chisel	Mean	STOVER DRY MATTER No Till	Chisel	Mean	STOVER MOISTURE No Till	Chisel	Mean
		-- plants/A*10^{-3} ---			------ tons/A -----			------- % --------		
Manure[1]	0	26.0	28.6	27.3	2.30	2.88	2.59	52.9	41.5	45.0
(Yr. after)	200	28.2	30.0	28.9	2.82	2.70	2.77	40.8	46.5	43.7
	Mean	27.5	29.4	28.3	2.60	2.79	2.67	46.0	44.0	44.4
Manure	0	25.9	29.3	27.6	3.72	2.98	3.13	45.3	44.8	47.2
(Yr. of)	200	25.9	29.8	27.8	2.91	2.36	2.64	42.8	44.7	43.3
	Mean	25.9	29.6	27.7	3.09	2.67	2.88	44.0	44.7	45.1
Manure	0	28.5	29.0	28.6	3.72	3.40	3.65	41.7	39.6	41.3
(Annual)	200	28.5	31.1	29.3	3.28	2.77	3.10	48.4	45.4	47.4
	Mean	28.5	30.3	29.0	3.51	3.02	3.38	44.8	43.1	44.3
Anhydrous-Ammonia	200	30.4	28.4	29.4	3.06	2.70	2.88	47.9	36.7	42.3
Mean		**27.9**	**29.5**	**28.5**	**3.15**	**2.79**	**3.00**	**45.5**	**42.1**	**44.1**

	Till(T)	Freq.(F)	T*F	K rate(K)	K*T	K*F	K*F*T
Plant population	.158	.641	.305	.067	.485	.559	.384
Stover dry matter	.105	.096	.222	.164	.474	.293	.656
Stover moisture	.173	.382	.061	.668	.274	.250	.263

[1]Manure applied in the spring of 1989 (year after) and 1990 (year of).

Table 5. Corn plant population as influenced by previous K application in Goodhue Co., MN in 1990[1].

K_2O lb/A	PLANT POPULATION
	-- plants/A*10^{-3} --
0	28.0
200	28.9
Pr>F (K rate)	.067

[1] Averaged over tillage and N treatments.

Table 6. Corn stover moisture as influenced by tillage and N application in Goodhue Co., MN in 1990[1].

Frequency & Source of N	STOVER MOISTURE No Till	Chisel
	------%--------	
Manure[1] (Yr. after)	46.0	44.0
Manure (Yr. of)	44.0	44.7
Manure (Annual)	44.8	43.1
Anhydrous Ammonia	47.9	36.7
Pr>F (Till.*N Source & Freq.)	.061	

[1] Averaged over K treatments.

Table 7. 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 1990.

Frequency[1] & Source of N	K_2O lb/A	GRAIN YIELD No Till	Chisel	Mean	GRAIN MOISTURE No Till	Chisel	Mean	TOTAL DRY MATTER No Till	Chisel	Mean
		---------bu/A--------			---------%----------			--------tons/A-----		
Manure (Yr. after)	0	128	129	129	33.9	31.3	32.6	5.39	6.21	5.80
	200	146	156	150	31.1	30.1	30.7	6.06	6.03	6.04
	Mean	140	144	142	32.0	30.6	31.4	5.77	6.12	5.93
Manure (Yr. of)	0	146	155	150	31.8	28.7	30.2	6.69	6.70	6.69
	200	142	151	146	29.9	29.6	29.8	6.29	6.04	6.16
	Mean	144	153	148	30.9	29.1	30.0	6.49	6.37	6.43
Manure (Annual)	0	166	171	167	30.1	27.9	29.7	7.50	7.73	7.55
	200	175	162	170	30.8	29.0	30.2	7.07	6.57	6.90
	Mean	170	166	169	30.5	28.6	29.9	7.30	7.04	7.22
Anhydrous Ammonia	200	164	153	159	34.2	29.7	31.9	6.93	6.33	6.63
Mean		**156**	**153**	**155**	**31.3**	**29.6**	**30.6**	**6.74**	**6.44**	**6.62**

Pr>F

	Till(T)	Freq.(F)	T*F	K rate(K)	K*T	K*F	K*F*T
Grain Yield	.988	.095	.856	.168	.855	.079	.690
Grain moisture	.156	.054	.424	.294	.019	.004	.756
Total dry matter	.811	.047	.714	.326	.439	.443	.894

[1] Manure applied in the spring of 1989 (year after) and 1990 (year of).

Table 8. Effects of tillage and K application on corn grain moisture in Goodhue Co., MN in 1990[1].

K_2O lb/A	GRAIN MOISTURE No Till	Chisel
	-------%------	
0	31.4	29.5
200	31.3	29.6
Pr>F (K rate*Till)	.019	

[1] Averaged over N and tillage treatments.

Table 9. Corn grain yield, and grain moisture as influenced by K rate, N source and frequency of application in Goodhue Co., MN in 1990[1].

Frequency & Source of N	K_2O lbs/A	GRAIN MOISTURE ------ %------	GRAIN YIELD --- bu/A ---
Manure[2] (Yr. after)	0	32.6	129
	200	30.7	150
Manure (Yr. of)	0	30.2	150
	200	29.8	146
Manure (Annual)	0	29.7	167
	200	30.2	170
Anhydrous Ammonia	200	31.9	159
Pr>F (N source & freq.*K)		.004	.079

[1] Averaged over tillage treatments.
[2] Manure applied in the spring of 1989 (year after) and 1990 (year of).

Table 10. Harvest index of corn as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1990.

Frequency[1] & Source of N	K_2O lb/A	HARVEST INDEX No Till	Chisel	Mean	Source	Pr>F
Manure	0	0.57	0.54	0.56		
(Yr. after)	200	0.53	0.55	0.54	Tillage (T)	.272
	Mean	0.55	0.55	0.55	Freq (F)	.986
Manure	0	0.51	0.56	0.53	T*F	.145
(Yr. of)	200	0.53	0.61	0.57		
	Mean	0.52	0.58	0.55	K Rate(K)	.223
Manure	0	0.50	0.56	0.52	K*T	.600
(Annual)	200	0.54	0.58	0.55	K*F	.334
	Mean	0.52	0.57	0.53		
Anhy. ammon.	200	0.56	0.57	0.57	K*F*T	.403

[1] Manure applied in the spring of 1989 (year after) and 1990 (year of).

Table 11. Significance table for 1989 fall soil moisture and nitrogen.

	Till(T)	N Freq(F)	T*F	ROW(R)	T*R	F*R	T*F*R	DEP(D)	T*D	F*D	T*F*D	R*D	T*R*D	F*R*D	T*F*R*D
MOISTURE	.448	.947	.226	.041	.813	.419	.188	.131	.805	.276	.636	.495	.699	.603	.771
TOTAL-N	.351	.000	.330	.000	.690	.013	.177	.000	.215	.000	.376	.016	.933	.377	.028
AMMO.-N	.594	.098	.530	.000	.079	.034	.554	.000	.142	.226	.000	.654	.871	.729	.868
NITR.-N	.403	.000	.353	.000	.952	.029	.117	.000	.349	.000	.795	.011	.957	.446	.022

Table 12. Gravimetric soil moisture by depth in Goodhue Co., MN during Oct. 24-Nov.2, 1989.

DEPTH (ft.)	MOISTURE (%, $g.g^{-1}$)
0-1	18.1
1-2	18.1
2-3	17.0
3-4	16.9
4-5	16.9
Pr>F	.131

Table 13. Gravimetric soil moisture by row position in Goodhue Co., MN during Oct. 24-Nov.2, 1989.

ROW POSITION	MOISTURE (%, g.g-1)
IN ROW	17.0
BET ROWS	17.8
Pr>F	.041

Table 14. Gravimetric soil moisture as affected by tillage, frequency of N application and row position in Goodhue Co., MN during Oct. 24-Nov.2, 1989.

N SOURCE AND FREQUENCY	ROW POSITION	MOISTURE (%, $g.g^{-1}$)	
		NO TILL	CHISEL
MANURE (YR OF)	IN	17.7	16.9
	BETWEEN	19.2	16.2
MANURE (ANNUAL)	IN	18.1	17.3
	BETWEEN	18.4	16.8
ANHYDROUS AMMONIA	IN	17.7	14.7
	BETWEEN	18.1	17.1
CHECK	IN	16.3	16.9
	BETWEEN	17.0	19.5
Pr>F		.188	

Table 15. Effects of the frequency of N application on soil mineral N in Goodhue Co., MN during Oct. 24- Nov. 2, 1989.

N SOURCE AND FREQUENCY	AMOUNT (lbs/A)		
	TOTAL-N	AMMON.-N	NITRATE-N
MANURE (YR OF)	125.9	74.8	51.6
MANURE (ANNUAL)	182.0	60.1	121.9
ANHYDROUS AMMONIA	299.9	68.5	231.4
CHECK	93.9	68.5	25.8
Pr>F	.001	.098	.000

Table 16. Soil mineral N distribution in the profile by depth segments in Goodhue Co., MN during Oct. 24- Nov. 2, 1989.

DEPTH (ft.)	AMOUNT (lbs/A)		
	TOTAL-N	AMMON.-N	NITRATE-N
0-1	55.4	22.3	48.3
1-2	43.8	16.1	27.7
2-3	31.6	15.1	16.5
3-4	14.3	7.1	7.2
4-5	14.3	7.1	7.2
Pr>F	.000	.000	.000

Table 17. Soil mineral N distribution in 5 ft. soil profile as affected by frequency of N applicaton and row position in Goodhue Co., MN during Oct. 24- Nov. 2, 1989.

SOURCE & FREQUENCY OF N APPLICATION	ROW POSITION	AMOUNT (lbs/A)		
		TOTAL-N	AMMON.-N	NITR.-N
MANURE (YR OF)	IN	106.9	70.3	39.3
	BETWEEN	143.3	79.4	64.0
MANURE (ANNUAL)	IN	137.0	49.5	87.4
	BETWEEN	227.0	70.7	156.3
ANHYDROUS AMMONIA	IN	249.3	59.9	189.4
	BETWEEN	350.8	76.8	273.8
CHECK	IN	91.7	66.8	24.9
	BETWEEN	96.5	70.2	26.3
Pr>F		.013	.034	.029

Table 18. Soil NH4-N in 5 ft. soil profile as affected by tillage and row position in Goodhue Co., MN during Oct. 24- Nov. 2, 1989.

TILLAGE	NH4-N (lbs/A)	
	IN ROW	BETWEEN ROWS
NO TILL	64.0	73.0
CHISEL	59.0	75.8
Pr>F	.079	

Table 19. Soil NH4-N by depth in soil profile as affected by the frequency of N application and tillage in Goodhue Co., MN during Oct. 24- Nov. 2, 1989.

SOURCE & FREQUENCY OF N APPLICATION	TILLAGE	NH4-N (lbs/A)				
		0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.
MANURE (YR OF)	NO TILL	30.8	16.2	16.9	7.8	7.8
	CHISEL	15.1	20.4	17.0	8.8	8.8
MANURE (ANNUAL)	NO TILL	21.8	14.1	13.1	6.3	6.3
	CHISEL	21.9	11.6	12.0	5.8	5.8
ANHYDROUS AMMONIA	NO TILL	22.4	15.6	14.4	7.2	7.2
	CHISEL	27.4	15.6	14.2	6.5	6.5
CHECK	NO TILL	21.3	17.1	16.3	6.9	6.9
	CHISEL	19.5	17.4	16.3	7.7	7.7
Pr>F		.000				

Table 20. Effects of tillage, frequency of N application and row position on soil NO3-N by depth in Goodhue Co., MN during Oct. 24- Nov. 2, 1989.

SOURCE & FREQUENCY OF N APPLICATION	ROW POSIT-ION	NO3-N (lbs/A)									
		0-1 ft.		1-2 ft.		2-3 ft.		3-4 ft.		4-5 ft.	
		NT	CHL	NT	CHL	NT	CHL	NT	CHL	NT	CHL
MANURE (YR OF)	IN	28.7	11.0	7.7	5.8	4.9	4.6	2.9	2.4	2.9	2.4
	BET	57.0	5.0	12.1	12.6	6.9	18.3	5.2	1.6	5.2	1.6
MANURE (ANNUAL)	IN	65.0	9.4	16.2	3.6	20.1	8.6	8.2	2.7	8.2	2.7
	BET	68.3	99.8	42.4	26.7	29.6	14.8	7.9	7.8	7.9	7.8
ANHYDROUS AMMONIA	IN	66.7	98.8	44.0	53.2	30.4	23.3	8.8	22.4	8.8	22.4
	BET	126.0	84.4	87.2	103.5	33.8	44.6	16.1	17.9	16.1	17.9
CHECK	IN	11.5	10.2	3.7	2.7	3.2	5.5	1.9	4.6	1.9	4.6
	BET	10.7	19.6	3.9	5.7	1.7	5.6	1.1	1.6	1.1	1.6
Pr>F		T*F*R*D= .022, F*D=.000 , R*D=.011									

Table 21. Significance table for soil analysis in Goodhue Co., MN on 5/2/90.

	Till(T)	N Freq(F)	T*F	ROW(R)	T*R	F*R	T*F*R	DEP(D)	T*D	F*D	T*F*D	R*D	T*R*D	F*R*D	T*F*R*D
MOISTURE	.359	.013	.972	.833	.970	.071	.359	.000	.000	.048	.226	.153	.176	.485	.969
TOTAL-N	.197	.000	.965	.518	.377	.994	.851	.009	.104	.000	.614	.289	.216	.921	.807
AMMO.-N	.224	.573	.685	.157	.697	.617	.489	.000	.553	.099	.848	.349	.499	.710	.976
NITR.-N	.610	.000	.975	.648	.404	.981	.907	.000	.103	.000	.573	.449	.269	.981	.517

Table 22. Effect of frequency of N application and row position on gravimetric soil moisture in Goodhue Co., ON 5/2/90.

SOURCE & FREQUENCY ON N APPLICATION	MOISTURE (%, $g.g^{-1}$)		
	IN ROW	BET ROWS	MEAN
MANURE (YEAR AFTER)	25.8	25.2	25.5
MANURE (YEAR OF)	25.5	24.7	25.1
MANURE (ANNUAL)	25.4	25.7	25.5
ANHYDROUS AMMONIA	24.1	25.5	24.8
CHECK	22.7	22.5	22.6
Pr>F	.071		.013

Table 23. Gravimetric soil moisture by tillage and depth in Goodhue Co., on 5/2/90.

DEPTH (ft.)	MOISTURE (%, $g.g^{-1}$)		
	NO TILL	CHISEL	MEAN
0-1	23.9	23.4	23.7
1-2	24.7	23.5	24.1
2-3	26.2	24.4	25.4
3-4	27.5	25.8	26.7
4-5	23.6	24.6	24.0
Pr>F	.000		.000

Table 24. Gravimetric soil moisture by frequency of N application and depth in Goodhue Co., on 5/2/90.

SOURCE & FREQUENCY OF N APPLICATION	MOISTURE (%, $g.g^{-1}$)				
	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.
MANURE (YR AFT)	24.7	24.4	25.3	27.5	25.6
MANURE (YR OF)	23.3	24.3	27.0	26.9	24.0
MANURE (ANNUAL)	24.7	24.8	26.2	27.6	24.4
ANHYDR. AMMONIA	23.2	23.8	25.1	27.2	24.7
CHECK	21.9	23.0	23.3	23.9	20.8
Pr>F	.000				

Table 25. Effect of frequency of N application on soil mineral N in Goodhue Co., on 5/2/90.

SOURCE & FREQUENCY OF N APPLICATION	AMOUNT (lbs/A)		
	TOTAL-N	AMMON-N	NITR-N
MANURE (YR AFT)	81.5	52.5	29.0
MANURE (YR OF)	82.5	50.5	34.0
MANURE (ANNUAL)	126.5	48.5	78.0
ANHYDROUS AMMON.	251.5	50.0	201.5
CHECK	60.5	45.0	15.5
Pr>F	.000	.009	.000

Table 26. Soil mineral N by depth in Goodhue Co.,MN on 5/2/90.

DEPTH (ft.)	Amount (lbs/A)		
	TOTAL-N	AMMON-N	NITR-N
0-1	24.9	16.6	8.3
1-2	25.5	9.5	16.0
2-3	27.5	8.4	19.1
3-4	23.5	7.6	15.9
4-5	19.9	7.1	12.8
Pr>F	.000	.009	.000

Table 27. Effect of frequency of N application on soil mineral N by depth in Goodhue Co., on 5/2/90.

SOURCE & FREQUENCY OF N APPLICATION	NO3-N (lbs/A)					
	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.	**0-5 ft.**
MANURE (YR AFT)	6.8	9.9	4.9	3.7	4.0	**29.3**
MANURE (YR OF)	9.2	10.0	7.0	4.9	3.0	**34.1**
MANURE (ANNUAL)	8.4	18.6	24.1	15.8	11.2	**78.1**
ANHYDROUS AMMON.	10.2	37.2	55.6	54.3	44.3	**201.6**
CHECK	7.2	2.9	1.6	1.4	2.3	**15.4**
Pr>F	.000					

FIGURE -1

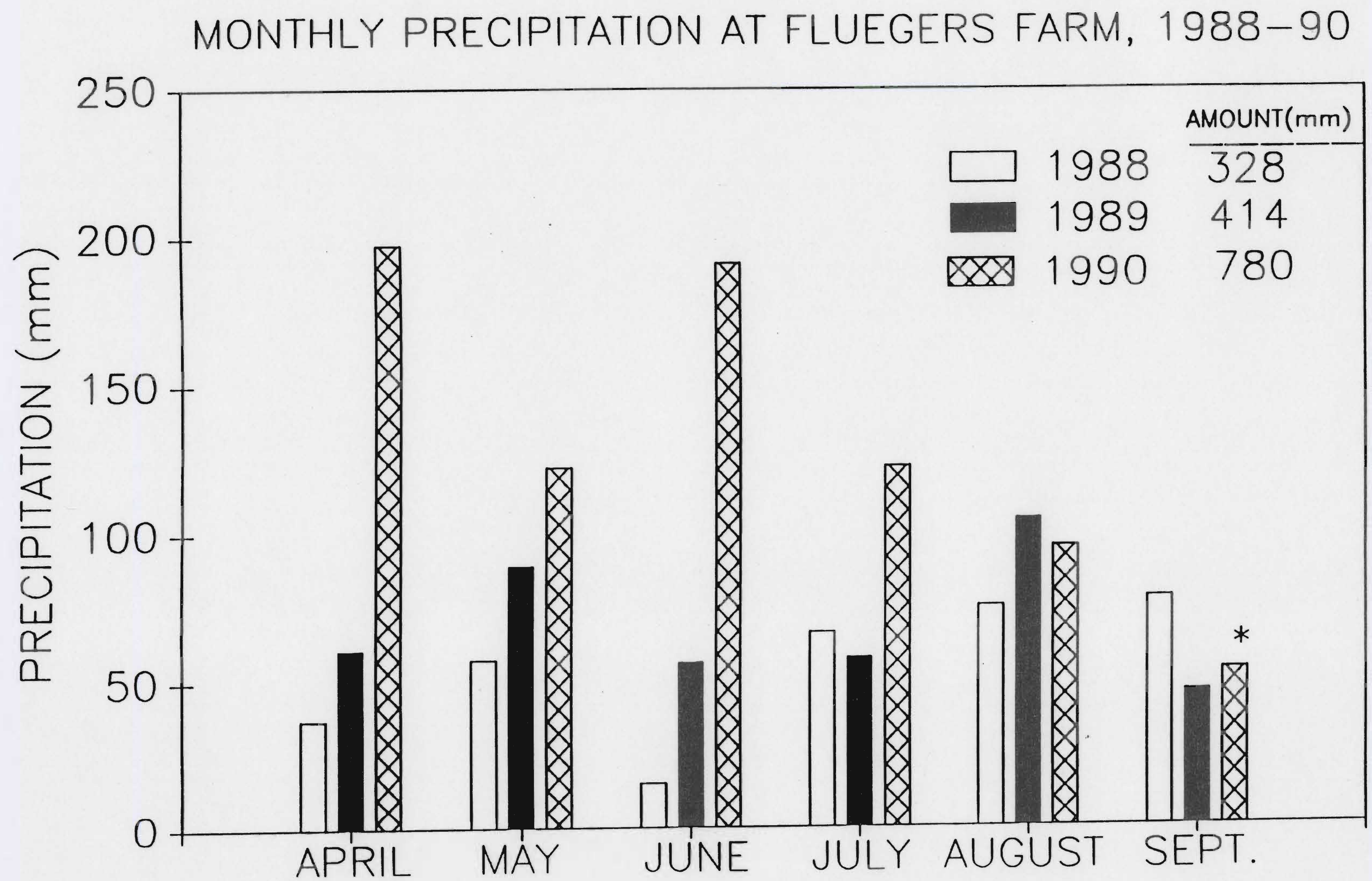

MONTHLY PRECIPITATION AT FLUEGERS FARM, 1988–90
PRECIPITATION (mm)
250
200
150
100
50
0
AMOUNT(mm)
1988 328
1989 414
1990 780
*
APRIL
MAY
JUNE
JULY
AUGUST
SEPT.

