Field Research in Soil Science 1994

(Soils Series #140)

Miscellaneous Publication 83–1994
Minnesota Agricultural Experiment Station
University of Minnesota

St. Paul, Minnesota

SOIL SERIES #140
Field Research in Soil Science

ACKNOWLEDGEMENTS

This 1994 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 1993 experiments and should be regarded on this basis. Since most of the data is from 1993 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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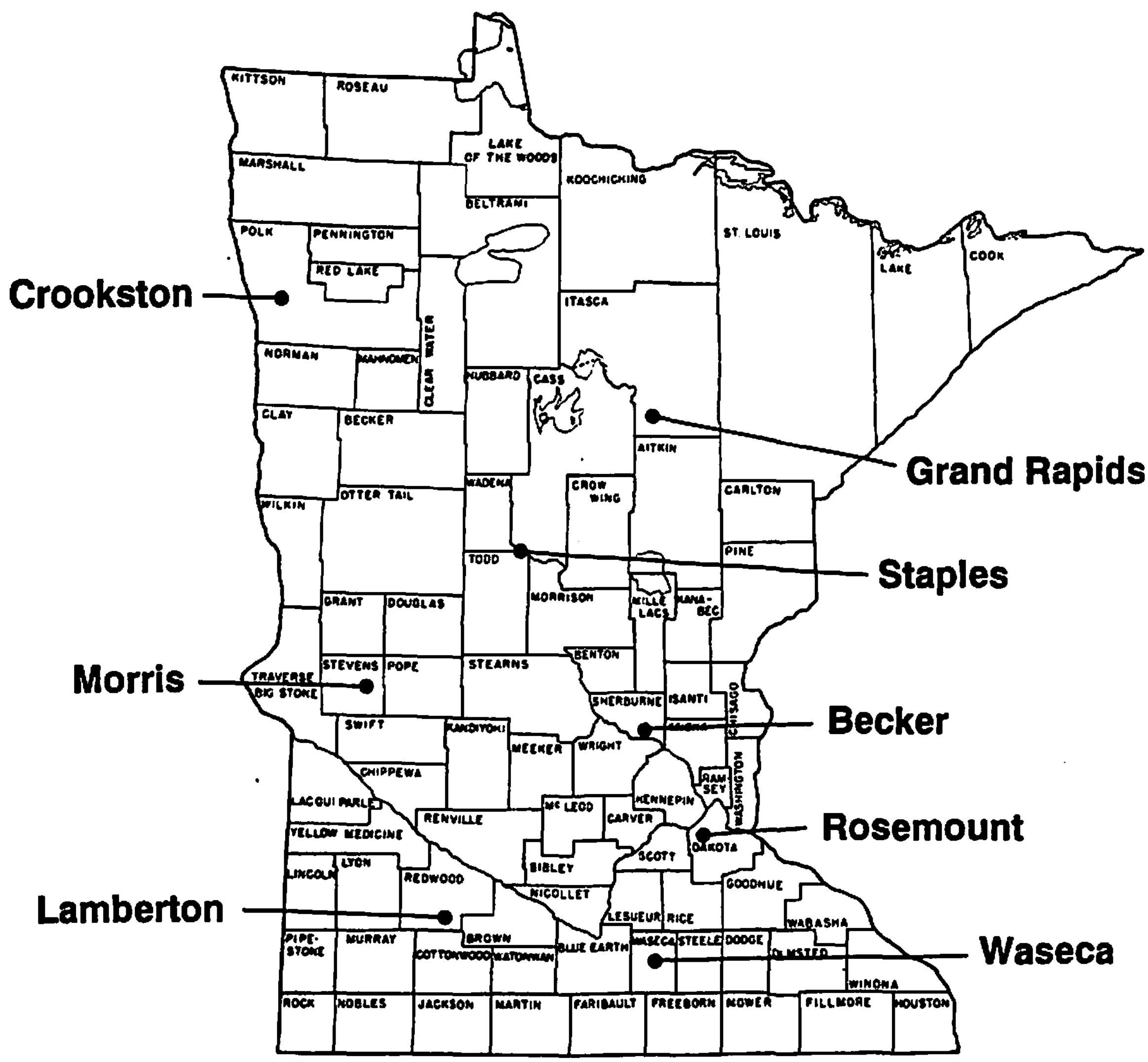

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CLIMATE UPDATE - FALL, 1993 AND WINTER, 1994

State Climatology Office[1]

The months of May through August of 1993 will be remembered as the wettest period in Minnesota's recorded climate history. The torrential rains that impacted nearly all of the Midwest left many locations in Minnesota with precipitation totals exceeding 200 percent of the mean, the equivalent of two summers worth of rain. Figure 1 shows that roughly one half of Minnesota ranked at, or above, the 99th percentile for May through August rainfall. A value above the 99th percentile means that those locations broke, or nearly broke, all-time May through August rainfall records. Four month totals exceeded 28 inches over much of southern Minnesota, the normal annual rainfall for many of those areas. Record breaking rainfall over such a broad area for such an extended period of time is unprecedented in Minnesota's 100-year climate record.