FIGURE -2

TILLAGE EFFECTS ON SOIL WATER N AT 1.5m DEPTH

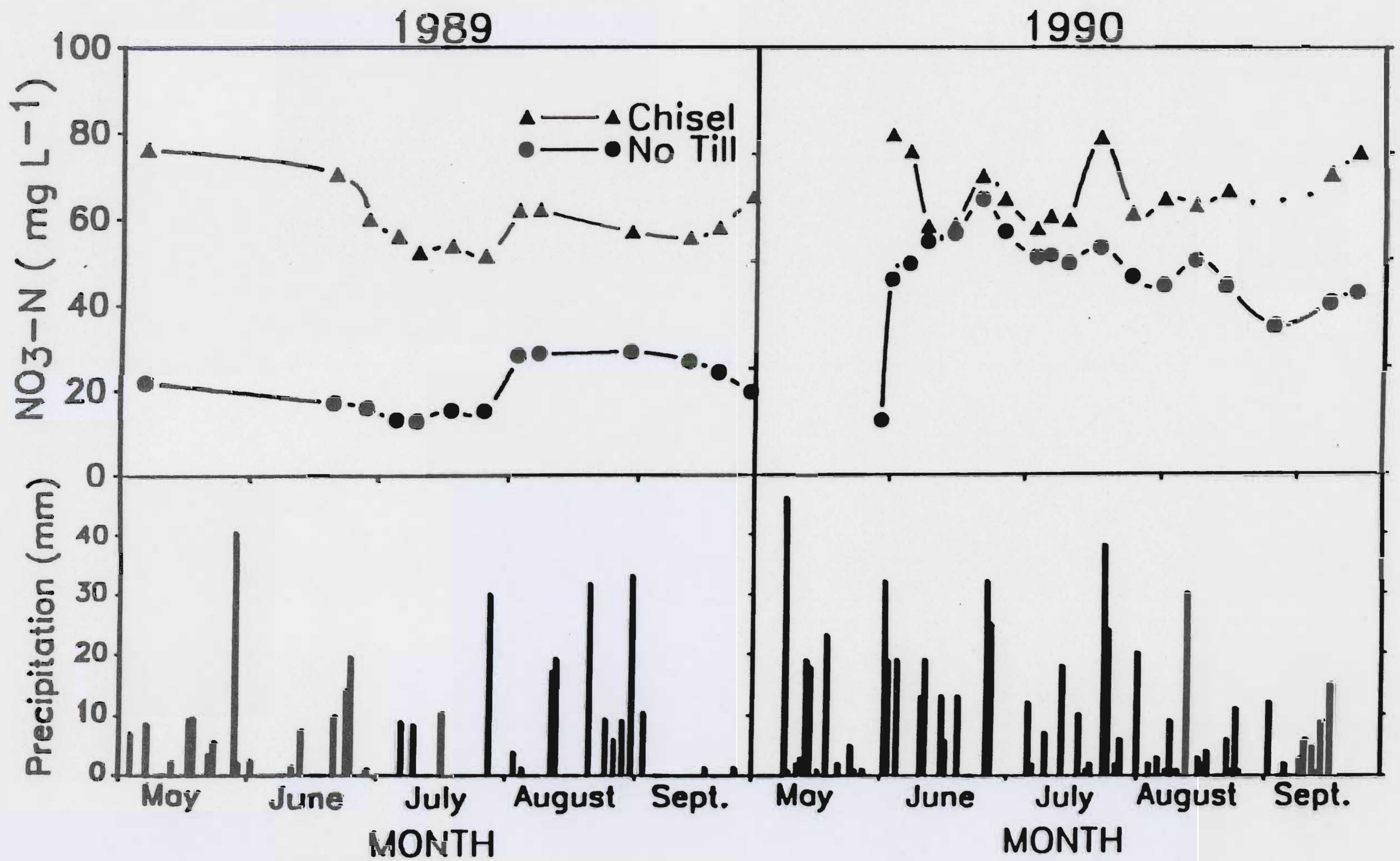
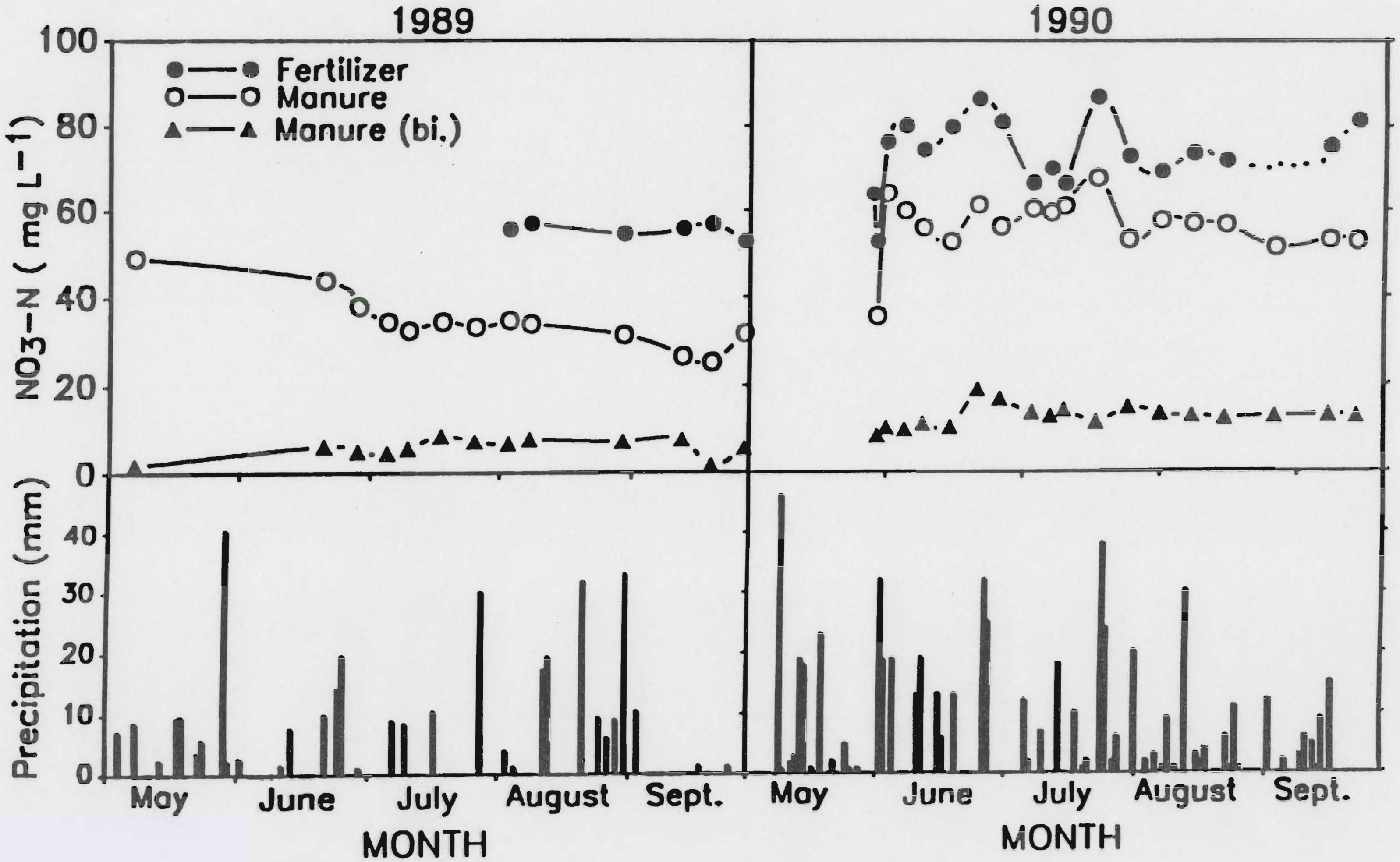


FIGURE -3

EFFECTS OF N SOURCE AND FREQUENCY ON SOIL WATER N AT 1.5m DEPTH



EFFECT OF TILLAGE AND SOURCE OF SWINE MANURE ON SOIL N, CORN YIELD, AND N UPTAKE[1]

J. R. Joshi, J. F. Moncrief, D. A. Andow, J. B. Swan, and G. L. Malzer[2]

Abstract: This was the fourth year of a study utilizing liquid swine manure under two conservation tillage systems (ridge tillage and chisel plowing). Liquid swine manure was applied from an anaerobic pit and an open lagoon at the rate of about 11,000 gallons/A equivalent to 152 lb N/A and 93 lb N/A, respectively. The manure treatments along with an anhydrous ammonia treatment at 170 lb/A rate were applied biennially. Also included in the study were a check without any N and an anhydrous ammonia treatment applied annually.

The system of tillage had no significant effects on grain or stover yields. The application of anhydrous ammonia resulted in higher yields than manure from either sources. The grain yields in the manure treatments were similar; whereas, the stover yields were higher by 0.45 ton/A in the treatments with manure from lagoon source than those receiving manure from the pit. The amount of surface residue was higher in the ridge tillage, and in the year when manure was not applied. There was a greater accumulation of soil N in the profile compared to the levels seen in the previous years, the increase being consistent with the amount of N added. Although tillage effects were significant in the amount of N, chisel plowed treatments had greater amounts in between the rows than in the rows. Soil water N levels increased by 10 to 20 ppm in manure and fertilizer treatments in both tillages compared to the levels in the previous year. The trend with respect to the tillage and N treatments were similar: nitrate was greater in ridge tillage than chisel plowing, and in anhydrous ammonia treatments than in manure treatments.

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 plowing treatments. Additional treatments included an anhydrous ammonia treatment, applied annually and every alternate year at a recommended rate of 170 lbs N/A, and a check treatment receiving neither manure nor fertilizer. Since 1989, the treatment with lower rate of pit manure was replaced with manure from an open lagoon. Most cultural practices followed were similar from year to year; the 1990 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 1990 are summarized in this report.

RESULTS AND DISCUSSION

Surface Residue Cover. Residue measurements were made on June 25, 1990 both in and between the rows in duplicate in the biennial manure and fertilizer treatments in both tillages. A table of significance using the analysis of variance is given in Table 2. On an average, there was about twice as much residue in between the rows than in the rows (Table 3). Among the biennial N treatments, the amount of residue was not different for the anhydrous ammonia treatment in the year of its application and in the year following its application. However, there was about 10-15% more residue in the year following application of the manure treatments as compared to the year of application. The difference in the amount of residue due to injection was seen both in and between the rows. There was more than twice as much residue in between the rows than in the rows in ridge till : whereas, in chisel plowing, the difference in the amount of residue was considerably less than in ridge till.

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[2] Graduate Research Asst., Assoc. Professor of Soil Sci., Assoc. Professor of Entomol., Professor of Agronomy at Iowa State Univ., and Professor of Soil Sci., Univ. of Minnesota, St. Paul, MN, 55108, respectively.

Plant Population and Stover Yield. The plant population, stover dry matter and stover moisture at harvest in the biennial treatments were not affected by tillage (Table 4). The source of N did not affect the plant population or stover moisture at harvest but had a significant effect on stover dry matter. Total stover dry matter was highest in anhydrous ammonia treatment followed by manure from lagoon, and the manure from pit. The year of the application of the biennial N treatments had a significant effect on stand, stover dry matter, and stover moisture (Table 6). There was an increase of about 800 plants/A and 0.75 ton stover dry matter per acre, and a decrease of about 8% in stover moisture in the year of N application. The difference in the stand was higher in manure treatments.

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 5. Tillage did not affect grain yield and total dry matter at harvest, but the ridge till system resulted in higher grain moisture than chisel plowing. The grain yields, grain moisture and total dry matter were significantly affected by the N source. Biennial application of anhydrous ammonia had an average of 139 bu/A followed by manure from the lagoon source with 118 bu/A and the manure from pit source(114 bu/A). Grain moisture was slightly lower with pit manure than the other N treatments. The total dry matter yield was highest with anhydrous ammonia followed by manure from lagoon, and manure from the pit. There was a significant decrease in the grain yield and total dry matter yield, and an increase in grain moisture in the year after application of the N treatments. The average decrease in the grain yields in the year following the application of the biennial N treatments was about 42 bu/A. The average increase in the grain moisture ranged from 2% in the year after application of N treatments (Table 6). The pit manure treatment had the lowest difference in grain moisture in the year of and the year following application.

Harvest Index. The harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover combined, Table 7) was not affected significantly by any treatments. It ranged from 0.52 to 0.60.

Insecticide Effects. In order to assess the effects of insecticide application, all the treatments were further split into insecticide and non-insecticide subplots. There was a difference of about 4 bu/A in grain yields between the treatments with or without insecticides (Table 8). The difference was not significant.

Soil Profile Nitrogen: Fall 1989. Total inorganic N, ammonium-N, and gravimetric soil moisture determinations were made on Fall soil samples taken in and between the rows separately to a depth of 5 ft. at 1 ft. depth increment in selected treatments. A table of significance on soil moisture and soil N in 1989 using the analysis of variance is given in Table 9. The effects of various treatments on soil moisture have already been included in 1989 report.

Of the various N treatments analyzed, total inorganic N in the 5 ft. soil profile was highest in anhydrous ammonia treatment applied annually followed by biennial anhydrous ammonia in the year of its application, biennial manure from pit source in the application year, and check (Table 10). Anhydrous ammonia even in the year following its application had higher N in soil profile than pit manure in its application year, which was not much different than the check. There was no significant difference between the treatments in the amount of ammonium-N. The nitrate-N made up the bulk of the difference in the total mineral N.

The amount of various N forms was highest in the top 0-1 ft. increment and gradually decreased down the profile (Table 11). Both the ridge till and chisel-plowed treatments had similar amounts of N in the row positions but chisel-plowing resulted in slightly higher N in between the rows (Table 12). At lower N rates, the difference in the amount of N in and between the rows was not so wide as compared to the higher N treatments where there was 2-3 times greater N in between the rows than in the rows (Table 13). The amount of nitrate-N in annual anhydrous ammonia treatment was considerably higher throughout the profile up to 5 ft. depth; whereas, it was mainly concentrated in the upper 0-2 ft. portion of the profile in the other treatments.

Soil Moisture: Spring 1990. Total inorganic N and gravimetric soil moisture determinations were made on soil samples taken during April 23-25, 1990 to a depth of 5 ft. at 1 ft. depth increment both in and between the row position. A table of significance of soil moisture and total inorganic N using the analysis of variance are given in Table 14. The soil moisture at the time of sampling ranged between 19.4 to 23.2% by weight (Table 15). The soil profile was slightly drier in 3-4 ft. depth increment and was wetter in the depths above and below. On an average, there was higher moisture in the rows than in between the rows (Table 16).

Soil Profile Nitrogen : Spring 1990. The total inorganic N in the profile in the Spring of 1990 was about 10-40 lbs/A lower than in the previous Fall (Table 17). However, the trend was similar: annual application of anhydrous ammonia had higher N than biennial anhydrous ammonia, biennial manure, and check treatments, respectively. The difference was mainly in the amount of nitrate-N. The highest amount of N was still in the top layer and the quantity decreased gradually with depth (Table 18). There was slightly higher N, mainly in ammonium form, in the rows than in between the rows in treatments with pit manure; whereas, most of the N was higher in between the rows in the other treatments (Table 19). The quantity of nitrate-N in ridge till was fairly uniform in and between the rows (Table 20), but was much higher in between the rows than in the rows in chisel plowing. The nitrate-N was fairly well distributed down to 5 ft. depth in anhydrous ammonia treatments but was mostly in the upper 0-2 ft. in manure and check treatments (Table 21).

Soil Water Nitrogen. Suction water samplers were established on manure (pit source) and anhydrous ammonia (annual) treatments to monitor nitrate-N in soil water at 5 ft. depth.

The effects of tillage on soil water N during 1989-90 growing seasons are presented in Fig. 1. The concentration of nitrate-N in soil water in 1989 stayed constant throughout the season suggesting little movement of water and N during sampling period. Ridge till consistently yielded about 10 ppm higher N than chisel plowing. In 1990, similar effects of tillage were observed. However, the nitrate levels increased in the spring and summer in both tillages suggesting a movement of water and N down the profile following as there were frequent precipitation events in 1990 compared to the dry season of 1988 and an intermediate season in 1989.

The effects of N source and frequency on soil water N are given in Fig. 2. There was more than 4 times higher concentration with anhydrous ammonia treatment than the either manure treatments in 1989 and the nitrate levels stayed mostly constant. In 1990, the trends due to the source of N remained similar, there was an increase in nitrate levels. Treatments in which manure applied in 1990 showed a greater increase the treatments that received manure the previous year.

Table 1. Cultural practices at the Nord Farm in Goodhue County, MN 1990.

Tillage
- Ridge Till- cultivated on June 28, 1990
- Chisel Plow- Chiseled on May 29, 1990

Cropping History
- Corn since 1974
- 1989-Corn Pioneer 3906
- 1990-Corn Pioneer 3751

Manure Application

Injected liquid swine manure with following rate and analysis on May 24-25, 1990.

		Rate of Application (1990)			
		Pit Source		Lagoon Source	
		Mean	Std. Dev.	Mean	Std. Dev.
Manure	(gal/A)	11,200	580	10,900	745
Total-N	(lbs/A)	152	14	93	1
NH_4-N	(lbs/A)	75	11	53	2

Planting Information

A six row Deustch Alis planter equipped with 1" fluted coulter and clearing disks in 1990.

Crop	Date	Rate	Harvested
Corn	May 29,1990	32,000 plants/A	October 22-24, 1990

Fertilizer

Material Analysis	Amount	Actual N -lb/A-	Date Applied	Method of Application
82-0-0		175	June 26, 1990	Injected after planting
7-21-7	10 gal/A		May 29, 1990	As a starter

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 lb a.i./A Counter 15G applied in furrow on May 29, 1990.

Table 2. Significance table for surface residue cover in Goodhue Co., 1990.

Till(T)	N Source(N)	T*N	Year(Y)	T*Y	N*Y	T*N*Y	Row(R)	T*R	N*R	T*N*R	Y*R	T*Y*R	N*Y*R	T*N*Y*R
.000	.057	.262	.000	.155	.084	.136	.000	.000	.980	.906	.027	.907	.434	.141

Table 3. Effect of tillage, N source and frequency, and row position on surface residue cover in Goodhue Co., MN in 1990.

Source and Frequency of N	Year of N application	Ridge Till			Chisel Plow		
		In Row	Bet Rows	Mean	In Row	Bet Rows	Mean
Manure (Pit)	Year After	22	75	49	26	38	32
	Year Of	23	51	37	11	17	14
	Mean	**22**	**63**	**43**	**18**	**27**	**23**
Anhy. Ammon. (Bi.)	Year After	44	75	59	25	43	34
	Year Of	44	87	65	19	21	20
	Mean	**44**	**81**	**62**	**22**	**32**	**27**
Manure (Lagoon)	Year After	42	88	65	23	40	31
	Year of	32	60	46	15	19	17
	Mean	**37**	**74**	**55**	**19**	**29**	**24**
Mean		**34**	**72**	**53**	**20**	**29**	**25**

Table 4. 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 1990[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 (Pit)	Yr.of	29.3	28.2	28.7	2.22	2.22	2.22	36.6	28.4	32.5
	Yr.after	27.7	26.2	27.0	1.76	1.65	1.70	42.6	39.5	41.1
	Mean	28.5	27.2	27.8	1.99	1.93	1.96	39.6	33.9	36.8
Manure (Lagoon)	Yr.of	29.1	28.8	29.0	3.20	2.56	2.88	33.8	35.6	34.7
	Yr.after	28.2	27.7	28.0	2.20	1.78	1.99	44.7	41.4	43.0
	Mean	28.7	28.2	28.5	2.70	2.17	2.43	39.2	38.5	38.9
Anhydrous Ammonia	Yr.of	27.2	28.9	28.0	3.12	3.17	3.15	31.4	30.1	30.7
	Yr.after	28.4	28.4	28.4	2.31	2.24	2.26	37.2	37.4	37.3
	Mean	27.8	28.6	28.2	2.71	2.71	2.71	34.3	33.7	34.0
Mean		28.3	28.0	28.2	2.47	2.27	2.37	37.7	35.4	36.5

Pr>F	Tillage(T)	N Source(N)	Year(Y)	T*N	T*Y	Y*N	Y*N*T
Population	.466	.688	.032	.342	.325	.059	.652
Stover dry matter	.407	.000	.000	.174	.709	.101	.467
Stover moisture	.590	.351	.006	.798	.698	.940	.604

[1] Averaged over insecticide treatments.
[2] Year refers to the year of application of the biennial treatments.

Table 5. The effect of tillage and N source on corn grain yield, grain moisture and total dry matter in Goodhue Co., MN in 1990[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	139	125	132	24.7	23.8	24.2	5.41	5.21	5.31
(Pit)	Yr.after	96	94	95	27.1	26.2	26.7	4.14	3.79	3.97
	Mean	118	109	114	26.0	25.0	25.5	4.78	4.50	4.64
Manure	Yr.of	147	137	142	25.3	24.6	24.9	6.67	6.06	6.37
(Lagoon)	Yr.after	95	92	93	27.5	27.4	27.4	4.67	3.78	4.22
	Mean	121	115	118	26.4	26.0	26.2	5.67	4.92	5.29
Anhydrous	Yr.of	159	158	158	27.1	25.1	25.6	6.84	7.18	7.00
Ammonia	Yr.after	121	118	119	26.0	26.0	26.5	5.26	5.61	5.44
	Mean	140	138	139	26.6	25.5	26.0	6.05	6.39	6.22
Mean		**126**	**121**	**123**	**26.3**	**25.5**	**25.9**	**5.50**	**5.27**	**5.38**

Pr>F	Tillage(T)	N Source(N)	Year(Y)	T*N	T*Y	Y*N	Y*N*T
Grain Yield	.536	.002	.000	.837	.327	.146	.599
Grain moisture	.013	.082	.000	.480	.939	.005	.796
Total dry matter	.651	.015	.000	.432	.732	.255	.854

[1] Averaged over insecticide treatments.
[2] Year refers to the year of application of the biennial 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 1990[1].

Year[2]	GRAIN YIELD	GRAIN MOISTURE	TOTAL DRY MATTER	STOVER DRY MATTER	STOVER MOISTURE	PLANT POPULATION
	--bu/A--	--%--	--tons/A--	--tons/A--	--%--	-Plants/A*10^{-3} -
Year of	144.2	24.9	6.23	2.75	32.6	28.6
Year After	102.6	26.9	4.54	1.99	40.4	27.8
Pr>F (Year)	.000	.000	.000	.000	.000	.032

[1] Averaged over tillage, insecticide, and biennial N treatments.
[2] Year refers to the year of application of the biennial treatments.

Table 7. Corn harvest index as affected by tillage, and N source in Goodhue Co., MN in 1990.

		HARVEST INDEX[1]				
Source of N	Year[2]	Ridge	Chisel	Mean	Source	Pr>F
Manure	Yr.of	0.59	0.57	0.58	Tillage(T)	.729
(Pit)	Yr.after	0.58	0.54	0.56	N source(N)	.207
	Mean	0.58	0.56	0.57	Year (Y)	.676
Manure	Yr.of	0.52	0.56	0.54	T*N	.402
(lagoon)	Yr.after	0.52	0.53	0.52	T*Y	.935
	Mean	0.52	0.54	0.53	Y*N	.499
Anhydrous	Yr.of	0.54	0.56	0.55	Y*N*T	.529
Ammonia	Yr.after	0.56	0.60	0.58		
	Mean	0.55	0.58	0.56		
Mean		**0.56**	**0.55**	**0.55**		

[1] Averaged over insecticide treatments.
[2] Year refers to the year of application of the biennial treatments.

Table 8. The effect of insecticide application on corn grain yield at harvest in Goodhue Co., MN in 1990[1].

Insecticide	GRAIN YIELD ---bu/A---
Yes	125
No	122
Pr>F (Insect.)	.172

[1] Means of all biennial N, insecticide and tillage treatments.

Table 9. Significance table for soil moisture and soil profile N in fall 1989.

	Till(T)	NSource(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
Moisture	.758	.776	.408	.302	.528	.991	.981	.000	.006	.002	.123	.923	.602	.996	.997
N	.647	.000	.953	.000	.132	.000	.813	.000	.979	.001	.864	.000	.898	.025	.341
NH_4-N	.535	.897	.695	.261	.345	.445	.205	.000	.846	.378	.985	.324	.896	.602	.987
NO_3-N	.738	.000	.776	.000	.156	.000	.912	.000	.958	.000	.531	.000	.826	.011	.131

Table 10. Effects of N source on soil profile N in 5 ft. soil profile in Goodhue Co., MN on Nov. 2-9, 1989.

N SOURCE AND FREQUENCY	AMOUNT (lbs/A)		
	TOTAL-N	AMMON.-N	NITRATE-N
ANHYDROUS AMMONIA (ANNUAL)	269	92	177
ANHYDROUS AMMONIA (BIENNIAL, YR OF)	181	88	93
ANHYDROUS AMMONIA (BIENNIAL, YR AFT)	125	87	38
PIT MANURE (BIENNIAL, YR OF)	110	88	22
CHECK	103	82	21
Pr>F	.000	.897	.000

Table 11. Soil profile N by depth in 5 ft. soil profile in Goodhue Co., MN on Nov. 2-9, 1989.

DEPTH (ft.)	AMOUNT (lbs/A)		
	TOTAL-N	AMMONIUM-N	NITRATE-N
0-1	48	26	22
1-2	32	18	14
2-3	29	16	13
3-4	25	14	11
4-5	23	13	10
Pr>F	.000	.000	.000

Table 12. Soil profile N by tillage and row position in 5 ft. soil profile in Goodhue Co., MN on Nov. 2-9, 1989.

TILLAGE	ROW POSITION	AMOUNT (lbs/A)		
		TOTAL-N	AMMON.-N	NITRATE-N
RIDGE TILL	IN ROW	138	85	53
	BETWEEN ROWS	165	86	79
CHISEL PLOW	IN ROW	138	88	50
	BETWEEN ROWS	191	92	99
Pr>F		.132	.345	.156

Table 13. Soil profile N by N source and row position in Goodhue Co., MN on Nov. 2-9, 1989.

N SOURCE & FREQUENCY	ROW POSITION	NO3-N (lbs/A)					
		0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.	**0-5 ft.**
PIT MANURE (BI, YR OF)	IN	9.4	2.5	2.3	2.2	2.2	**18.5**
	BETWEEN	13.6	4.2	2.4	2.4	2.5	**25.0**
ANHY. AMM. (BI, YR OF)	IN	23.0	6.7	6.0	7.3	9.7	**51.7**
	BETWEEN	56.5	37.7	13.5	12.2	10.3	**132.0**
ANHY. AMM.(BI, YR AFT)	IN	10.8	4.9	5.2	7.4	6.5	**34.9**
	BETWEEN	14.8	5.3	7.3	8.4	4.8	**40.7**
ANHY. AMM. (ANNUAL)	IN	22.5	20.2	31.5	30.1	28.9	**133.7**
	BETWEEN	51.1	56.7	49.3	38.1	28.6	**220.7**
CHECK	IN	7.6	2.8	1.9	2.1	2.6	**17.2**
	BETWEEN	8.9	2.2	7.4	2.9	2.3	**24.7**
Pr>F		N*R*D=.001					N*R=.000

Table 14. Significance table for soil moisture and soil profile N in spring 1990.

	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
Moisture	.953	.874	.970	.090	.245	.205	.161	.018	.907	.300	.295	.334	.729	.803	.606
N	.987	.000	.150	.001	.150	.004	.798	.000	.177	.116	.260	.170	.483	.132	.897
NH_4-N	.858	.809	.142	.615	.241	.048	.015	.000	.488	.175	.663	.895	.875	.241	.009
NO_3-N	.463	.000	.295	.001	.023	.062	.281	.000	.127	.016	.266	.213	.308	.544	.809

Table 15. Gravimetric soil moisture by depth in Goodhue Co., MN during April 23-25, 1990.

DEPTH (ft.)	MOISTURE (%, wt./wt.)
0-1	23.1
1-2	23.2
2-3	21.6
3-4	19.4
4-5	22.9
Pr>F	.018

Table 16. Gravimetric soil moisture by row position in Goodhue Co., MN during April 23-25, 1990.

ROW POSITION	MOISTURE (%, wt./wt.)
IN ROW	22.8
BETWEEN ROWS	21.3
Pr>F	.090

Table 17. Soil profile N as affected by N source in Goodhue Co., MN during April 23-25, 1990.

N SOURCE & FREQUENCY	AMOUNT (lbs/A)		
	TOTAL-N	AMMONIUM-N	NITRATE-N
PIT MANURE (BI, 1989)	102	74	28
ANHY. AMMON. (BI, 1988)	146	73	73
ANHY. AMMON. (ANNUAL)	229	70	159
CHECK	89	68	21
Pr>F	.000	.809	.000

Table 18. Soil profile N by depth in Goodhue Co., MN during April 23-25, 1990.

DEPTH (ft.)	AMOUNT (lbs/A)		
	TOTAL-N	AMMON.-N	NITRATE-N
0-1	40.4	21.9	18.5
1-2	30.0	14.4	16.0
2-3	27.4	13.6	13.8
3-4	22.5	11.4	11.1
4-5	20.5	10.1	10.4
Pr>F	.000	.000	.000

Table 19. Soil profile N as affected by N source and row position in Goodhue Co., MN during April 23-25, 1990.

N SOURCE & FREQUENCY	ROW POSITION	AMOUNT (lbs/A)		
		TOTAL-N	AMMONIUM-N	NITRATE-N
PIT MANURE (yr of)	IN	108	79	29
	BETWEEN	96	69	27
ANHY. AMMO. (yr of)	IN	127	71	56
	BETWEEN	165	74	91
ANHY. AMMO. (annual)	IN	203	65	138
	BETWEEN	254	76	178
CHECK	IN	82	68	14
	BETWEEN	95	68	27
Pr>F		.004	.048	.062

Table 20. Soil profile NO3-N as affected by tillage and row position in Goodhue Co., MN during April 23-25, 1990.

TILLAGE	NO3-N (lbs/A)	
	IN ROW	BET ROWS
RIDGE TILL	69	75
CHISEL PLOW	50	88
Pr>F	.023	

Table 21. Soil profile NO3-N as affected by tillage, N source and depth in Goodhue Co., MN during April 23-25, 1990.

N SOURCE & FREQUENCY	NO3-N (lbs/A)				
	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.
PIT MANURE (bi, 1989)	12.9	6.8	3.4	2.5	2.5
ANHY. AMMO.(bi, 1989)	21.5	21.9	10.6	8.3	11.1
ANHY. AMMO.(annual)	31.6	33.0	38.4	31.4	23.9
CHECK	8.1	3.3	2.6	1.9	4.8
Pr>F	.016				

FIGURE -1

TILLAGE EFFECTS ON SOIL WATER N AT 1.5m DEPTH

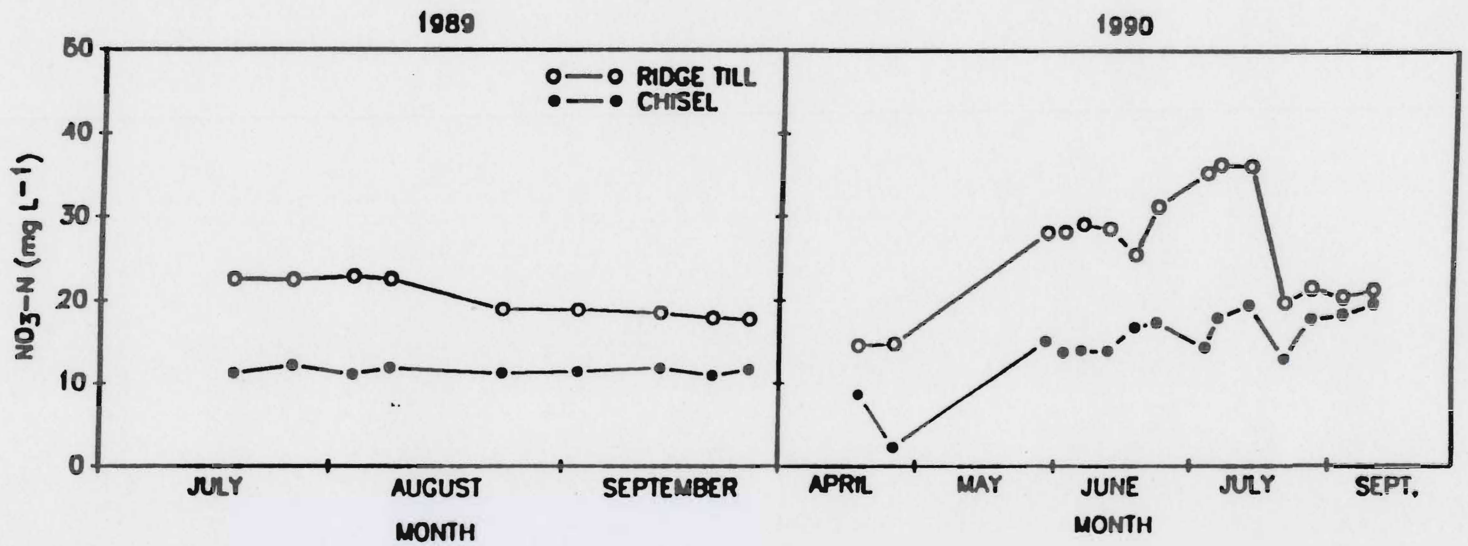
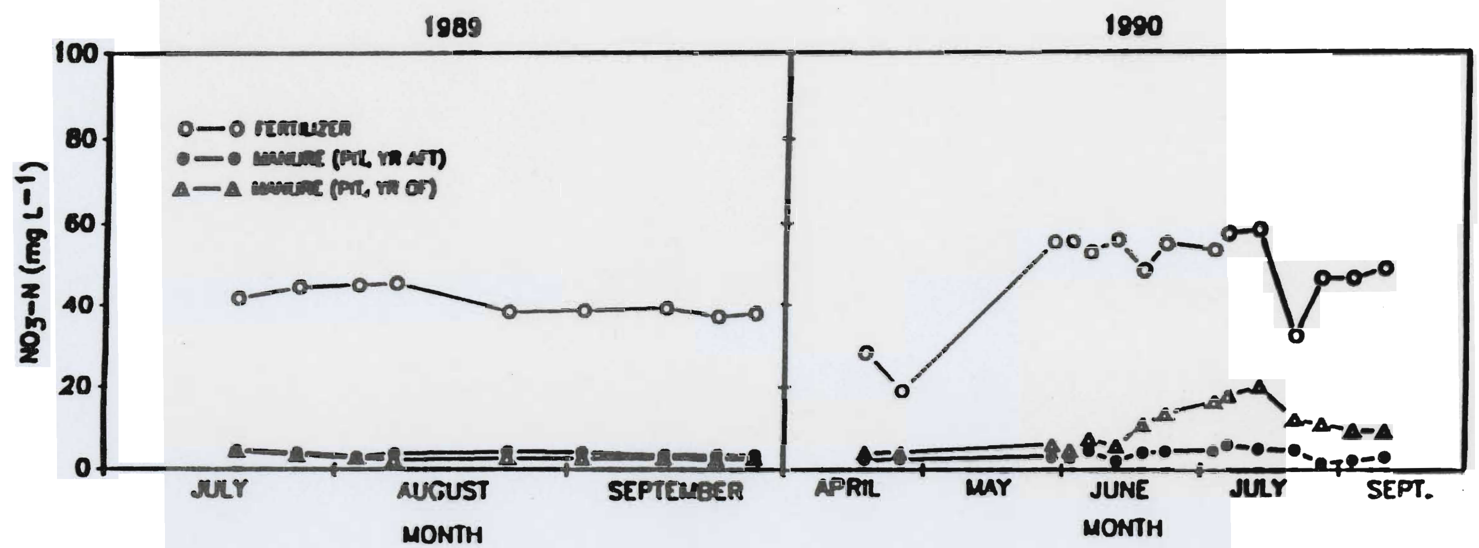


FIGURE -2

EFFECTS OF N SOURCE AND FREQUENCY ON SOIL WATER N AT 1.5m DEPTH



Tillage and time of application effects on corn response to manure in Meeker County, MN[1]

J.F. Moncrief, M.B. Kells, and J.J. Kuznia[2]

Chisel plowing provided adequate soil cover by crop residue to control soil erosion. There was no effect of tillage or nitrogen source on corn stand establishment. There was no effect of tillage on nitrogen availability to corn with the possible exception of the an increase with moldboard plowing of fall applied manure. Due to low rainfall, there was no difference in available N and grain yields with fall or spring applications of manure. There was a 22 bushel per acre increase in grain yield due to a response to nitrogen. Chisel plowing resulted in a 18 bushel per acre reduction in yield and an increase of grain moisture of 2.7 percent. This was likely due to a higher than recommended level of "in row" soil cover (16 percent vs 2.5 for chisel and moldboard plowing respectively), the cool spring in 1990 a uniform northern aspect with about 8% slope.

Methods and Materials

Fall and spring applications of dairy and pig manure are being compared to evaluate losses due to rainfall. At this site soil test values for nitrate and ammonium have been measured in late June. Ear leaf concentrations of nitrogen (7/30/90) have also been used to evaluate the time and N source treatments.

The composition of the manures at the Meeker county site are shown in table 1 for fall and spring applications. This site has a soil test P and K of 47 and 238 lbs/acre respectively. Soil test show that the N and K are needed.

The rate of manure was similar in the fall and spring. The rate of N was not however. In the fall N applied as pig and dairy manure was 146 and 86 pounds per acre respectively. In the spring the N rates were 108 and 164 pounds per acre with pig and dairy manure respectively. The manure composition is quite variable at this site.

As well as evaluating two sources of manure, tillage systems, and times of manure application, anhydrous ammonia and no nitrogen were also control treatments. The statistical analysis was done with two experimental designs: a randomized complete block with two tillage treatments split with six N source treatments, and a randomized complete block with two times of application split with two levels of tillage split with two sources of manure. The anhydrous ammonia and no nitrogen treatments were excluded from this analysis.

Results and Discussion

Corn yields were about 80 bushels per acre at this site in 1989. Soil cover after planting in 1990 was fairly high considering the yield levels in the previous year (tables 2 and 3). There was almost 40% cover with the chisel plowing system. The spring tines that clear the row area worked fairly well reducing the cover to about 16% in the row although this is higher than an ideal of less than 10%. Soil cover by corn residue was low with moldboard plowing.

There was bedding in the dairy source of manure. The soil cover by corn residue between the row was higher when manure was applied in the spring after fall moldboard plowing but a reverse trend with fall chisel plowing (table 3). The soil cover in the row after chisel plowing was higher with the hog source of manure because the tine row cleaners were more effective at removing straw bedding from the dairy source of manure rather than fecal material from the hog manure source.

Corn stands were quite good and not affected by tillage or manure treatments (tables 4 and 5). Any yield differences due to manure or tillage are not due to differences in corn stand.