The same atmospheric conditions that led to the heavy rains also led to extraordinarily low evaporation rates. Cloudy and cool weather, in tandem with persistently high relative humidity, combined to dramatically reduce the atmosphere's ability to evaporate water from the surface. For the first time since such records have been kept, precipitation totals exceeded pan evaporation values for the May through August period. The lack of evaporation exaggerated an already serious hydrologic imbalance.

The most significant rainfall event of the late summer occurred on August 15th and 16th along a line that stretched from near New Ulm to south of Austin. A multi-county area received more than four inches of precipitation in this storm. Eight inches of rain or more fell in southern Freeborn and Mower counties. Falling upon already saturated ground, this storm caused wide-spread soil erosion and rural flooding, as well as serious urban flooding in Austin and elsewhere.

Fortunately, the rain slackened in the late summer and early fall. However, this dry weather was not accompanied by the warm temperatures needed to adequately dry crops and soils. September was one of the coolest on record, and with some exceptions, October was also quite cool.

At this time, soil moisture levels are very high for nearly all of Minnesota. As the soil freezes, the soil moisture status will remain generally unchanged through the winter season. Wetlands, lakes, rivers and streams are also at unusually high levels for this time of year. While it is too early to sound the alarm, it is important to recognize that the potential for significant spring flooding in 1994 does exist.

During Minnesota's winters the levels of our hydrologic systems remain relatively constant. The frozen soil allows little movement of water within the soil, and from the surface into the soil. Our winter precipitation most often falls as a solid, laying upon the ground as a latent supply of water, waiting to be released by the spring thaw. Minnesota's cold winter temperatures nearly eliminate evaporation (actually sublimation) from the surface to the atmosphere. Stream flows are driven almost entirely by base flow from the ground water. Therefore winter is a time to evaluate the previous seasons in an effort to anticipate the hydrologic conditions of the spring to come.

In soil measurements made this past fall, the data indicate that nearly all of Minnesota's soil are at or above their long term average soil moisture content. The fall soil moisture status is a good indicator of the amount of buffer space that the soil will offer after the spring thaw.

After a relatively dry fall, winter has brought a significant snow cover. As of February 1st, nearly all of Minnesota was covered with a snow depth that ranked at least in the 80th percentile (meaning that in 100 years, only 20 years would have more snow on the ground at this time of year). Early in January, Finland along the north shore, received over 4 feet of snow in a single storm. Preliminary estimates show that the snow pack across Minnesota contains from one to four inches of water.

Snow cover can act as an insulating blanket for the soil, inhibiting frost penetration. A shallower frost layer means fewer broken water pipes and less energy required to warm the ground in spring, opening the soils earlier to infiltration. Frost protection was critical during January when Minnesota experienced its coldest month in over a decade. Many minimum temperature records were broken as the thermometer dropped well below zero for extended periods of time.

Ground water base flow into surface water systems remains significant as the result of extraordinary rainfall that fell during the summer of 1993. All of the southern one third of Minnesota received over 36 inches of precipitation during the 1993 Water Year (October 1992 - September 1993). Some areas in Martin County received well over 50 inches of precipitation. Elsewhere across the state, Water Year precipitation ranged from 20 to 32 inches. Over two dozen counties in southern Minnesota reported precipitation departures of over one foot above the norm. With some exceptions in the northwest and the north, all of Minnesota received greater than normal precipitation for the period. The heavy precipitation fell upon a state already wet from the climate events of the early 1990s.

With soil moisture values high, surface water levels above average for this time of year, and a significant snow pack on the ground, Minnesotans must recognize that the potential exists for significant spring flooding, especially in the south.

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[1]The State Climatology, Division of Waters, Department of Natural Resources, U. of M., St Paul Campus.