By the end of July tillage and manure treatments were visible in the height of corn (tables 4 and 5). Anhydrous ammonia and fall applied manure treatments resulted in corn that was taller than plots with no nitrogen applied (table 4). In the fall there appeared to be an advantage to moldboard plowing after manure

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[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.B. Kells is the Tri-County Project coordinator.*

application. Spring manure and anhydrous ammonia treatments were not affected by tillage. On average moldboard plowing resulted in corn that was about four inches taller than those grown with a chisel system.

Although tillage affected corn height at the end of July, it did not affect the color (tables 4 and 5). Nitrogen source did have an affect on corn color. Anhydrous ammonia was the greenest, followed by fall manure treatments. Spring manure treatments resulted in corn that was only slightly greener than check plots.

Ear leaf N concentrations were similarly affected by N source but not tillage (tables 4 and 5). Fall and spring applied manure treatments resulted in corn with similar leaf N levels and were much higher than check plots. Anhydrous ammonia grown corn was higher than manure treatments. The trends in ear leaf N concentrations were followed closely by grain yields although N source was not statistically significant.

The two sources of manure were equally effective in providing N to corn whether fall or spring applied (125 and 127 bushels per acre respectively, table 5). This is not surprising in view of the rainfall that occurred between the fall and spring manure applications (figure 1). There was very little rainfall and little N was lost due to leaching in the fall or early spring. There were substantial leaching rains during the growing season especially during May and June. It is likely that the mineral portion of the manure that was applied was nitrified (converted to nitrate) and subject to leaching or denitrification (converted to gases) losses during these rains. Anhydrous ammonia, due to the inhospitable environment in the injection zone for nitrifying bacteria, is nitrified more slowly than manure sources and would be less likely to leach.

Soil mineral N on June 25, 1990 is presented in tables 6-8. Although soil samples represent 10 core composites for each plot, there was too much variability in these data to discern treatment differences. There was no statistically significant effect of tillage or N source on soil nitrogen. The anhydrous ammonia band was avoided when samples were taken in this treatment. Most of the soil ammonium was in the top one foot of soil. There was slightly higher levels of ammonium than nitrate. Soil nitrogen levels are generally low due to the heavy rainfall in the early summer (figure 1).

However, the trends in total soil nitrogen on this date follow the treatment influences in tissue levels of N.

Meeker County

Table 1. Cultural practices at Meeker County, MN. 1990.

Tillage
- Fall Chisel Plowed, spring field cultivated
- Fall Moldboard Plowed, spring field cultivated

1990 Crop
- Corn-Pioneer 3751

Planting and Harvest Dates

Plots were planted with a four row John Deere Maximerge planter equipped with spring tine row cleaners at a 38 inch row spacing.

Crop	Planting Date	Planting Rate	Harvested
Corn	May 8, 1990	28,000 seeds/A	October 15, 1990

1990 Fertilizer and Manure Analysis

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			----	lb/A	----	
Corn	9-23-30[1]	150 lb/A	14	35	45	May 8, 1990
	82-0-0[2]	85 lb/A	70	0	0	April 24, 1990

1. Planter placement 2" beside and 2" below row.
2. Anhydrous ammonia was applied on selected plots.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Fall-1989.

Manure Type and Rate of Application: Source	Rate	Nitrogen: Mineral	Organic	Total	$[1]	Available	Phosphorus: P_2O_5	$[1]	Potassium: K_2O	$[1]
		-------	lb/A	--------		- lb/A --	lb/A		lb/A	
Dairy	13.2 t/A	62	97	159	15.90	86	107	21.40	134	13.40
Pig	4,100 g/A	120	75	195	19.50	146	212	46.68	100	10.00

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Spring-1990 (4/5/90 for liquid and 5/18/90 for dairy).

Manure Type and Rate of Application		Nitrogen					Phosphorus		Potassium	
		Mineral	Organic	Total	$[1]	Available	P_2O_5	$[1]	K_2O	$[1]
Source	Rate	-------	lb/A	-------		- lb/A --	lb/A		lb/A	
Dairy	11.6 t/A	149	61	210	21.00	164	89	17.80	217	21.70
Pig	4,100 g/A	93	43	136	13.60	108	127	25.40	82	8.20

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively.

Soil

The soils present at this site are as follows: 60% is Koronis fine sandy loam (Mollic Haplaudalfs, fine-loamy, mixed, mesic) with good internal drainage; 20% Cordova loam (Typic Argiaquolls, fine-loamy, mixed, mesic) with poor internal drainage; and the remaining 20% is Marcellon loam (Aquic Argiudolls, fine-loamy, mixed, mesic) with somewhat poor internal drainage.

Weed Control

3 qt/A (3.0 lb/A) Lasso applied preemergence on May 24, 1990.
.5 lb/A (0.45 lb/A) Atrazine 90 DF + 1 pt/A (0.25 lb/A) Buctril applied on June 22, 1990.

Insect Control

7 lb/A (1.05 lb/A) Counter 15G applied with planter.

Table 2. Effect of tillage and nitrogen source on soil cover by corn residue, 1990[1].

Treatments	Row Position[2] In	Row Position[2] Between	Avg.
	---------	%	---------
Tillage			
Moldboard	2.5b	11.0b	6.8b
Chisel	16.3a	37.8a	27.1a
Signif. (Pr > F)	0.017	0.002	0.003
	n=48	n=48	n=96
Nitrogen Source			
Fall Hog	13.0a	30.0a	21.5a
Spring Hog	12.0ab	25.8a	18.9ab
Fall Dairy	6.8bc	23.5ab	15.1b
Spring Dairy	10.0abc	26.0a	18.0ab
Anhydrous	5.3c	23.8ab	14.5b
Check	9.5abc	17.5b	13.5b
Signif. (Pr > F)	0.149	0.113	0.185
	n=16	n=16	n=32
Interactions			
Tillage X Nitrogen Source			
Mldbd Fall Hog	2.5	8.5	5.5
Mldbd Spring Hog	2.5	16.5	9.5
Mldbd Fall Dairy	2.0	12.0	7.0
Mldbd Spring Dairy	4.0	16.5	10.3
Mldbd Anhydrous	2.0	5.5	3.8
Mldbd Check	2.0	7.0	4.5
Chisel Fall Hog	23.5	51.5	37.5
Chisel Spring Hog	21.5	35.0	28.3
Chisel Fall Dairy	11.5	35.0	23.3
Chisel Spring Dairy	16.0	35.0	25.8
Chisel Anhydrous	8.5	42.0	25.3
Chisel Check	17.0	28.0	22.5
Signif. (Pr > F)	0.208	0.018	0.188
	n=8	n=8	n=16

1. Means within the same column with the same letter are not significantly different (α=.10).
2. In row is defined as a strip 4 inches wide centered over the row. Between row is the remainder (38 inch rows).

Table 3. Effect of time, tillage, and manure source on residue and its relative position to the row, 1990[1].

Treatments	Row Position In	Row Position Between	Avg.
	-------	%	---------
Application Time			
Fall	11.0a	26.8a	18.3a
Spring	9.9a	25.9a	18.4a
Signif. (Pr > F)	0.478	0.635	0.893
	n=32	n=32	n=64
Tillage			
Moldboard	2.8b	13.4b	8.1b
Chisel	18.1a	39.3a	28.7a
Signif. (Pr > F)	0.001	0.001	0.001
	n=32	n=32	n=64
Manure Source			
Hog	12.5a	27.9a	20.2a
Dairy	8.4a	24.8a	16.6a
Signif. (Pr > F)	0.101	0.351	0.180
	n=32	n=32	n=64
Interactions[2]			
Application Time X Tillage			
Fall Moldboard	2.3	10.3	6.3
Fall Chisel	17.5	43.3	30.4
Spring Moldboard	3.3	16.5	9.9
Spring Chisel	18.8	35.3	27.0
Signif. (Pr > F)	0.940	0.056	0.064
	n=16	n=16	n=32
Tillage X Manure Source			
Moldboard Hog	2.5	12.5	7.5
Moldboard Dairy	3.0	14.3	8.6
Chisel Hog	22.5	43.3	32.9
Chisel Dairy	13.8	35.3	24.5
Signif. (Pr > F)	0.067	0.149	0.087
	n=16	n=16	n=32

1. Means within the same column with the same letter are not significantly different (α=.10).
2. Only interactions with a (Pr > F) value less than .100 are reported.

Table 4. Effect of tillage and nitrogen source on corn response at Meeker Co., Ecker farm, 1990[1].

Treatment	Grain Yield	Grain Moisture	Grain Protein	Protein Yield	Population	Plant Height	Color Rating	Earleaf N
	bu/A	%	%	lb/A	plants/A x 10^{-3}	ft	1=Yellow 5=green	%
Tillage (n=24)								
Moldboard	133.9a	24.5b	8.00a	563.1a	27.5a	6.99a	4.24a	2.34a
Chisel	117.9b	27.2a	7.70a	478.0b	27.7a	6.65b	4.14a	2.42a
Signif. (Pr > F)	.007	.016	.102	.019	.861	.079	.266	.743
Nitrogen Source (n=8)								
Fall Hog	122.4ab	26.2a	7.86a	508.5ab	27.4a	6.72a	4.16b	2.47ab
Spring Hog	130.7ab	25.8a	7.76a	533.0ab	27.6a	6.72bc	4.00b	2.33b
Fall Dairy	127.1ab	25.4a	7.96a	530.9ab	27.5a	7.13ab	4.28b	2.50ab
Spring Dairy	123.5ab	26.1a	7.77a	505.5ab	27.7a	6.41c	4.03b	2.41b
Anhydrous	136.5a	25.3a	8.05a	575.8a	27.9a	7.28a	4.78a	2.71a
Check	115.0b	26.5a	7.73a	469.7b	27.4a	6.67bc	3.94b	1.99c
Signif. (Pr > F)	.282	.400	.545	.344	.989	.037	.007	.001
Interactions								
Tillage X Nitrogen Source (n=4)								
Mldbd Fall Hog	135.8	24.4	8.19	586.5	27.8	7.38	4.50	2.47
Mldbd Sp Hog	127.9	24.8	7.85	527.6	26.7	6.69	3.75	2.27
Mldbd Fall Dairy	139.3	24.1	8.06	586.9	27.3	7.38	4.44	2.48
Mldbd Sp Dairy	136.3	24.2	7.92	567.0	26.9	6.69	4.25	2.53
Mldbd Anhydrous	147.4	23.9	8.28	636.5	27.8	7.31	4.75	2.67
Mldbd Check	116.7	25.7	7.71	474.3	28.5	6.50	3.88	1.85
Chisel Fall Hog	108.9	27.9	7.52	430.6	27.1	6.06	3.81	2.48
Chisel Sp Hog	133.5	26.8	7.67	538.5	28.5	6.75	4.25	2.38
Chisel Fall Dairy	115.0	26.6	7.85	475.0	27.7	6.88	4.13	2.51
Chisel Sp Dairy	110.8	27.9	7.61	444.1	28.5	6.13	3.81	2.28
Chisel Anhydrous	125.6	26.7	7.81	515.1	27.9	7.25	4.81	2.74
Chisel Check	113.4	27.4	7.75	464.8	26.3	6.81	4.00	2.13
Signif. (Pr > F)	.365	.600	.579	.383	.050	.085	.145	.580

1. Means within the same columns with the same letter are not significantly different (α=.10).

Table 5. Effect of application time, tillage, and manure source on various plant characteristics of corn at Meeker Co., Ecker farm, 1990[1].

Treatment	Grain Yield	Grain Moisture	Grain Protein	Protein Yield	Population	Plant Height	Color Rating	Earleaf N
	bu/A	%	%	lb/A	plants/A x 10^{-3}	ft	1=Yellow 5=green	%
Application Time (n=16)								
Fall	124.8a	25.8a	7.91a	519.7a	27.5a	6.92a	4.22a	2.49a
Spring	127.1a	25.9a	7.76a	517.3a	27.6a	6.56a	4.02a	2.37a
Signif. (Pr > F)	.730	.625	.534	.992	.795	.271	.322	.495
Tillage (n=16)								
Moldboard	134.8a	24.4b	8.00a	567.0a	27.2a	7.03a	4.23a	2.44a
Chisel	117.0b	27.3a	7.66a	472.0b	27.9a	6.45b	4.00a	2.47a
Signif. (Pr > F)	.045	.001	.139	.053	.254	.009	.259	.829
Manure Source (n=16)								
Hog	126.5a	26.0a	7.81a	520.8a	27.5a	6.72a	4.16a	2.40a
Dairy	125.3a	25.7a	7.86a	518.2a	27.6a	6.77a	4.08a	2.45a
Signif. (Pr > F)	.833	.476	.560	.918	.855	.796	.588	.618
Interactions								
Application Time X Tillage (n=8)								
Fall Moldboard	137.6	24.3	8.13	586.7	27.6	7.38	4.47	2.47
Fall Chisel	112.0	27.2	7.69	452.8	27.4	6.47	3.97	2.50
Spring Moldboard	132.1	24.5	7.88	547.3	26.8	6.69	4.00	2.40
Spring Chisel	122.1	27.4	7.64	491.3	28.5	6.44	4.03	2.33
Signif. (Pr > F)	.309	.839	.640	.362	.170	.077	.208	.639
Application Time X Manure Source (n=8)								
Fall Hog	122.4	26.2	7.86	508.5	27.4	6.72	4.16	2.47
Fall Dairy	127.1	25.4	7.96	530.9	27.5	7.13	4.28	2.50
Spring Hog	130.7	25.8	7.76	533.0	27.6	6.72	4.00	2.33
Spring Dairy	123.5	26.1	7.77	505.5	27.7	6.41	4.03	2.41
Signif. (Pr > F)	.300	.170	.625	.325	1.00	.052	.745	.793
Tillage X Manure Source (n=8)								
Moldboard Hog	131.9	20.4	8.02	557.0	27.3	7.03	4.13	2.37
Moldboard Dairy	137.8	17.8	7.99	576.9	27.1	7.03	4.34	2.51
Chisel Hog	121.2	26.5	7.59	484.6	27.8	6.41	4.03	2.43
Chisel Dairy	112.9	25.3	7.73	459.5	28.1	6.50	3.97	2.39
Signif. (Pr > F)	.220	.560	.392	.375	.648	.796	.331	.389
Application Time X Manure Source X Tillage (n=4)								
Fall Hog Mldbd	135.8	24.4	8.19	586.5	27.8	7.38	4.50	2.47
Fall Dairy Mldbd	139.3	24.1	8.06	586.9	27.3	7.38	4.44	2.48
Fall Hog Chisel	108.9	27.9	7.52	430.6	27.1	6.06	3.81	2.48
Fall Dairy Chisel	115.0	26.6	7.85	475.0	27.7	6.88	4.13	2.51
Sp Hog Mldbd	127.9	24.8	7.85	527.6	26.7	6.69	3.75	2.27
Sp Dairy Mldbd	136.3	24.2	7.92	567.0	26.9	6.69	4.25	2.53
Sp Hog Chisel	133.5	26.8	7.67	538.5	28.5	6.75	4.25	2.38
Sp Dairy Chisel	110.8	27.9	7.61	444.1	28.5	6.13	3.81	2.28
Signif. (Pr > F)	.151	.090	.129	.093	.522	.052	.027	.354

1. Means within the same columns with the same letter are not significantly different (α=.10).

Table 6. The effect of time of manure application and depth on soil ammonium N (lbs/acre) Meeker County, MN, 6/25/90[1].

	Fall Applied		Spring Applied				
Depth	Pig	Dairy	Pig	Dairy	Anhyd.	Check	**Average**
0-1 feet	42	33	41	43	45	43	**41**
1-2 feet	27	26	29	29	26	30	**28**
Total	**69**	**60**	**70**	**73**			
Average	65		72		**72**	**73**	

1. The p values for time, N source, depth, and the time by N source interaction are: .086, .812, <.001, and .452 respectively (excluding the anhydrous ammonia and check treatments).

Table 7. The effect of time of manure application and tillage on soil nitrate (lbs/acre) Meeker County, MN, 6/25/90[1].

	Fall Applied		Spring Applied				
Depth	Pig	Dairy	Pig	Dairy	Anhyd.	Check	**Average**
0-1 feet	41	29	31	32	39	21	**32**
1-2 feet	40	37	25	29	34	18	**31**
Total	**81**	**66**	**56**	**61**			
Average	74		59		**73**	**39**	

1. The p values for time, N source, depth, and the time by N source interaction are: .427, .456, .898, and .208 respectively (excluding the anhydrous ammonia and check treatments).

Table 8. The effect of time of manure application and depth on total soil mineral N (lbs/acre) Meeker County, MN, 6/25/90[1].

	Fall Applied		Spring Applied				
Depth	Pig	Dairy	Pig	Dairy	Anhyd.	Check	**Average**
0-1 feet	82	63	72	76	85	64	**74**
1-2 feet	68	64	54	58	60	47	**59**
Total	**150**	**126**	**126**	**134**			
Average	138		130		**144**	**111**	

1. The p values for time, N source, depth, and the time by N source interaction are: .623, .218, .006, and .029 respectively (excluding the anhydrous ammonia and check treatments).

The tillage effect on grain yields was much more consistent than the effect of N source. There was a 16 bushel per acre reduction in yield with the chisel plowing system (tables 4 and 5). The yield reduction associated with chisel plowing was also correlated with an almost 3% increase in grain moisture. Increases in grain moisture indicate slowed corn development. This can be the result of "in row" cover reducing soil temperatures. Cover in the row by crop residue was 16% with the chisel plowing system. This may of had an influence on corn development due to the uniform northern aspect with about 8% slope at this site. Data from other locations suggests that soil cover by corn residue in a strip one third the row width should be less than 20% to minimize any impact on corn establishment and early growth.

Stand was not affected by the corn residue in the row area. When "in row" residue levels slow the growth of corn there is usually also a stand reduction.

Increased grain moisture can also be the result of nutrient stress. Tissue levels of nitrogen suggests that nitrogen deficiency was not the cause. Phosphorus and potassium are likely not limiting because 30 and 45 pounds per acre respectively were applied with the planter based on the soil test level at this site. It is not likely that nutrient stress was the causal agent.

The best guess is that the delayed development of the corn grown with the chisel plowing system was due to excessive corn residue in the row area.

The grain nitrogen (protein) levels followed trends that were similar to ear leaf nitrogen trends although fall applied manure and anhydrous ammonia treatments were closer and slightly higher than spring applied manure or nothing. Also moldboard plowing both sources of fall applied manure seemed to provide an advantage for N availability in 1990. This trend is consistent for color ratings, grain yields, grain N, and N uptake by grain (table 9). Tillage effects on these variables without manure applied (check plots) suggest that the advantage is not due to increased mineralization of soil organic matter with moldboard plowing but to the available N from manure.

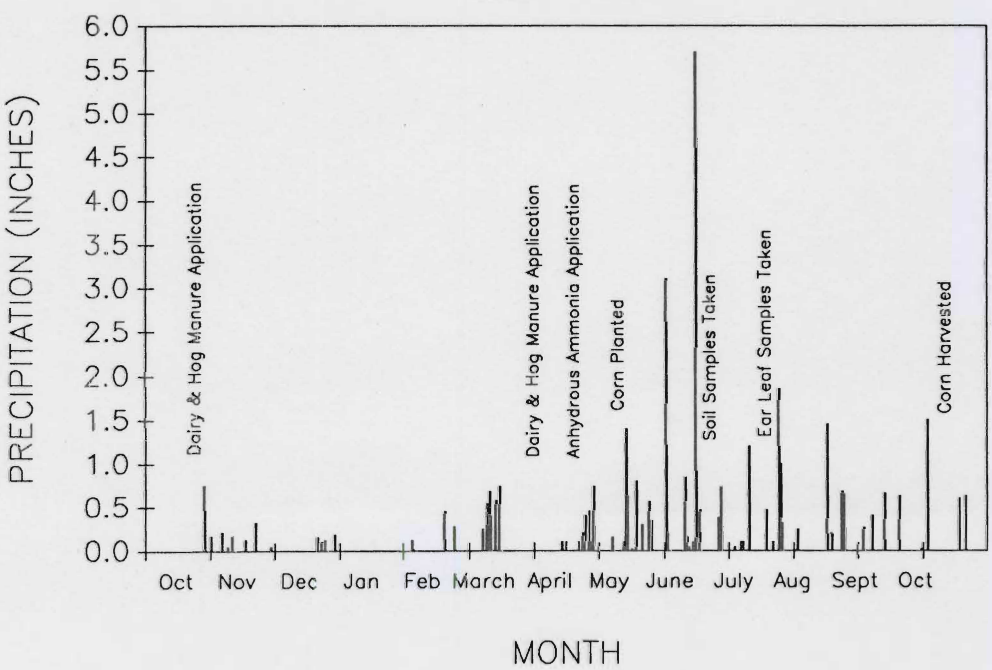
Table 9. The effect of time of manure application and tillage on grain N uptake (lbs/acre), Meeker County, MN, 10/15/90[1].

	Fall Applied		Spring Applied				
Depth	Pig	Dairy	Pig	Dairy	Anhyd.	Check	**Average**
Moldboard	94	94	84	91	102	76	**90**
Chisel	69	76	86	71	82	74	**76**
Average	81	85	85	81			
	83		83		92	75	

1. The p values for tillage, N source, and the tillage by N source interaction are: .019, .344, and .383 respectively.

Nitrogen uptake by grain (which usually accounts for 2/3 of the total plant uptake) are shown in table 9. Final N uptake data show that fall and spring applied manure resulted in the same nitrogen uptake. There were very little losses from fall applied manure do to low rainfall during fall and spring period. Moldboard plowing to incorporate the fall applied manure showed a small advantage over chisel plowing. These data follow yield response trends as well as other soil and plant N diagnostic measurements.

Figure 1.
MEEKER COUNTY, ECKER FARM PRECIPITATION
1989–1990



Tillage effects on soybean response to residual effects of manure in Stearns County, MN[1]

J.F. Moncrief, M.B. Kells, and J.J. Kuznia[2]

Conservation tillage reduced the early growth of soybeans in 1990. As tillage was reduced early growth was also reduced. Differences in early growth were not correlated with soil cover in the row area or final grain yields. Plant tissue N was less at 10% bloom with chisel plowing than other tillage systems. Chisel plowing also resulted in a yield reduction over moldboard plowing with other systems being intermediate. Manure application in 1989 resulted in higher N concentrations in plant tissue at 10% bloom. Nitrogen concentrations in grain were similar for all treatments.

Manure was applied at the Stearns county site in the spring of 1989 following soybeans and preceding corn. The soil test P and K at this site is 53 and 223 lbs/acre respectively. Although the manure pack-barnyard source of manure was applied at a similar rate as the fresh barn gutter source the water content was about one half. Most of the nitrogen was in the organic form which means it will require bacterial breakdown before being available to corn and provide more residual nitrogen for succeeding crops.

Methods and Materials

Two manure sources were evaluated for ability to provide nitrogen for corn in 1989 and residual N, P, and K for soybeans in 1990: fresh manure from barn gutters and a manure pack around a hay rack in the barnyard. In the corn year (1989) 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 in 1989 prior to chisel plowing but following moldboard plowing. A treatment summary is presented 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 similarly estimated by tallying the number of plants in ten feet of row at each monitoring site.

Soybean trifoliate samples were taken at 10% bloom (July 25) and analyzed for nitrogen.

Grain yields were estimated by combining two rows of soybeans 300 feet long and weighing to the nearest 5 pounds with a weigh wagon. Subsamples were taken for moisture determination and nitrogen analysis.

Results and Discussion

Soil cover by corn residue and soybean stands are shown in table 2. Even with the relatively modest corn yields the year before there is more than fifty percent soil cover by crop residue with only the tillage associated with the no till drill. There is adequate soil cover for erosion control with all the conservation tillage systems. All the soybean stands are high enough not to be yield limiting (table 3). The ridge till stand is lower because it was established with a ridge till planter.

The effects of tillage and manure on soybean early growth are also shown in table 3. Tillage effects on early growth were not very well correlated to soil cover in the row. This suggests that the soil temperature reduction associated with crop residues over the row area was not responsible for differences in early

[1] *Support for this project was provided by the Agricultural Utilization and Research Institute, the Central Minnesota Initiative Fund, the Soil Conservation Service, the Clearwater River Watershed District, and the Minnesota Extension Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.B. Kells is the Tri-County Project coordinator.*

growth. As tillage decreased early growth also decreased. Tillage effects on early growth of soybeans is very rarely correlated with yields. There was no effect of manure application in 1989 on early growth of soybeans in 1990.

One objective of this study was to evaluate residual nitrogen from manure on response by soybeans in the year after application. Very striking visual symptoms of what appeared to be nitrogen stress in unmanured plots were observed in July but had become less apparent in August. Plant tissue levels of nitrogen on July 25, 1990 are shown in table 4. There was a trend for a higher level of tissue nitrogen in manured plots which apparently did not interact with tillage. Soybeans grown with chisel plowing however had lower N concentrations than the other tillage systems tested.

Yields are given in table 5 and were quite high for this soil. Tillage system affected soybean yields. Yields were somewhat consistent with tissue nitrogen concentrations in that chisel plowing resulted in a 3.4 bushel per acre reduction in yield. Also, manure in 1989 increased yields 2.4 bushels per acre.

Protein concentration in grain (also nitrogen) was not affected by tillage or previous manure application (table 7).

STEARNS COUNTY

Table 1. Cultural practices at Stearns County, MN. 1990.

Tillage

No Till
Ridge Till
Spring Chisel Plowed and tandem disced twice
Spring Moldboard Plowed and tandem disced twice
Cultivated on July 5, 1990, and
ridges formed on July 17, 1990.

Cropping History

1981-red clover and oats, 1982-corn, 1983-soybeans, 1984-corn, 1985-corn, 1986-soybeans, 1987-corn, 1988-Soybeans 1989-corn

1990 Crop Soybeans-Pioneer 9161

Planting and Harvest Dates

Ridge till plots were planted with a four row Buffalo Till planter equipped with 12" sweeps at a 36 inch row spacing. Other tillage treatments were planted with a Tye no till drill with 8 inch row spacing equipped with 2 inch fluted coulters ahead of the double disc openers.

	Planting		
Crop	Date	Rate	Harvested
Soybeans	May 29, 1990	225,000 seeds/A	October 11, 1990

Fertilization History 1981-1987

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 lb/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	----	lb/A	----	Date Applied
Soybeans	9-18-9[1]	4 gal/A	Ridge Till	4	8	4	May 16, 1986
	0-0-60[2]	90 lb/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 and Manure Analysis

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			----	lb/A	----	
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.

Analysis and rate of application of manure.

Manure Source	Date Applied	NH_4	NO_3	Mineral	Organic	Total N	Total P	Total K	Manure Density	Manure Rate	Solids Total	Solids Volatile	Solids Fixed
		-------------------			%			-------------------	lb/ft[3]	T/A	--------	%	---------
Barn Gutter[1]	4/13/89	.260	.012	.272	.264	.536	.109	.424	64.8	16.4	27.66	45.96	54.04
Barnyard[2]	4/25/89	.050	.003	.053	.639	.692	.204	.377	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, available and value[1] of nitrogen[2], phosphorus, and potassium.

Source	Mineral	Organic	Nitrogen	$	Available Nitrogen 1989	Available Nitrogen 1990	P_2O_5	$	K_2O	$
	-- Applied	N lb/acre	---		------ lb/A	------	lb/A		lb/A	
Barn Gutter	89	87	176	17.60	111	11	82	16.40	167	16.70
Barnyard	16	192	208	20.80	64	24	140	28.00	136	13.60

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively.
2. It is assumed that all of the mineral N and 25% of the organic N will be available during the year of application.

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 - 1.5 pt/A (0.281 lb/A) Poast + 2 pt/A (1.0 lb/A) Basagran applied on June 25, 1990.

Table 2. Effect of tillage and row position on corn residue in soybeans at Stearns Co. on May 30, 1990.

Location	Tillage NoTill	Tillage Ridge	Tillage Chisel	Tillage Mldbd	Avg.
	---------	% cover	----------		
In Row	36.8a	6.3c	14.5b	3.0c	15.1b
Between Row	56.3a	39.0b	24.8c	3.3d	30.8a
Average	46.5a	22.6b	19.6b	3.1c	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=64), .001 (n=32), and .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 manure applied in 1989 on population (5/30/90) and early growth (7/12/90) of soybeans at Stearns Co[1].

Manure 1989	Tillage Ridge[2]	Tillage Chisel	Tillage Mldbd	Avg.
	---- plants/A X 10^{-3}		----	
Manure	160.3	172.3	177.6	175.0a
No Manure	158.4	183.0	192.8	187.9a
Average	159.4	177.6a	185.2a	
Manure 1989	------ nodes/plant		------	
Manure	5.2	5.7	5.5	5.5a
No Manure	5.1	5.6	5.9	5.5a
Average	5.1b	5.7a	5.7a	

1. The p value for manure, tillage, and tillage by manure interaction for population are .207 (n=32), .444 (n=32), and .824 (n=16). The p value for manure, tillage, and tillage by manure interaction for growth stage are .554 (n=240), .072 (n=160), and .325 (n=80) respectively. 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 4. Effect of tillage and manure applied in 1989 on % N in trifoliate leaf tissue at Stearns Co. on July 25, 1990[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Manure 1989	----------	% N	----------	Avg.
Manure	5.97	5.63	5.91	5.84a
No Manure	5.89	5.55	5.79	5.74a
Average	5.93a	5.59b	5.85a	

1. The p value for manure, tillage, and tillage by manure interaction are .195 (n=12), .002 (n=8), and .962 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage and manure applied in 1989 on soybean yield and moisture at Stearns Co. on October 10 & 15, 1990[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Manure 1989	----------	bu/A	---------	Avg.
Manure	43.6	39.6	45.7	43.0a
No Manure	40.0	37.6	44.3	40.6a
Average	41.8ab	38.6b	45.0a	
Manure 1989	-----------	%	-----------	
Manure	8.6	8.8	9.0	8.8a
No Manure	8.6	8.8	8.9	8.8a
Average	8.6a	8.8a	9.0a	

1. The p value for manure, tillage, and tillage by manure interaction for yield are .123 (n=12), .070 (n=8), and .802 (n=4) respectively. The p value for manure, tillage, and tillage by manure interaction are .695 (n=12), .431 (n=8), and .981 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage and manure applied in 1989 on soybean protein at Stearns Co. 1990[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Manure 1989	-----------	%	-----------	Avg.
Manure	45.2	44.2	43.8	44.4a
No Manure	45.1	44.9	44.2	44.7a
Average	45.2a	44.5ab	44.0a	

1. The p value for manure, tillage, and tillage by manure interaction are .065 (n=12), .073 (n=8), and .198 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage on % N in trifoliate leaf tissue, early growth, population, protein content, yield and moisture of soybeans with **no manure** applied.

	Tillage				
	No Till	Ridge	Chisel	Mldbd	
	-------	plants/A X 10^{-3}		-----	Sig.
Population	267.5a	160.4[1]	183.0b	192.8b	.001
	---------	nodes/plant		-------	
Early Growth	4.9c	5.1c	5.6b	5.9a	.001
	--------------	% N		----------	
Leaf N	5.77a	5.89a	5.55b	5.79a	.056
	------------	bu/A		-----------	
Yield	42.7ab	40.0ab	37.6b	44.3a	.198
	--------------	%		------------	
Moisture	8.3b	8.6ab	8.8ab	8.9a	.205
	--------------	%		------------	
Protein	44.1a	45.1a	44.9a	44.2a	.229

Tillage effects on corn growth, stand establishment, and yield, Isanti County, MN[1]

J.F. Moncrief, S. D. Grosland, and J.J. Kuznia[2]

Corn residue levels in the row higher than 20% resulted in a corn growth delay of 1 leaf and 3% higher grain moisture. At these levels yields were reduced more than 30 bushels per acre. The yield reduction was due to stand loss and delayed development. Corn grain response to plant population was linear from 18 to 31 thousand plants per acre. Planter applied P resulted in an average grain yield increase of 16 bushels per acre at a high soil test.

This is the fourth year of a study that evaluates conservation tillage on corn growth and yield in a continuous corn cropping sequence. Also being evaluated at this site are corn population and planter applied P effects on corn yield.

The cultural practices at this site are shown in table 1. Soil cover by crop residue and the corn response to tillage are shown in table 2. Clearing discs were evaluated on the no till plots. Soil cover by crop residue was 20% or less with all but the no till system. Cover in the row was reduced from 82% to 52% with planter mounted clearing discs under no till conditions. The high level of soil cover in the row with this treatment resulted in decreased early growth, plant stands, grain moisture and yields. Soil cover by corn residue must be less than 20% to minimize any detrimental effects on corn growth.

The corn grain response to plant population appeared to be linear from about 18 to 30 thousand plants per acre (table 4).

At a high and very high soil test P level there was a 22 and 10 bushels per acre grain yield response respectively (table 6).

ISANTI COUNTY

Table 1. Cultural practices of conservation tillage plot on corn at Isanti County, MN. 1990.

Tillage

No Till
Spring Disc
Spring Chisel and tandem disced twice
Spring Moldboard and tandem disced twice
Spring tillage was done on May 6, 1990.

Cropping History

1986-Soybeans, 1987-Corn Pioneer 3790,
1988-Corn Pioneer 3772, 1989-Corn Pioneer 3751

1990 Crop

Corn Pioneer 3788

Planting and harvest information

A six row John Deere 7000 planter with 30 inch row spacing and equipped with 2 inch fluted coulters, disc row cleaners, and Yetter coulters for fertilizer.

Crop	Date	Rate	Harvested
Corn	May 6, 1987	27,200 seeds/A	Oct. 6, 1987
Corn	May 3, 1988	28,500 seeds/A	Oct. 14, 1988
Corn	May 3, 1989	29,000 seeds/A	Oct. 26, 1989
Corn	**May 7, 1990**	**29,600 seeds/A.**	**Nov. 13, 1990**

Fertilizer 1987

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Mg	Date Applied
		------ lb/A				------	
Corn	12-14-26-4-3[1] (277 lb/A)	33	39	72	11	8	May 6, 1987
	82-0-0 (146 lb/A)	120	0	0	0	0	June 5, 1987

1. Planter applied 2" beside and 2" below seed.

[1] *Support for this project was provided by the Soil Conservation Service and the Minnesota Extension Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. S. D. Grosland is the County Agricultural Agent in Isanti County, MN.*

Fertilizer 1988

Crop	Material Analysis (rate)	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Actual Mg	Date Applied
		------	lb/A	------			
Corn	12-14-26-4-3[1] (277 lb/A)	33	39	72	11	8	May 3, 1988
	82-0-0 (220 lb/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	Actual P_2O_5	Actual K_2O	Actual S	Actual Mg	Date Applied
		------	lb/A	------			
Corn	12-14-26-4-3[1] (277 lb/A)	33	39	72	11	8	May 3, 1989
	82-0-0 (146 lb/A)	120	0	0	0	0	June 5, 1989

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1990

Crop	Material Analysis (rate)	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		----	lb/A	-----		
Corn	12-14-27-4[1] (250 lb/A)	30	35	68	10	May 7, 1990
	82-0-0 (146 lb/A)	120	0	0	0	June 25, 1990

1. Planter applied 2" beside and 2" below seed.

1987 Soil Test

Organic Matter	pH	Bray 1 Phosphorus	Potassium	Sulfur	Zinc
		------- lb/A	--------	---- ppm	---
Medium	7.0	115	238	15	1.1

Soil

The soil at this site is a Ames fine sandy loam (Typic Albaqualfs, fine, montmorillonitic, mesic), 0 to 2 percent slope and is moderate to slowly drained.

Weed Control

1 pt/A (1.0 lb/A) Dual + 1 lb/A (0.9 lb/A) Bladex 90DF + 1 lb/A (0.9 lb/A) Atrazine 90DF on May 10, 1990.

Table 2. Effect of tillage on residue, stand, early growth, harvest stand, grain yield, and grain moisture at Isanti Co., 1990[1].

Tillage	Residue 6/20/90 In Row	Residue 6/20/90 Between Row	Residue 6/20/90 Avg.	6/20/90 Early Growth	6/20/90 Population	11/13/90 Harvest Population	Grain 11/13/90 Yield	Grain 11/13/90 Moisture
	-----------	%	-----------	leaves	plants/A	plants/A	bu/A	--- % --
No till w/o row cleaner	81.5	84.3	82.9a	2.3d	17,200c	18,900b	84.4c	25.3a
No till w/ row cleaner	51.5	72.5	62.0b	2.7c	22,900b	19,800b	105.4b	24.0b
Disk	20.3	21.8	21.0c	3.4b	27,700a	26,500a	137.0a	22.5c
Chisel	17.0	19.3	18.1c	3.4b	26,100a	24,900a	138.2a	22.1cd
Moldboard	7.8	7.5	7.6d	3.6a	26,600a	27,000a	136.4a	21.7d
Average	35.6b	41.1a						
Signif. (Pr > F)	0.003		0.001	0.001	0.001	0.001	0.001	0.001
			n=32	n=80	n=8	n=8	n=4	n=4

1. Means within the same group with the same letter are not significantly different (α=.10).

Table 3. Cultural practices of population plot on corn at Isanti County, MN. 1990.

Tillage

Spring Chisel and tandem disced twice
Spring tillage was done on May 6, 1990.

Cropping History

1986-Soybeans, 1987-Corn Pioneer 3790,
1988-Corn Pioneer 3772, 1989-Corn Pioneer 3751

1990 Crop

Corn Pioneer 3788

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	Harvested
Corn	May 6, 1987	Oct. 6, 1987
Corn	May 3, 1988	Oct. 14, 1988
Corn	May 3, 1989	Oct. 26, 1989
Corn	**May 7, 1990**	**Nov. 13, 1990**

Fertilizer 1987

Crop	Material Analysis (rate)	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Actual Mg	Date Applied
		------	lb/A	------			
Corn	12-14-26-4-3[1] (277 lb/A)	33	39	72	11	8	May 6, 1987
	82-0-0 (146 lb/A)	120	0	0	0	0	June 5, 1987

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1988

Crop	Material Analysis (rate)	N	P_2O_5	K_2O	S	Mg	Date Applied
		------	lb/A	------			
Corn	12-14-26-4-3[1] (277 lb/A)	33	39	72	11	8	May 3, 1988
	82-0-0 (220 lb/A)	180	0	0	0	0	June 3, 1988

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1989

Crop	Material Analysis (rate)	N	P_2O_5	K_2O	S	Mg	Date Applied
		------	lb/A	------			
Corn	12-14-26-4-3[1] (277 lb/A)	33	39	72	11	8	May 3, 1989
	82-0-0 (146 lb/A)	120	0	0	0	0	June 5, 1989

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1990

Crop	Material Analysis (rate)	N	P_2O_5	K_2O	S	Date Applied
		----	lb/A	-----		
Corn	12-14-27-4[1] (250 lb/A)	30	35	68	10	May 7, 1990
	82-0-0 (146 lb/A)	120	0	0	0	June 25, 1990

1. Planter applied 2" beside and 2" below seed.

Soil

The soil at this site is a Ames fine sandy loam (Typic Albaqualfs, fine, montmorillonitic, mesic), 0 to 2 percent slope and is moderate to slowly drained.

Weed Control

1 pt/A (1.0 lb/A) Dual + 1 lb/A (0.9 lb/A) Bladex 90DF + 1 lb/A (0.9 lb/A) Atrazine 90DF on May 10, 1990.

Table 4. Effect of seed population on early plant stand grain yield, grain moisture, test weight, and harvest plant stand at Isanti Co., 1990[1].

Sprocket Setting	6/20/90 Population	11/13/90 Population	Average Population	11/13/90 Grain Yield	11/13/90 Grain Moisture	11/13/90 Grain Test Wt.
Seeds/A	plants/A	plants/A	plants/A	bu/A	-- % ---	lb/bu
19,600	18,000	17,600d	17,800	117.6c	24.8d	51.0a
21,780	19,200	19,600cd	19,400	122.9bc	25.7c	51.0a
24,500	19,600	21,000c	20,300	123.9bc	27.2a	51.0a
26,300	23,100	23,700b	23,400	129.4b	26.1bc	51.0a
28,400	24,800	25,900b	25,400	129.4b	26.7ab	51.0a
29,600	27,900	26,000b	27,000	128.4b	26.7ab	51.0a
32,980	30,100	29,600a	29,900	138.0a	27.2a	51.0a
34,300	31,800	30,000a	30,900	145.1a	26.4abc	51.0a
	n=4	n=2		n=2	n=2	n=2
Signif.(Pr > F)		0.001		0.005	0.009	0.0

1. Means within the same column with the same letter are not significantly different (α=.10).

Table 5. Cultural practices of planter applied P plot on corn at Isanti County, MN. 1990.