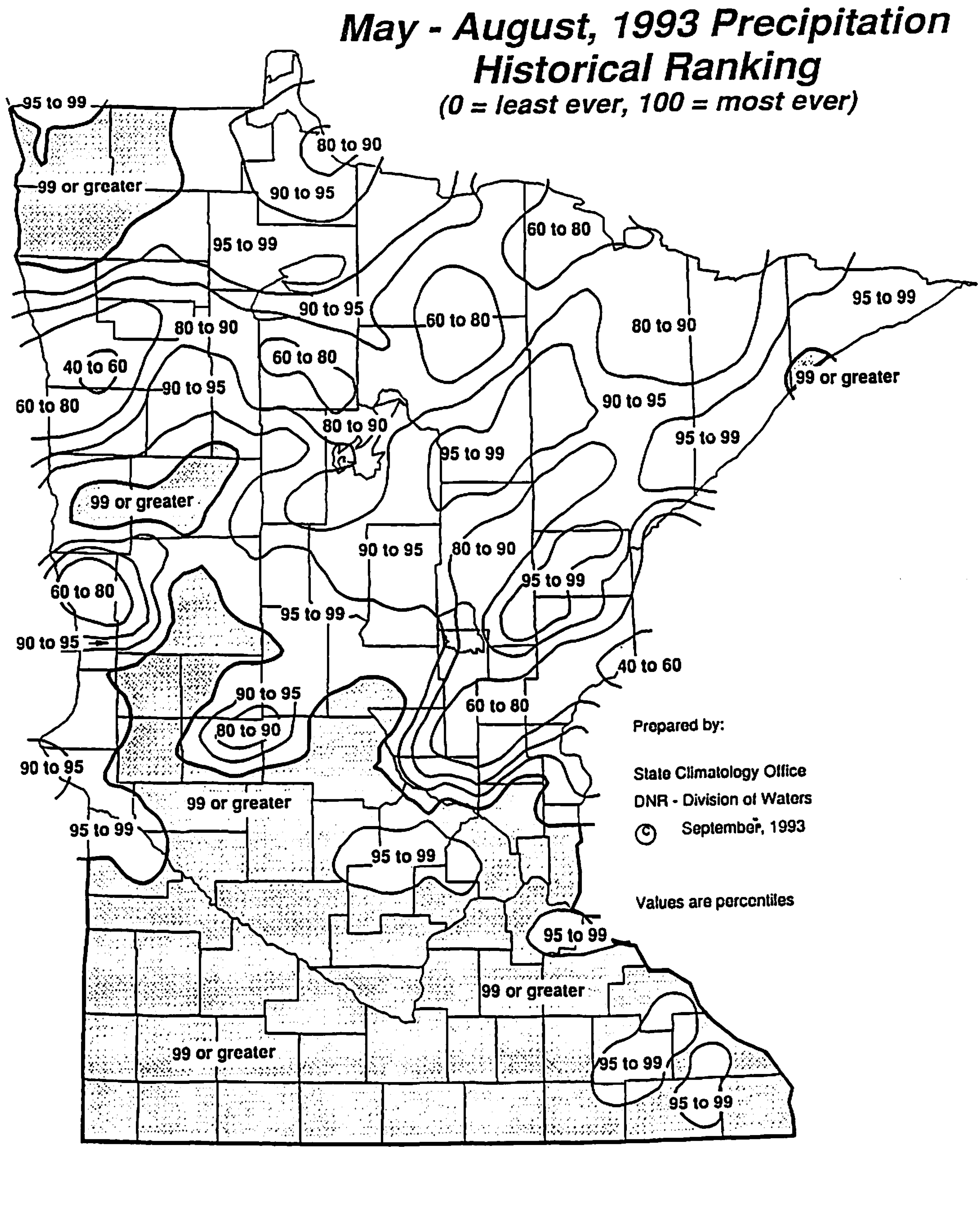

Fig. 1. This map depicts where the May to August 1993 precipitation totals fall in the context of history (100 years of climate data). A value of 99 or greater means the May to August all-time rainfall record was nearly matched or broken. A value of 90 means that greater amounts would only be expected one out of ten years.

SOIL MOISTURE, 1993[1]

G. Randall, D. Fuchs, D. Huggins, S. Evans J. Cameron, D. Ruschy and D. Baker[2]

The soil moisture monitoring program continues at the Crookston, Lamberton, Morris, and Waseca stations. The results for the year are shown in Fig. 2 and 3, and are a reflection of the annual precipitation amounts this past summer. As noted in the "Climate Update-Fall and Winter, 1993" article by the State Climatology Office the southern half of the state was inundated while the northern half received much less. At Morris, Fig. 2, there were several sampling times that had to be skipped due to the high water content of the soil. At Lamberton, Fig. 2, the familiar mid-season decrease in soil moisture was absent this year. This indicated that the precipitation essentially equalled the evapotranspiration and little or no soil water reserves remained about constant. The Lamberton soil profile ended the season containing about 2 inches more than average. At Waseca the profile contained only about one-half inch above average.