Tillage

Spring Disced on twice on May 6, 1990.

1990 Crop

Corn Pioneer 3790

Planting and harvest information

A six row John Deere 7000 planter with 30 inch row spacing and equipped with 2 inch fluted coulters, and Yetter coulters for fertilizer.

Crop	Planting Date	Planting Rate	Harvested
Corn	May 8, 1990	29,600 seeds/A	Nov. 16, 1990

Cropping History

1985-Soybeans then continued with a corn soybean rotation.

1990 Soil Test

Soil Type	Organic Matter	pH	Bray 1 Phosphorus	Potassium
			-------- lb/A	---------
Hayden	Low	6.4	140	236
Bluffton	High	6.5	60	184

Fertilizer 1990

Soil Type	Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Date Applied
			---- lb/A -----				
Hayden	Corn	12-14-27-4[1] (250 lb/A)	30	35	68	10	May 8, 1990
		12-0-35-4[1] (250 lb/A)	30	0	88	10	May 8, 1990
		82-0-0 (146 lb/A)	120	0	0	0	June 25, 1990
Bluffton	Corn	12-14-27-4[1] (250 lb/A)	30	35	68	10	May 8, 1990
		12-0-35-4[1] (250 lb/A)	30	0	88	10	May 8, 1990
		82-0-0 (146 lb/A)	120	0	0	0	June 25, 1990

1. Plots split with starter on each soil type, planter applied 2" beside and 2" below seed.

Soil

Hayden silt loam (Typic Hapludalfs, fine-loamy, mixed, mesic), 2 to 7 percent slope and its surface drainage is medium but internal drainage is somewhat restricted.

Bluffton loam and silty clay loam (Typic Haplaquolls, fine-loamy, mixed, frigid), drainage is poor.

Weed Control

2 qt/A (3.35 lb/A) Eradicane + 1 lb/A (0.9 lb/A) Bladex 90DF + 1 lb/A (0.9 lb/A) Atrazine 90DF on May 10, 1990.

Table 6. Effect of phosphorus in starter fertilizer on corn grain yield (n=3), moisture (n=3), and test weight (n=3) at Isanti Co. on November 16, 1990[1].

	Soil Type					
	Hayden			Bluffton		
Starter	Yield	Moisture	Test Wt	Yield	Moisture	Test Wt
	bu/A	--- % --	lb/bu	bu/A	--- % --	lb/bu
30-00-87-11	145.1b	22.5a	54.2b	122.1b	26.8a	52.5b
30-35-69-11	155.8a	21.6a	55.5a	145.4a	24.3a	54.0a
Signif. (Pr > F)	0.080	0.210	0.015	0.066	0.222	0.001

1. Means within the same column with the same letter are not significantly different (α=.10).

Tillage effects on continuous corn in Dodge County, MN[1]

J.F. Moncrief, T.L. Wagar, and J.J. Kuznia[2]

This is the 5th year of a study evaluating tillage system (main plots) with deep tillage (subplots). There was no affect of deep tillage or primary tillage on grain yields.

This study was established in 1986. Main plots are tillage with deep chiseling subplots with a continuous corn rotation. In previous years there has been a consistent advantage to deep tillage independent of other tillage. In 1990 there was neither a significant effect of tillage or deep tillage. Although there was no effect of tillage on grain yields it did affect grain moisture however. A 1.5 percent reduction in grain moisture with conservation tillage options suggests delayed corn development.

DODGE COUNTY

Table 1. Cultural practices at Dodge County, MN. 1990.

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 was done prior to planting.

All plots were rotary hoed on June 9, 1990, cultivated once on June 25, 1990, and ridges formed on July 16, 1990.

Preceding Crop
1985-1989 Corn

1990 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 29, 1990	28,000 seeds/A	October 12, 1990

Fertilization History

			Actual				
	Material		N	P_2O_5	K_2O		
Crop	Analysis	Rate	---	lb/A	---	Date Applied	Method of Application
Corn:	46-0-0	370 lb/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 lb/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
Corn:	82-0-0	220 lb/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

1990 Fertilizer

			Actual				
	Material		N	P_2O_5	K_2O		
Crop	Analysis	Rate	---	lb/A	---	Date Applied	Method of Application
Corn:	82-0-0	213 lb/A	175	0	0	April 16, 1990	Injected
	7-21-7	6 gal/A	5	14	5	May 29, 1990	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.

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[1] *Support for this project was provided by the Soil Conservation Service and the Minnesota Extension Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. T.L. Wagar is the Southeast Area Crops and Soils Agent at Rochester, MN.*

Weed Control

2 pt/A (2.0 lb/A) Dual + 2.2 lb/A (2.0 lb/A) Bladex 90 DF applied preemergence on May 30, 1990.

Insecticide Control

8 lb/A (1.2 lb/A) Force 15G at time of planting.

Table 2. Effect of tillage and deep chiseling on corn yield, moisture and protein at Dodge Co. on October 12, 1990[1].

	Tillage				
	Moldboard	Ridge Till	Disc	Chisel	
	bu/A				Avg.
Deep Chisel	119	125	129	118	123a
No Deep Chisel	126	125	125	119	124a
Average	122a	125a	127a	119a	
	% moisture				
Deep Chisel	30.4	31.5	31.3	31.3	31.1a
No Deep Chisel	29.9	31.4	31.7	31.9	31.2a
Average	30.1a	31.4b	31.5b	31.6b	
	% protein				
Deep Chisel	8.4	8.7	9.1	8.4	8.7a
No Deep Chisel	8.4	8.6	8.9	8.4	8.6a
Average	8.4b	8.6b	9.0a	8.4b	

1. The p value for deep chisel, tillage, and tillage by deep chisel interaction for yield are 0.671 (n=12), 0.578 (n=6), and 0.595 (n=3) respectively. The p value for deep chisel, tillage, and tillage by deep chisel interaction for moisture are 0.801 (n=12), 0.070 (n=6), and 0.209 (n=3) respectively. The p value for deep chisel, tillage, and tillage by deep chisel interaction for grain protein are 0.158 (n=12), 0.032 (n=6), and 0.574 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

CONSERVATION TILLAGE, AND CORN AND SOYBEAN PRODUCTION IN THE CLEARWATER RIVER WATERSHED:[1] A FOUR YEAR SUMMARY

J.F. Moncrief, J.J. Kuznia, M.B. Kells, and B.A. Kjeldahl[2]

This project evaluates conservation tillage for corn and soybean production in the Clearwater River Watershed which occupies the contiguous corners of Meeker, Stearns, and Wright Counties. Generally corn and soybean early growth was affected by tillage but did not show consistent yield responses. Conservation tillage systems were generally more profitable than moldboard plowing systems.

PROJECT BACKGROUND

In recent years there has been concern for the water quality in the Clearwater River Chain of Lakes due to entry of phosphorus from various sources. There has been direct discharge of effluent either from lake shore owners or industry that has contributed. Also phosphorus has entered the lakes from eroded stream banks from some soils in the watershed that are natively high in phosphorus. There has also been entry of phosphorus from agricultural sources due largely to erosion. Phosphorus from agricultural activities that enters water bodies is usually associated with the sediment that is carried off fields during heavy rainfall. Most will agree that the solution to this problem is at the source. In the case of the agricultural contribution erosion control in conjunction with banded phosphorus applications is the obvious answer. Phosphorus is applied below the surface and erosion is controlled with crop residue.

Most will also agree that the most cost effective method of controlling erosion is by crop residue management with conservation tillage. In an effort to evaluate conservation tillage options under the specific conditions of the watershed, plots were established in Stearns and Wright counties in the spring of 1986 and in Meeker county in the fall of 1986. Corn and soybeans were grown at Meeker and Wright counties every year and alternated at the Stearns county site. The tillage systems being evaluated are: moldboard and chisel plowing, ridge till, and no till. Soybeans were planted with a no till drill in all treatments except the ridge till.

An evaluation of tillage effects on corn and soybean yields, as well as an economic summary for the history of the project will be presented.

BANDED PHOSPHORUS APPLICATION

The effect of phosphorus placement on corn grain yields is shown in table 1. In 1988 at the Meeker county site a comparison between broadcast and planter applied P was made. In other years the comparison was between planter applied P (also small amounts of N and K) and no fertilizer. On average there was a five bushel per acre advantage to planter applied fertilizer. The soil test P ranged from 24 to 53 pounds per acre. This is in the medium to high level. The motivation for applying fertilizer P with the planter is the likelihood of getting a corn response even with relatively high background soil test levels. This is largely due to minimizing soil "tie up" because fertilizer is being mixed with a smaller volume of soil. In some cases the yield response interacted with tillage while others did not. Since starter-tillage interactions were not consistent averages over tillage systems are presented.

The average row fertilizer response is valued at $11.50 per acre at $2.20 per bushel. Phosphorus rates varied from 5 to 36 pounds per acre. Most of the row P corn grain response is obtained with a relatively low rate. The P value at the rates used ranged from $1.10 to $7.90 per acre.

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[1] *Data collection was assisted by many local people with the Soil Conservation Service, the Soil and Water Conservation Districts, and the Minnesota Extension Service. This project would not have been possible without their assistance. Also thanks to Richard Echman, Richard Kuechle, and Lyndon Johnson, farmer-cooperators, for their valuable assistance and advice. Financial support was provided by the Central Minnesota Initiative Fund, and the Minnesota Pollution Control Agency, and the Soil Conservation Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department, University of Minnesota. M.B. Kells is the Tri County Conservation Project Coordinator, Waite Park, MN. B.A. Kjeldahl is an Undergraduate Research Assistant at the University of Minnesota.*

Table 1. Corn response to row applied fertilizer at planting.

Year	No Row phosphorus	Row phosphorus
	----------- bu/acre	-----------
1988	40	45[1]
1989	107	106[1]
1990	128	133[1]
1987	81	91[2]
1990	107	114[3]
Average	93	98

1. Meeker county data that in 1988 compares 76 and 36 lbs P_2O_5 per acre broadcast and row applied with the planter respectively, in 1989 and 1990 35 and 42 lbs P_2O_5 per acre respectively row applied with the planter was compared to no P applied. The soil test P is 25 pounds per acre.
2. Stearns county data compares 5 or 9 lbs P_2O_5 per acre row applied with the planter to no P. The soil test P is 53 pounds per acre.
3. Wright county data compares 20 lbs P_2O_5 per acre to no P. The soil test P is 24 pounds per acre.

GROWTH AND YIELD

MEEKER COUNTY

Soil Cover by Soybean Residue,
Corn Growth, Stand Establishment,
Grain Moisture, and Yield

Soil cover by soybean residue is shown in table 2. There is adequate soil cover to control erosion with the no till and ridge till systems although it was marginal in 1987. The soil cover between the row needs to be close to 30% to provide adequate erosion control. Soil cover in the row area is higher than desirable to minimize detrimental influences on corn growth under no till conditions. Corn growth is delayed when the soil cover by crop residue in the row is higher than 20% (table 3). In 1987 soil moisture dominated the early growth of corn. The conservation tillage systems resulted in quicker emergence and early growth due to higher levels of soil moisture. The soil was very cloddy under moldboard plowing in this year. On average corn grown with ridge tillage and chisel plowing was similar to that of moldboard plowing. No till grown corn was .25 leaves delayed in growth over the other systems.
Stand was only affected in one year at this site (1987-table 4). Due to cloddy conditions there was a stand loss with moldboard plowing. Average stands were within 700 plants per acre. Stand differences would not be expected to affect yield.

Grain moisture was only affected by tillage one year at this site (1990-table 5). Average grain moisture varied .7% between tillage systems.

Corn yields were affected by tillage in 1990 only (table 6). In this year it was very cool in the early season. It is possible that the delayed growth associated with the no till system was responsible for the 10 bushels per acre yield decline with this system. The yield loss with the ridge till system is likely due to stand loss at cultivation that was not reflected in the stand measurements. Average yields were within five bushels per acre between tillage systems.

Table 2. The effect of tillage on soil cover by soybean residue at Meeker County, MN (p value <.001 for all years).

	IN-ROW COVER					BETWEEN-ROW COVER				
	1987	1988	1989	1990	Ave.	1987	1988	1989	1990	Ave.
					%					
No till	29.0	66.8	13.3	30.0	34.8	24.0	59.5	66.9	58.5	52.2
Ridge	20.0	20.8	6.4	12.3	14.9	22.0	36.8	47.9	33.0	34.9
Chisel	10.0	18.8	5.8	20.0	13.7	10.0	14.8	10.9	21.8	14.4
Moldboard	3.0	0.8	2.0	3.5	2.3	2.0	1.5	2.4	6.0	3.0
Date	5/27	6/14	5/11	6/12		5/27	6/14	5/11	6/12	

Table 3. The effect of tillage on early corn growth, Meeker County, MN.

	1987	1988	1989	1990	Ave.
	-------- leaves/plant -----------				
No till	3.31	6.88	1.45	2.55	3.55
Ridge	3.76	7.47	1.71	2.69	3.91
Chisel	3.25	7.41	2.02	2.61	3.82
Moldboard	3.00	7.54	2.06	2.61	3.80
p value	.001	.007	.004	.097	
Date	5/27	6/14	6/2	6/12	

Table 4. The effect of tillage on corn stand at Meeker County, MN.

	1987	1988	1989	1990	Ave.
	--------- plants/acre -----------				
No till	37.4	30.5	29.0	29.0	31.5
Ridge	37.7	31.6	29.2	29.7	32.1
Chisel	36.6	31.4	29.7	30.1	32.0
Moldboard	34.3	32.6	29.9	28.6	31.4
p value	.092	.647	.631	.351	
Date	5/27	6/14	6/2	6/12	

Table 5 Effect of tillage on corn grain moisture, Meeker County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	------------ % -------------				
1987	21.2	21.5	20.6	19.9	.311
1988	29.9	27.7	27.4	25.5	.680
1989	21.2	21.0	22.1	21.3	.442
1990	22.8	22.1	23.0	25.5	.001
Avg.	23.8	23.1	23.3	23.1	

Table 6. Effect of tillage on corn yield following soybeans, Meeker County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	--------- bu/acre ----------				
1987	189	187	179	189	.176
1988	46	40	49	43	.179
1989	103	113	103	108	.333
1990	136	134	125	124	.055
Ave.	119	119	114	116	

Soil Cover by Corn Residue,
Soybean Growth, Stand Establishment,
Grain Moisture, and Yield

Soil cover by corn residue is shown in table 7. There is adequate soil cover by corn residue in all conservation tillage systems. Tillage delayed development of soybeans a maximum of .38 nodes at this site (table 8). It did not affect yields however (table 9). This is consistent with other Minnesota data which show soybeans to be fairly insensitive to the effects of changes in soil physical properties associated with conservation tillage.

Table 7. The effect of tillage on soil cover by corn residue at Meeker County, MN (p value <.001 for all years).

	IN-ROW COVER					BETWEEN-ROW COVER				
	1987	1988	1989	1990	Ave.	1987	1988	1989	1990	Ave.
	---------------------------%---------------------------									
No till	45.0	73.5	52.6	56.6	56.9	43.0	58.8	61.6	55.5	54.7
Ridge	35.0	21.8	17.5	9.3	20.9	39.0	53.5	40.3	32.8	41.4
Chisel	35.0	33.3	22.8	30.2	30.3	29.0	23.3	25.1	35.0	28.1
Moldboard	8.0	10.5	4.8	4.3	6.9	7.0	9.8	4.4	4.5	6.4
Date	5/27	6/16	5/22	5/30		5/27	6/16	5/22	5/30	

Table 8. The effect of tillage on early soybean growth, Meeker County, MN.

	1987	1988	1989	1990	Ave.
	--------- nodes/plant -----------				
No till	2.30	4.11	5.44	2.79	3.66
Ridge	2.40	3.95	5.28	2.90	3.63
Chisel	2.20	4.42	5.73	2.86	3.80
Moldboard	2.43	4.86	5.79	2.94	4.01
p value	.396	.016	.001	.060	
Date	5/27	6/16	7/6	6/12	

Table 9. Effect of tillage on soybean yield, Meeker County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	--------- bu/acre ----------				
1987	52.0	51.0	50.0	51.0	.896
1988	13.6	13.8	13.8	15.2	.367
1989	28.0	29.0	30.0	30.0	.452
1990	49.8	48.9	50.0	42.8	.482
Avg.	35.9	35.7	36.0	34.8	

WRIGHT COUNTY

Soil Cover by Soybean Residue,
Corn Growth, Stand Establishment,
Grain Moisture, and Yield

Tillage effects on soil cover by crop residue are shown in table 10. Soil cover was adequate for erosion control only one year with the chisel plowing system at this site. There was very little effect of crop residue on corn growth at this site. Soil cover in the row was low with all systems and early corn growth showed minimal response to tillage (table 11).

Stands were affected three years out of four. Tillage affects on stand were variable however and average stand values were similar and not expected to affect yield.

Grain moisture was never affected by tillage at this site. This is consistent with the lack of response by early corn to tillage.

Grain yields were affected the first year. This was due to lambsquarter in the ridge and no till plots. Plots were not sprayed with 2,4-D amine this year. Average yields were within six bushels per acre of the moldboard system.

Table 10. The effect of tillage on soil cover by soybean residue at Wright County, MN (p value <.001 for all years).

	IN-ROW COVER					BETWEEN-ROW COVER				
	1987	1988	1989	1990	Ave.	1987	1988	1989	1990	Ave.
	%									
No till	49.5	57.3	19.0	55.8	45.4	78.2	93.5	49.5	71.3	73.1
Ridge	7.2	7.8	2.3	1.8	4.8	31.2	32.0	21.8	9.7	23.7
Chisel	14.5	22.3	3.8	3.0	10.9	19.7	29.5	9.3	6.0	16.1
Moldboard	1.7	4.5	0.3	0.3	1.7	2.5	6.0	0.8	4.3	3.4
Date	6/1	5/12	5/11	6/12		6/1	5/12	5/11	6/12	

Table 11. The effect of tillage on early corn growth, Wright County, MN.

	1987	1988	1989	1990	Ave.
	leaves/plant				
No till	3.83	8.28	1.74	2.75	4.15
Ridge	4.26	8.06	2.03	2.93	4.32
Chisel	3.59	8.37	1.92	2.87	4.19
Moldboard	3.59	8.93	1.97	2.82	4.33
p value	.252	<.001	.001	.038	
Date	6/1	6/16	6/1	6/12	

Table 12. The effect of tillage on corn stand at Wright County, MN.

	1987	1988	1989	1990	Ave.
	plants/acre				
No till	27.1	31.3	31.5	31.2	30.3
Ridge	30.7	29.5	29.9	30.6	30.2
Chisel	28.3	29.3	32.0	30.2	30.0
Moldboard	27.4	28.9	30.2	28.2	28.7
p value	.046	.214	.066	.010	
Date	6/1	6/16	6/1	6/12	

Table 13. Effect of tillage on corn grain moisture, Wright County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	%				
1987	14.2	14.3	15.3	16.1	.136
1988	----	----	----	----	
1989	25.0	23.9	23.6	24.9	.653
1990	15.4	15.0	14.6	14.7	.364
Avg.	18.2	13.3	17.8	18.6	

Table 14. Effect of tillage on corn yield following soybeans, Wright County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	bu/acre				
1987	121	123	110	106	.034
1988	---	---	---	---	
1989	85	75	104	79	.203
1990	111	110	105	115	.720
Avg.	106	103	106	100	

Soil Cover by Corn Residue,
Soybean Growth, Stand Establishment,
Grain Moisture, and Yield

Soil cover by corn residue is shown in table 15. Cover was adequate for erosion control in most years with conservation tillage systems at this site. In 1988 there was a total crop failure due to the drought and subsequently very little residue in 1989.

As with the corn, the soybeans showed no consistent early growth response to tillage. Average early growth values showed about .1 and .2 nodes per plant reduction in growth for the chisel or ridge till and no till systems respectively.

There was a large reduction in soybean yields in the first year of the study. This is most likely due to a row spacing response. Ridge till soybeans were planted on 30" rows and all other systems on 7" row spacing. There was no affect of tillage on soybean yields the next three years. Average soybean yields were about 2 bushels per acre lower with the ridge till system.

Table 15. The effect of tillage on soil cover by corn residue at Wright County, MN (p value <.001 for all years).

	IN-ROW COVER					BETWEEN-ROW COVER				
	1987	1988	1989	1990	Ave.	1987	1988	1989	1990	Ave.
	%									
No till	61.0	43.8	34.3	54.3	48.4	60.0	57.0	45.5	64.5	56.8
Ridge	20.0	7.0	3.8	7.3	9.5	47.7	35.0	14.5	33.5	32.7
Chisel	44.0	24.0	10.8	17.5	24.2	46.7	23.8	9.4	22.3	25.6
Moldboard	5.7	7.8	3.6	5.3	5.6	5.5	7.8	3.4	7.5	6.1
Date	6/1	5/12	5/22	6/12		6/1	5/12	5/22	6/12	

Table 16. The effect of tillage on early soybean growth, Wright County, MN.

	1987	1988	1989	1990	Ave.
	nodes/plant				
No till	2.40	3.94	4.82	2.75	3.48
Ridge	2.40	4.29	4.53	2.93	3.54
Chisel	2.97	3.84	4.53	2.87	3.55
Moldboard	2.90	4.14	4.78	2.82	3.66
p value	.174	.042	.001	.038	
Date	6/1	6/16	7/5	6/12	

Table 17. Effect of tillage on soybean yield following corn, Wright County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	bu/acre				
1987	39.1	38.1	31.1	40.2	.004
1988	0.4	1.6	1.8	0.3	.306
1989	26.3	25.5	25.9	28.2	.455
1990	38.2	42.2	39.6	38.0	.443
Avg.	26.0	26.9	24.6	26.7	

STEARNS COUNTY

Soil Cover by Soybean Residue, Corn Growth, Stand Establishment, Grain Moisture, and Yield

There was adequate cover for erosion control by soybean residue with conservation tillage systems at this site in all but 1989 following the drought year of 1988 (table 18). Early growth of corn was reduced when soil cover by soybean residue exceeded 20% (table 19-only the no till treatment).

There was no affect of tillage on stand establishment (table 20). All systems resulted in about 20,000 plants per acre. Although corn development was delayed by .4 leaves per plant under no till conditions there was no measurable difference in grain moisture (table 21).

Corn yields were lower under a no till system in 1987. This was likely due to giant foxtail competition. In 1989 yields were higher with no tillage. On average yields were similar between tillage systems.

Table 18. The effect of tillage on soil cover by soybean residue at Stearns County, MN (p value <.001 for all years).

	IN-ROW COVER			BETWEEN-ROW COVER		
	1987	1989	Ave.	1987	1989	Ave.
	%					
No till	30.0	33.3	31.7	77.5	37.8	57.7
Ridge	16.7	3.3	10.0	61.7	36.8	49.3
Chisel	22.5	9.3	15.9	32.5	6.3	19.4
Moldboard	5.0	4.0	4.5	5.5	2.8	4.2
Date	5/29	6/1		5/29	6/1	

Table 19. The effect of tillage on early corn growth, Stearns County, MN.

	1987	1989	Ave.
	leaves/plant		
No till	3.88	1.65	2.77
Ridge	4.20	1.92	3.06
Chisel	4.30	1.96	3.13
Moldboard	4.35	2.00	3.18
p value	<.001	.001	
Date	5/29	6/1	

Table 20. The effect of tillage on corn stand at Stearns County, MN.

	1987	1989	Ave.
	--- plants/acre ----		
No till	19.1	20.7	19.9
Ridge	20.7	20.7	20.7
Chisel	20.1	21.1	20.6
Moldboard	20.6	20.8	20.7
p value	.417	.958	
Date	5/29	6/1	

Table 21. Effect of tillage on corn grain moisture, Stearns County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	------------ % -------------				
1987	18.9	19.0	20.1	19.7	.780
1989	19.7	20.0	19.0	19.5	.263
Avg.	19.3	19.5	19.6	19.6	

Table 22. Effect of tillage on corn yield following soybeans, Stearns County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	--------- bu/acre ----------				
1987	92	101	91	80	.002
1989	63	60	53	82	.108
Avg.	78	81	72	81	

Soil Cover by Corn Residue,
Soybean Growth, Stand Establishment,
Grain Moisture, and Yield

Soil cover by corn residue was only marginally adequate for erosion control with the chisel plowing system (table 23). Early soybean growth was positively correlated with soil cover in the row with corn residue (table 24). Growth was reduced by .3 and .9 nodes per plant with 20% and 54 per cover in the row with the ridge till and chisel plowing or no tillage respectively.

As with the Wright County site in 1987, yields were lower with the ridge till system in 1986. This was likely due to a row spacing response. Ridge tillage resulted in higher yields in 1988 although yields were extremely low. The chisel plowing system resulted in lower yields in 1990. In no year were grain yields correlated tillage effects on early growth. On average the chisel and ridge till systems resulted in a yield decline of 2 bushels per acre.

Table 23. The effect of tillage on soil cover by corn residue at Stearns County, MN (p value <.001 for all years).

	IN-ROW COVER				BETWEEN-ROW COVER			
	1986[1]	1988	1990	Ave.	1986[1]	1988	1990	Ave.
	------------------------------ % ------------------------------							
No till	26.8	72.0	36.8	54.4	20.3	73.8	56.3	65.1
Ridge	6.5	36.0	6.3	21.2	25.5	48.0	39.0	43.5
Chisel	16.5	25.0	14.5	19.8	17.5	22.0	24.8	23.4
Moldboard	3.0	5.3	3.1	4.2	4.0	2.5	3.3	2.9
Date	5/29	6/15	5/30		5/29	6/15	6/30	

1. This site was ridge tilled prior to this study. In 1986 ridges were disced to prepare for the no till treatment. This year is not included in the average values.

Table 24. The effect of tillage on early soybean growth, Stearns County, MN.

	1988	1990	Ave.
	---- nodes/plant -----		
No till	2.75	4.94	3.85
Ridge	3.44	5.11	4.28
Chisel	3.21	5.63	4.42
Moldboard	3.58	5.90	4.74
p value	<.001	<.001	
Date	6/16	7/12	

Table 25. Effect of tillage on soybean yield following corn, Stearns County, MN.

	Tillage				
	Mldbd	Chsl	Ridge	NoTil	Sig.
Year	--------- bu/acre ----------				
1986	40.9	39.8	36.4	40.6	.000
1988	1.6	0.9	4.0	1.5	.006
1990	44.2	37.6	40.0	42.7	.070
Avg.	28.9	26.1	26.8	28.3	

INPUTS, OUTPUT, AND TILLAGE SYSTEM

Crop production inputs that are affected by tillage system such as tractor costs, tillage implements, fuel, labor, and herbicides are tallied for each of the tillage systems being evaluated at each of the three sites.

This is weighed against the crop output generated by each system. Tillage affected grain yields at some sites in some years but was not consistent. Because of this, the average yield over all years of the demonstration for each tillage system at each site is used to estimate output.

MEEKER COUNTY

Conservation tillage methods for corn and soybean production in Meeker County showed higher profitability than moldboard plowing. No till corn had a 3 bushels per acre yield decrease. This decrease was made up for in lower variable costs. Herbicide costs were twice as high with the no till system, but this was compensated for with the reduction in machinery and fuel costs. The machinery and fuel categories were cut by about 1/3 from the moldboard system. Soybeans under the no till system had lower variable costs that more than made up the 1.1 bushels per acre decrease in yield. Machinery and fuel costs were cut by 80%, although herbicide costs rose by 300%.

Ridge tillage also showed a significant increase in profitability over moldboard plowing. Corn yields were 5 bushels lower with the ridge till system, but lower variable costs made up for that difference. Soybeans had a slight, 0.1 bushel yield increase with ridge till. The lower machinery and fuel costs with ridge till contributed to the increase in net profit in ridge till soybeans.

Chisel plowing showed a slight increase in profitability in Meeker County. Chisel and moldboard plowed systems resulted in similar corn yields. A slight decrease in variable costs was found in the chisel plowed system. These differences came from the machinery/fuel categories. Soybeans yields had very little variance, the chisel plowed system had a 0.2 bushel average yield decrease. The higher profitability again came from the savings in the machinery and fuel costs.

Table 26. Profitability of conservation tillage systems compared to a moldboard plowing system at Meeker County.

	No-till		Ridge till		Chisel		Moldboard	
	Corn	Soybean	Corn	Soybean	Corn	Soybean	Corn	Soybean
Bushels	116.0	34.8	114.0	36.0	119.0	35.7	119.0	35.9
Gross return	255.20	191.40	250.80	198.00	261.80	196.35	261.80	197.45
Variable costs-								
Machinery/labor	18.49	7.98	41.55	36.46	53.94	36.60	55.53	39.37
Fuel	1.50	1.40	3.30	2.80	6.00	4.90	6.50	5.40
Herbicides	26.96	33.47	14.63	11.70	13.74	11.39	13.74	11.39
Total costs	46.95	42.85	59.48	48.16	73.68	52.89	75.77	56.16
Return over variable costs	208.25	148.55	191.32	149.84	188.12	143.46	186.03	141.29
Comparison to moldboard system	+22.22	+7.26	+5.29	+8.55	+2.09	+2.17		
Corn/soy average	+14.74		+6.92		+2.13			

WRIGHT COUNTY

The demonstration in Wright County resulted in average net return for corn grain with the no till system less than for the moldboard system. The variable costs for corn were equal, but the no till showed a yield reduction of 5.7 bushels. This was due to competition by lambsquarter in the first year of the demonstration. No till corn had higher herbicide costs, but lower machinery costs than moldboard tillage, so the variable costs for corn were approximately even. Profitability of the no till soybeans was not reduced as much as corn. The yield of no till soybeans was 0.7 bushels higher, but the variable costs were also greater for no till. The herbicide costs were substantially higher with no till grown soybeans.

Ridge tillage showed an increase in average returns over moldboard. This was due to the increase in profitability of corn. The yield of ridge till corn was increased by 0.5 bushels per acre, but more importantly, the variable costs were reduced. Herbicide costs in corn and soybeans were equal for ridge till, chisel, and moldboard systems. The ridge till system showed a reduction in variable costs because of the lower machinery and fuel costs. Ridge till soybeans were not as profitable as the moldboard system. The variable costs were lower, but not enough to make up for the 1.4 bushel loss in yield.

Chisel plowing also showed a slight increase in profitability over moldboard plowing. Corn was less profitable, because of lower yields. The variable costs were lower in the machinery and fuel categories, but not enough to make up for the 3 bushel yield reduction. Soybeans were more profitable under the chisel plowing system. This is due to the increased yield and lower variable costs, again due to lower machinery and fuel costs.

Table 27. Profitability of conservation tillage systems compared to a moldboard plowing system at Wright County.

	No-till		Ridge till		Chisel		Moldboard	
	Corn	Soybean	Corn	Soybean	Corn	Soybean	Corn	Soybean
Bushels	100.0	26.7	106.3	24.6	102.7	26.9	105.7	26.0
Gross return	220.00	146.85	233.86	135.30	225.94	147.95	232.54	143.00
Variable costs-								
Machinery/labor	36.62	14.20	28.55	22.94	39.52	19.94	41.73	23.26
Fuel	1.70	1.40	3.40	2.80	5.80	4.90	6.40	6.20
Herbicides	17.76	33.47	9.82	10.22	9.32	11.39	9.32	11.39
Total costs	56.08	49.07	41.77	35.96	54.64	36.23	57.45	40.85
Return over variable costs	163.92	97.78	192.09	99.34	171.30	111.72	175.09	102.15
Comparison to moldboard system	-11.17	-4.37	+17.00	-2.81	-3.79	+9.57		
Corn/soy average	-7.77		+7.10		+2.89			

STEARNS COUNTY

The no till system in Stearns County shows a greater average profitability than moldboard plowing. Corn is more profitable because of 3.5 bushel higher average yields and lower variable costs. Machinery and fuel costs are substantially lower, although herbicide costs are higher. Soybeans were not as profitable under no till as moldboard system. The no till grown soybeans had a .6 bushel per acre lower yield than with a moldboard system, and variable costs were greater. This is due to no till herbicide costs about three times higher than the moldboard system. Machinery costs for no till were about half of what they were under the moldboard system.

Ridge till corn and soybeans were both more profitable than the moldboard system. Corn yields were lower, but variable costs were also much lower. This is due to lower machinery and fuel costs with about equal herbicide costs. Soybean yields were 2.1 bushels lower, but lower variable costs due to the lower machinery and fuel costs made up for this difference.

The profitability of the chisel plowing system was about equal to that of moldboard. Corn was more profitable, due to a 2.8 bushel yield increase and slightly lower variable costs. Soybeans were not as profitable with chisel plowing, due to lower yields. Variable costs were slightly lower in the machinery and fuel categories, but not enough to make up for the 2.8 bushel yield difference.

Table 28. Profitability of conservation tillage systems compared to a moldboard plowing system at Stearns County.

	No-till		Ridge till		Chisel		Moldboard	
	Corn	Soybean	Corn	Soybean	Corn	Soybean	Corn	Soybean
Bushels	81.2	28.3	71.8	26.8	80.5	26.1	77.7	28.9
Gross return	178.64	155.65	157.96	147.40	177.10	143.55	170.94	158.95
Variable costs-								
Machinery/labor	21.04	15.64	14.47	14.47	33.68	25.35	36.50	29.39
Fuel	1.20	1.40	2.00	2.00	4.90	4.20	5.90	5.50
Herbicides	22.36	33.47	9.90	9.95	9.40	11.39	9.40	11.39
Total costs	44.60	50.51	26.37	26.42	47.98	40.94	51.80	46.28
Return over variable costs	134.04	105.14	131.59	120.98	129.12	102.61	119.14	112.67
Comparison to moldboard system	+14.90	-7.53	+12.45	+8.31	+9.98	-10.06		
Corn/soy average	+7.37		+10.38		-.04			

Profitability analysis makes the following assumptions:

1. Corn is priced at $2.20/bushel
2. Soybeans are priced at $5.50/bushel
3. Labor costs are at $5/hour
4. Fuel costs are $1/gallon

Tillage effects on corn and soybean production in Meeker County, MN[1]

J.F. Moncrief, M.B. Kells, and J.J. Kuznia[2]

Conservation tillage systems provided adequate soil cover by corn and soybean residue for erosion control. Early corn growth (dry matter production) was slightly less with ridge till and more so with no till grown corn compared to chisel and moldboard systems. Starter fertilizer had more influence on early corn growth than tillage. Early dry matter production was 50% higher with starter fertilizer. Corn grain moisture was 2.9% higher with a no till system compared to other tillage systems evaluated. When starter fertilizer was applied at planting grain moisture was 2.5% lower. Corn grain yields were 10 bushels per acre lower with ridge till and no till systems. There was a 5 bushel per acre increase in corn grain yields due to row applied fertilizer across all tillage systems. Systems with high levels of "in row" cover with corn residue (chisel and no till) tended to have slightly slower early soybean development. Soybean grain yields were not affected by tillage. Row applied P and K had no effect on soybeans grown with a ridge till system.

Results and Discussion

Soil cover by corn and soybean residue resulting from the tillage systems demonstrated at this site are shown in tables 4 and 8. The soil cover by soybean residue is marginally adequate for erosion control with the chisel system but adequate with the ridge till and no till systems. After corn there is adequate cover with all conservation tillage systems for erosion control. The soil cover in the row by soybean residue should be less than 20% to minimize impact on the early development of corn. The chisel plowing system is marginal in this respect. There was some row cleaning with the no till system but in row cover was 30% after planting.

The soybean residue in the row area did not have any impact on corn stand establishment (table 5). It did however, affect early development. The no till system had about .1 leaf less than the other systems. The ridge till system tended to have the highest early development. Trends in dry matter production were slightly different. Chisel and moldboard plowing resulted in a slightly higher dry matter production by corn over the ridge tillage system at this time. Corn grown under no till conditions was a distant 3rd in early dry matter production. Row applied fertilizer at planting had a large influence on dry matter production and corn development.

The dry matter response did not interact with tillage. However, the starter fertilizer influence on corn development did depend on the tillage system (Table 5). It is usually the case that conservation tillage options will respond to starter fertilizer more frequently and more than with moldboard plowing. The ridge till system resulted in the largest benefit to planter applied fertilizer. This is common. What is not common is almost an equal response by corn grown with moldboard plowing and the absence of a response by corn grown with a no till system.

Grain yields and moisture are also shown in table 7. Tillage effects on the early growth of corn follows a similar trend in grain moisture. This is common in Minnesota research. Early delay of corn development carries through to physiological maturity. Grain yields were about 10 bushels per acre less with ridge till and no till systems. This is first year at this site that tillage had an affect on grain yields.

Starter fertilizer increased early dry matter production by 50% and development by about .1 leaf. Row fertilizer reduced grain moisture by 2.4 percent. There was a 5 bushel per acre response to row fertilizer which did not interact with tillage system.

Tillage effects on soybean production are shown in tables 9-11. Stands were slightly higher with the no till system. All stands were high enough to eliminate it as a yield influencing factor. Early growth was reduced slightly with soybeans grown with tillage systems that resulted in high levels of crop residue in the row (30 and 57% with chisel plowing and no till systems respectively.

Grain yields were not affected by tillage. This has been the case at this site for five years. Row applied

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[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.B. Kells is the Tri-County Project coordinator.*

fertilizer had no affect on soybean growth or yields with a ridge till system. Soybean row spacing (30" vs 8") had no effect on soybean yields.

MEEKER COUNTY

Table 1. Cultural practices at Meeker County MN. 1990.

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 July 6, 1990.
  - Ridged soybean plots on July 19, 1990.

Cropping History
Corn-soybean rotation since 1978.

1990 Crop
Corn-Pioneer 3790
Soybeans-Pioneer 9161

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 equipped with 2 inch fluted coulter ahead of the double disc openers.

	Planting			
Crop	Date	Planter	Rate	Harvested
Corn	May 10, 1990	Row	32,000 seeds/A	October 10, 1990
Soybeans	May 8, 1990	Drill	225,000 seeds/A	October 10, 1990
Soybeans	May 10, 1990	Row	225,000 seeds/A	October 10, 1990

Fertilizer History 1985-1989

			Actual			
Crop	Material Analysis	Rate	N	P_2O_5	K_2O	Date Applied
			----	lb/A	----	
Corn:	82-0-0	183 lb/A	150	0	0	Spring 1985
	4-15-40[1]	250 lb/A	10	38	100	Planting 1985
Corn:	4-15-40	300 lb/A	12	45	120	October 27, 1986
	7-21-7[1]	17 gal/A	13	40	13	April 28, 1987
	82-0-0	159 lb/A	130	0	0	May 15, 1987
Soybeans:	4-15-40	300 lb/A	12	45	120	October 27, 1986
	0-46-0[2]	45 lb/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 lb/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 lb/A	0	165	0	May 5, 1988
Corn:	7-21-7[4]	15 gal/A	12	35	12	May 10, 1989
	82-0-0	183 lb/A	150	0	0	May 31, 1989
Soybeans:	7-21-7[5]	15 gal/A	12	35	12	May 22, 1989

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.
4. Planter placement 2" x 2" on 1/2 the plots.
5. Planter placement 2" x 2" on 1/2 the plots, Ridge Till only.

1990 Fertilizer

			Actual				
Crop	Material Analysis	Rate	N	P_2O_5	K_2O	Date Applied	Method of Application
			----	lb/A	----		
Corn:	7-21-7	18 gal/A	14	42	14	May 10, 1990	Row placement 2" x 2" on 1/2 the plots
	82-0-0	220 lb/A	180	0	0	July 5, 1990	Anhydrous applicator
Soybeans:	7-21-7	18 gal/A	14	42	14	May 10, 1990	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

2.5 qt/A (2.5 lb/A) Lasso + 2.2 lb/A (2.0 lb/A) Bladex 90 DF applied on May 24, 1990.

Soybeans

1.5 pt/A (0.188 lb/A) Fusilade 2000 + 1 pt/A (0.459 lb/a) Galaxy a premix of (0.375 lb/A Basagran + 0.084 lb/a Blazer) + 2 qt/A oil concentrate on June 14, 1990.

1 pt/A (0.5 lb/A) Basagran + 2 pt/A (0.375 lb/A) Poast + 1 qt/A Dash oil concentrate + 2 qt/A 28% UAN on June 26, 1990.

Soil Test

Table 2. Soil test results for corn following soybeans on April 7, 1987.

	Tillage					
	No Till	Ridge	Chisel	Moldboard		
Nutrient	lb/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	lb/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 row position on soybean residue in corn at Meeker Co. on May 10, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	30.0a	12.3c	20.0b	3.5d	16.4b
Between Row	58.5a	33.0b	21.8c	6.0d	29.8a
Average	44.3a	22.7b	20.9b	4.8c	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=64), .001 (n=32), and .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage and starter on early growth and emergence of corn at Meeker Co[1].

	Tillage				
Population	NoTill	Ridge	Chisel	Mldbd	
June 12, 1990	plants/A X 10^{-3}				Avg.
Starter	29.0	30.2	30.2	28.4	29.4a
No Starter	29.0	29.3	30.1	28.9	29.3a
Average	29.0a	29.7a	30.1a	28.6a	
July 6, 1990	plants/A X 10^{-3}				
Starter	29.5	30.3	30.1	28.9	29.7a
No Starter	29.2	28.7	30.1	28.6	29.2a
Average	29.3a	29.5a	30.1a	28.7a	
Growth stage					
June 12, 1990	leaves/plant				
Starter	2.6	2.8	2.6	2.7	2.7a
No Starter	2.5	2.6	2.6	2.5	2.6b
Average	2.5b	2.7a	2.6ab	2.6ab	

1. The p value for starter, tillage, and tillage by starter interaction for June 12, population are .780 (n=64), .351 (n=32), and .816 (n=16) respectively. The p value for starter, tillage, and tillage by starter interaction for July 6, population are .293 (n=64), .461 (n=32), and .691 (n=16) respectively. The p value for starter, tillage, and tillage by starter interaction for growth stage are .001 (n=320), .097 (n=160), and .041 (n=80) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage and starter fertilizer on dry matter, percent nitrogen, and nitrogen uptake on early whole plant samples of corn at Meeker Co. on June 19, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Dry Matter	grams/plant				Avg.
Starter	1.95	2.23	2.35	2.50	2.26a
No Starter	1.08	1.48	1.70	1.58	1.46b
Average	1.51c	1.85b	2.03a	2.04a	
Tissue N	% N/plant				
Starter	2.35	2.54	2.58	3.03	2.63a
No Starter	2.21	2.69	2.84	2.98	2.68a
Average	2.28c	2.61b	2.71ab	3.00a	
N Uptake	mg N/plant				
Starter	46.1	56.2	61.1	75.4	59.7a
No Starter	23.2	39.2	48.4	46.9	39.4b
Average	34.7d	47.7c	54.8b	61.1a	

1. The p value for starter, tillage, and tillage by starter interaction for dry matter are .001 (n=16), .001 (n=8), and .705 (n=4) respectively. The p value for starter, tillage, and tillage by starter interaction for tissue N are .561 (n=16), .014 (n=8), and .354 (n=4) respectively. The p value for starter, tillage, and tillage by starter interaction for N uptake are .001 (n=16), .001 (n=8), and .123 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage and starter fertilizer on corn yield and moisture at Meeker Co on October 10, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Grain Yield	bu/A				Avg.
Starter	127.4	126.5	137.0	140.2	132.8a
No Starter	123.6	121.9	132.0	132.6	127.5b
Average	125.5b	124.2b	134.5a	136.4a	
Moisture	%				
Starter	23.9	21.9	21.1	21.5	22.1b
No starter	27.0	24.2	23.0	24.0	24.6a
Average	25.5a	23.0b	22.1b	22.8b	

1. The p value for starter, tillage, and tillage by starter interaction for yield are .012 (n=16), .055 (n=8), and .888 (n=4) respectively. The p value for starter, tillage, and tillage by starter interaction for moisture are .001 (n=16), .001 (n=8), and .652 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 8. Effect of tillage and row position on corn residue in soybeans at Meeker Co. on June 12, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	56.5a	9.3c	30.3b	4.3c	25.1b
Between Row	55.1a	32.8b	35.0b	4.5c	31.9a
Average	56.0a	21.0c	32.6b	4.4d	

1. The p value for residue location, tillage and tillage by location interaction are .016 (n=64), .001 (n=32), and .009 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 9. Effect of tillage on population (n=16) and early growth (n=80) of soybeans at Meeker Co.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Population[1]	plants/A X 10^{-3}				Sig.
6/12/90	239.0a[2]	152.6	192.2a	196.6a	.159
7/19/90	222.2a	149.3	190.7a	185.8a	.175
Growth stage	nodes/plant				
6/12/90	2.79b	2.90a	2.86ab	2.94a	.069

1. The ridge till treatment was excluded from statistical analysis of population because a different type planter was used.
2. Means within the same row with the same letter are not significantly different (α=.10).

Table 10. Effect of tillage on soybean yield and moisture at Meeker Co. on October 10, 1990.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	42.8a[1]	50.0a	48.9a	49.8a	.482
	%				
Moisture	9.1a	8.2a	7.7a	7.9a	.639

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 11. Effect of starter fertilizer on population, growth stage, yield, and moisture of ridge till grown soybeans at Meeker Co. on October 10, 1990.

	Ridge Till		
	Starter[1]	No Starter	
Population (n=16)	plants/A X 10^{-3}		Sig.
June 12, 1990	154.1a[2]	152.6a	.760
July 19, 1990	152.8a	149.3a	.603
	nodes/plant		
Growth Stage (n=80)	2.8a	2.9a	.269
	bu/A		
Yield (n=4)	46.1a	50.0a	.621
	%		
Moisture (n=4)	8.1a	8.2a	.623

1. Starter was 18 gals/A 7-21-7.
2. Means within the same row with the same letter are not significantly different (α=.10).

Tillage effects on corn and soybean production in Wright County, MN[1]

J.F. Moncrief, M.B. Kells, and J.J. Kuznia[2]

Soil cover by crop residue was adequate with no tillage following soybeans and ridge till and no till systems following corn. Corn stands were reduced 2 thousand plants per acre with moldboard plowing. Early corn dry matter production was reduced slightly with ridge tillage and greatly with no tillage. Early corn development was reduced with a no till system only. There was no effect of tillage on corn grain yields. Tillage did not affect stand establishment of soybeans. Early soybean development was reduced with ridge till and no till systems. There was no effect of tillage on soybean grain yields.

Methods and Materials

Tillage systems evaluated are: fall chisel and moldboard plowing, ridge till, and no tillage. The soil at this site is very draughty. The rotation is corn and soybeans with each crop present each year.

Results and Discussion

Treatment effects on soil cover are shown in tables 2 and 6. Following soybeans the soil cover by crop residue is less than adequate at this site with all except the no till treatment. Following corn there is adequate soil cover with the ridge till and no till treatments. The soil cover following corn is marginal following chisel plowing and discing.

Tillage and starter fertilizer effects on corn growth and stand are shown in table 3. Stands were reduced with moldboard plowing by about 2 thousand plants per acre. Ridge till grown corn also had faster development than that grown with moldboard plowing. The ridge till system resulted in slightly less early dry matter production and the no till system a distant third. This implies that the slight reduction in dry matter production associated with the ridge till system is not related to soil temperature.

Early growth differences did not follow through to grain yields. There was no effect of tillage on corn grain yields at this site.

Starter fertilizer increase early growth (table 4) and development (table 3) greatly (66 and 5% respectively). There was also a significant grain yield response (7 bushels per acre, table 5). This response was consistent across all the tillage systems.

Tillage effects on soybean growth and yield are shown in tables 7 and 8. Tillage did not affect soybean stand at this site. There was a reduction in development associated with the ridge till and no till systems. This delayed growth was not reflected in grain yields however. It is unusual that the row spacing difference between the ridge till and other systems did not affect grain yields. It is not unusual that soybean yields were not affected by tillage.

WRIGHT COUNTY

Table 1. Cultural practices at Wright County, MN. 1990.

Tillage
- No Till
- Ridge Till
- Fall Chisel Plow
- Fall Moldboard Plow
  - Corn-Cultivated May 14, 1990, ridged July 2, 1990.
  - Soybeans-Ridged July 2, 1990.

Preceding Crops
- Corn-soybean rotation since 1982.

1990 Crops
- Corn-Pioneer 3751
- Soybeans-Pioneer 9061

[1] *Support for this project was provided by the Agricultural Utilization and Research Institute, the Central Minnesota Initiative Fund, the Soil Conservation Service, the Clearwater River Watershed District, and the Minnesota Extension Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.B. Kells is the Tri-County Project coordinator.*

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 ahead of the double disc openers.

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 with sweeps raised.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 11, 1990	29,600 seeds/A	November 9, 1990
Soybeans	May 11, 1990	250,000 seeds/A	October 10, 1990

Fertilization History

From 1983 to 1986 both corn and soybeans received 100 to 150 lb/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:

	Material		Actual				
			N	P_2O_5	K_2O	S	
Crop	Analysis	Rate	------	lb/a	------		Date Applied
Corn:	8-23-30[1]	140 lb/A	11	32	42	0	May 2, 1986
	28-0-0[2] UAN	37 gal/A	110	0	0	0	June 13, 1986
Corn:	8-20-32[1]	140 lb/A	11	28	45	0	May 4, 1987
	82-0-0	183 lb/A	150	0	0	0	June 15, 1987
Corn:	9-20-33[1]	140 lb/A	13	28	46	0	May 6, 1988
	82-0-0	150 lb/A	123	0	0	0	June 8, 1988
Soybeans:	4-10-47-7[3]	131 lb/A	5	13	62	9	May 22, 1989
Corn:	6-14-42-7[1]	143 lb/A	9	20	60	10	May 11, 1989
	82-0-0	134 lb/A	110	0	0	0	June 14, 1989

1. Planter placement 2" beside and 2" below row.
2. Surface banded between rows.
3. Soybean ridge till plots were split with starter, planter placement 2" beside and 2" below row.

1990 Fertilizer

	Material		Actual			
			N	P_2O_5	K_2O	
Crop	Analysis	Rate	----	lb/A	----	Date Applied
Soybeans	9-23-30[1]	87 lb/A	8	20	26	May 11, 1990
Corn	9-23-30[1]	87 lb/A	8	20	26	May 11, 1990
	82-0-0	120 lb/A	98	0	0	June 27, 1990

1. Planter placement 2" beside and 2" below row, all corn plots and soybean ridge till plots were split with starter fertilizer at planting.

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

2.5 qt/A (2.5 lb/A) Lasso + 2 qt/A (2 lb/A) Bladex on May 24, 1990.

Soybeans

2 pt/A (0.918 lb/a) Galaxy a premix of (0.75 lb/A Basagran + 0.168 lb/a Blazer) + 1 qt/A oil concentrate on June 14, 1990.

1 pt/A (0.5 lb/A) Basagran + 1.25 pt/A (0.234 lb/A) Poast + 1 qt/A Dash oil concentrate + 2 qt/A 28% UAN on June 26, 1990.

Table 2. Effect of tillage and row position on soybean residue in corn at Wright Co. on May 30, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	---------	% cover	----------		Avg.
In Row	55.8a	1.8b	3.0b	0.3b	15.2b
Between Row	71.3a	9.8b	6.0b	4.3b	22.8a
Average	63.5a	5.8b	4.5b	2.3b	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=64), .001 (n=32), and .175 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage and starter fertilizer on population and early growth of corn at Wright Co. on June 12, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Population	------	plants/A X 10^{-3}		-----	Avg.
Starter	29.9	30.6	30.9	28.0	29.9a
No Starter	32.5	30.6	29.5	28.4	30.2a
Average	31.2a	30.6a	30.2a	28.2b	
Growth stage	-------	leaves/plant	-------		
Starter	2.8	3.0	2.9	2.9	2.9a
No Starter	2.7	2.8	2.8	2.7	2.8b
Average	2.7c	2.9a	2.9ab	2.8bc	

1. The p value for starter, tillage, and tillage by starter interaction for population are .633 (n=64), .011 (n=32), and .380 (n=16) respectively. The p value for starter, tillage, and tillage by starter interaction for growth stage are .001 (n=320), .038 (n=160), and .148 (n=80) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage and starter fertilizer on dry matter, percent nitrogen and nitrogen uptake on early whole plant samples of corn at Wright Co. on June 19, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Dry Matter	--------	grams/plant	-------		Avg.
Starter	1.80	2.18	2.23	2.18	2.09a
No Starter	1.03	1.13	1.45	1.43	1.26b
Average	1.41b	1.65ab	1.84a	1.80a	
Tissue N	---------	% N/plant	--------		
Starter	3.20	3.04	3.58	3.71	3.38b
No Starter	3.55	3.49	3.65	3.74	3.61a
Average	3.38b	3.26b	3.62a	3.73a	
N Uptake	---------	mg N/plant	--------		
Starter	54.4	66.1	79.7	80.6	71.0a
No Starter	36.3	38.8	53.1	53.0	45.3b
Average	46.8b	52.5b	66.4a	66.8a	

1. The p value for starter, tillage, and tillage by starter interaction for dry matter are .001 (n=16), .057 (n=8), and .186 (n=4) respectively. The p value for starter, tillage, and tillage by starter interaction for tissue N are .006 (n=16), .024 (n=8), and .132 (n=4) respectively. The p value for starter, tillage, and tillage by starter interaction for N uptake are .001 (n=16), .007 (n=8), and .869 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage and starter fertilizer on corn yield and moisture at Wright Co. on November 9, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Grain Yield	-----------	bu/A	-----------		Avg.
Starter	119.0	111.2	113.3	112.9	114.1a
No Starter	111.0	99.5	107.9	109.4	106.9b
Average	115.0a	105.3a	110.6a	111.2a	
Moisture	-------------	%	------------		
Starter	14.8	14.5	14.8	15.5	14.9a
No Starter	14.6	14.7	15.2	14.9	14.8a
Average	14.7a	14.6a	15.0a	15.2a	

1. The p value for starter, tillage, and tillage by starter interaction for yield are .052 (n=16), .720 (n=8), and .834 (n=4) respectively. The p value for starter, tillage, and tillage by starter interaction for moisture are .965 (n=16), .364 (n=8), and .855 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage and row position on corn residue in soybeans at Wright Co. on June 12, 1990[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	--------- % cover ----------				Avg.
In Row	54.3a	7.3c	17.5b	5.3c	21.1b
Between Row	64.5a	33.5b	25.3b	7.5c	32.7a
Average	59.4a	20.4b	21.4b	6.4c	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=64), .001 (n=32), and .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage on population (n=16) and early growth (n=80) of soybeans at Wright Co. on June 12, 1990.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	------ plants/A X 10^{-3} -----				Sig.
Population[1]	324.3a[2]	140.3	304.2a	338.5a	.293
	------- nodes/plant --------				
Growth stage	2.7b	2.6b	2.9a	2.9a	.001

1. The ridge till treatment was excluded from statistical analysis of population because a different planter was used.
2. Means within the same row with the same letter are not significantly different (α=.10).

Table 8. Effect of tillage on soybean yield and moisture at Wright Co. on October 10, 1990.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	----------- bu/A -----------				Sig.
Grain Yield	38.0a[1]	39.6a	42.2a	38.2a	.443
	------------- % ------------				
Moisture	7.9a	9.2a	8.2a	8.3a	.652

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 9. Effect of starter fertilizer on population, growth stage, yield, and moisture of ridge till grown soybeans at Wright Co. on October 10, 1990.

	Ridge Till		
	Starter[1]	No Starter	
	- plants/A X 10^{-3} -		Sig.
Population (n=16)	145.6a[2]	140.3a	.311
	--- nodes/plant ---		
Growth Stage (n=80)	2.7a	2.6a	.246
	------- bu/A ------		
Yield (n=4)	39.3a	39.6a	.884
	-------- % --------		
Moisture (n=4)	7.9a	9.2a	.377

1. Starter was 87 lb/A 9-23-30.
2. Means within the same row with the same letter are not significantly different (α=.10).

Tillage effects on soybeans following barley and spring wheat in Douglas County, MN[1]

J.F. Moncrief, L. Zilliox, and J.J. Kuznia[2]

There was no effect of tillage on soybean yields following barley or spring wheat.

This site was established in 1984 and has been in a small grain-soybean rotation for the last three years. In 1989 one half of the plot area was in barley and the other half in spring wheat. In 1990 soybeans were planted.

Grain yields are shown in table 2. There was no effect of tillage on soybean yields following either barley or wheat. This is consistent with other years and sites.

DOUGLAS COUNTY

Table 1. Cultural practices at Douglas County, MN. 1990

Tillage
- No Till
- Fall Chisel Plow-field cultivated twice in spring
- Fall Moldboard Plow-field cultivated twice in spring

1990 Crop
- Soybeans-9061

Preceding Crop
- 1985-Soybeans, 1986-Barley-Robust,
- 1987-Spring Wheat-Pioneer 2369 and Winter Wheat-Bighorn and Roughrider
- 1988-Soybeans-Pioneer 1082
- 1989-Spring Wheat-Pioneer 2369 Barley-Robust

Planting and Harvest Date

Planter was a Great Plains with 6.75 inch row spacing with 1 inch fluted coulters mounted on the tongue.

Crop	Planting Date	Planting Rate	Harvested
Soybeans	May 12, 1990	225,000 seeds/A	October 5, 1990

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			----	lb/A	----	
Barley	18-46-0[1]	100 lb/A	18	46	0	April 25, 1986
	46-0-0[2]	217 lb/A	100	0	0	Spring 1986
Winter Wheat	18-46-0[1]	100 lb/A	18	46	0	September 29, 1986
	46-0-0[2]	217 lb/A	100	0	0	May 29, 1987
Spring Wheat	18-46-0[1]	100 lb/A	18	46	0	April 21, 1987
	46-0-0[2]	217 lb/A	100	0	0	May 29, 1987
Tillage						
All	18-46-0[1]	100 lb/A	18	46	0	April 26, 1989
No Till	46-0-0[2]	283 lb/A	130	0	0	May 2, 1989
All Others	46-0-0[2]	217 lb/A	100	0	0	May 2, 1989

1. Drill applied with seed.
2. Urea was broadcast.

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.

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[1] *Support for this project was provided by the Soil Conservation Service and the Minnesota Extension Service. Their support is greatly appreciated.*

[2] *J.F. Moncrief and J.J. Kuznia are Associate Professor and Assistant Scientist in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. L. Zilliox is the County Agricultural Agent in Douglas County, MN.*

Weed Control

Chisel and Moldboard Plots:

1 qt/A (1 lb/A) Treflan applied May 7, 1990, just prior to planting and incorporated with two passes with a field cultivator.

No Till Plots:

1 pt/A (0.188 lb/A) Poast.

All Plots:

1 pt/A (0.5 lb/A) Basagran + 1 pt/A (0.25 lb/A) blazer + 1 qt/A oil concentrate.

Table 2. The effect of tillage on soybean yield and moisture Douglas Co. on October 5, 1990[1].

	Tillage			
Previous Crop	No Till	Chisel	Moldboard	
	bu/A			Avg.
Barley	38	35	37	37a
Spring Wheat	36	35	38	36a
Average	37a	35a	38a	
	% moisture			Avg.
Barley	6.0	5.7	5.7	5.8a
Spring Wheat	5.8	5.6	5.7	5.7a
Average	5.9a	5.6b	5.7ab	

1. The p value for tillage, previous crop, and tillage by previous crop interaction for yield are 0.750 (n=6), 0.925 (n=9), and 0.939 (n=3) respectively. The p value for tillage, previous crop, and tillage by previous crop interaction for moisture are 0.095 (n=6), 0.656 (n=9), and 0.748 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

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