The above average amounts at the Lamberton, Morris and Waseca stations give an early indication that flooding could be a problem this spring. This is true particularly for the Minnesota valley where snow and soil moisture amounts are well above average.

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

[2]Gyles Randall, Southern AES; Dennis Fuchs and Dave Huggins, Southwest AES; Sam Evans, West Central AES; James Cameron, Northwest AES; and Dave Ruschy and Donald Baker at the St. Paul AES.

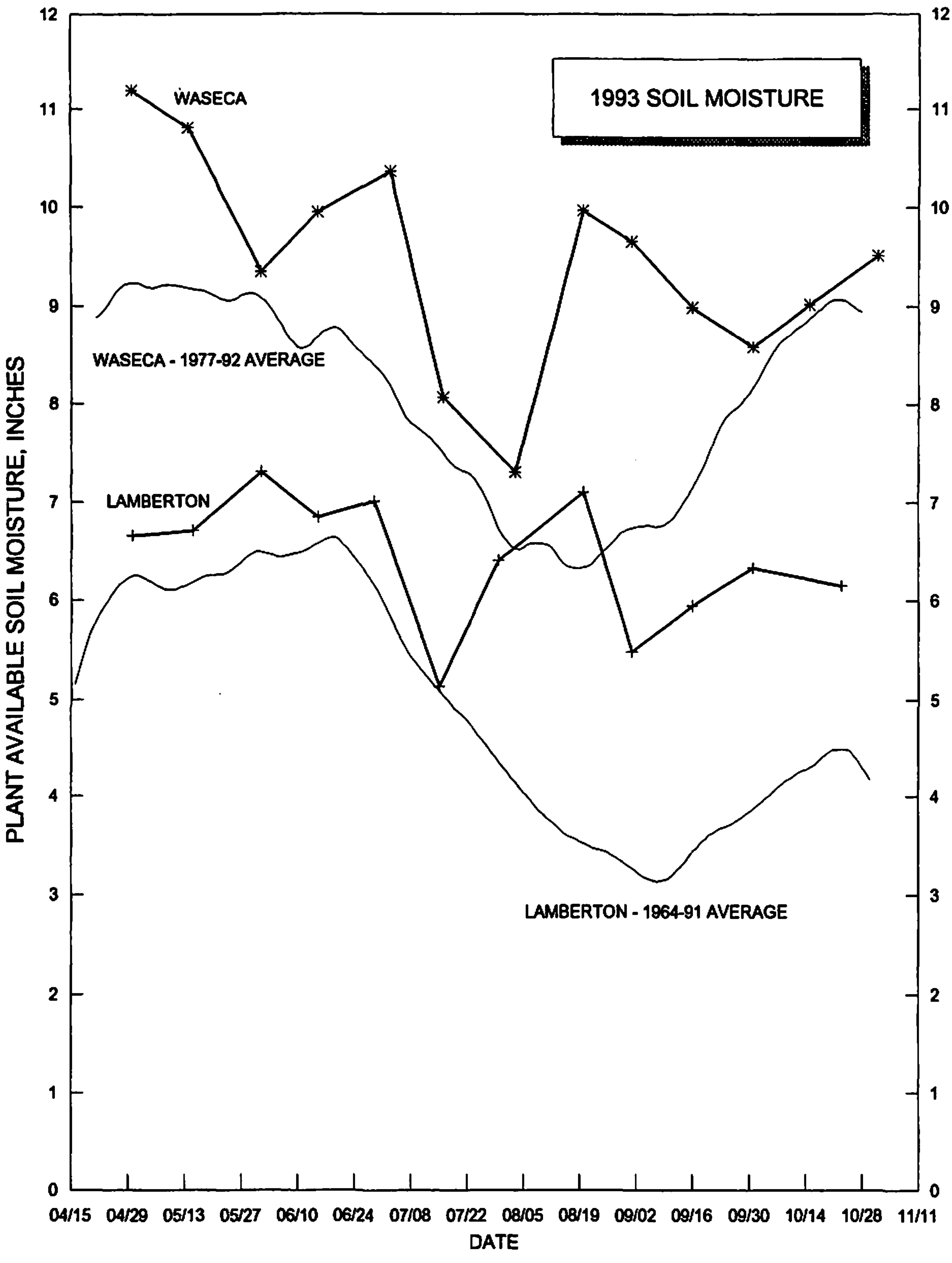

Fig. 2. Comparison of the total plant available soil moisture in a 5-foot column of soil under corn at the Lamberton and Waseca Agricultural Experiment Stations. The heavier lines are the 1993 totals and the lighter lines are the long-term averages.

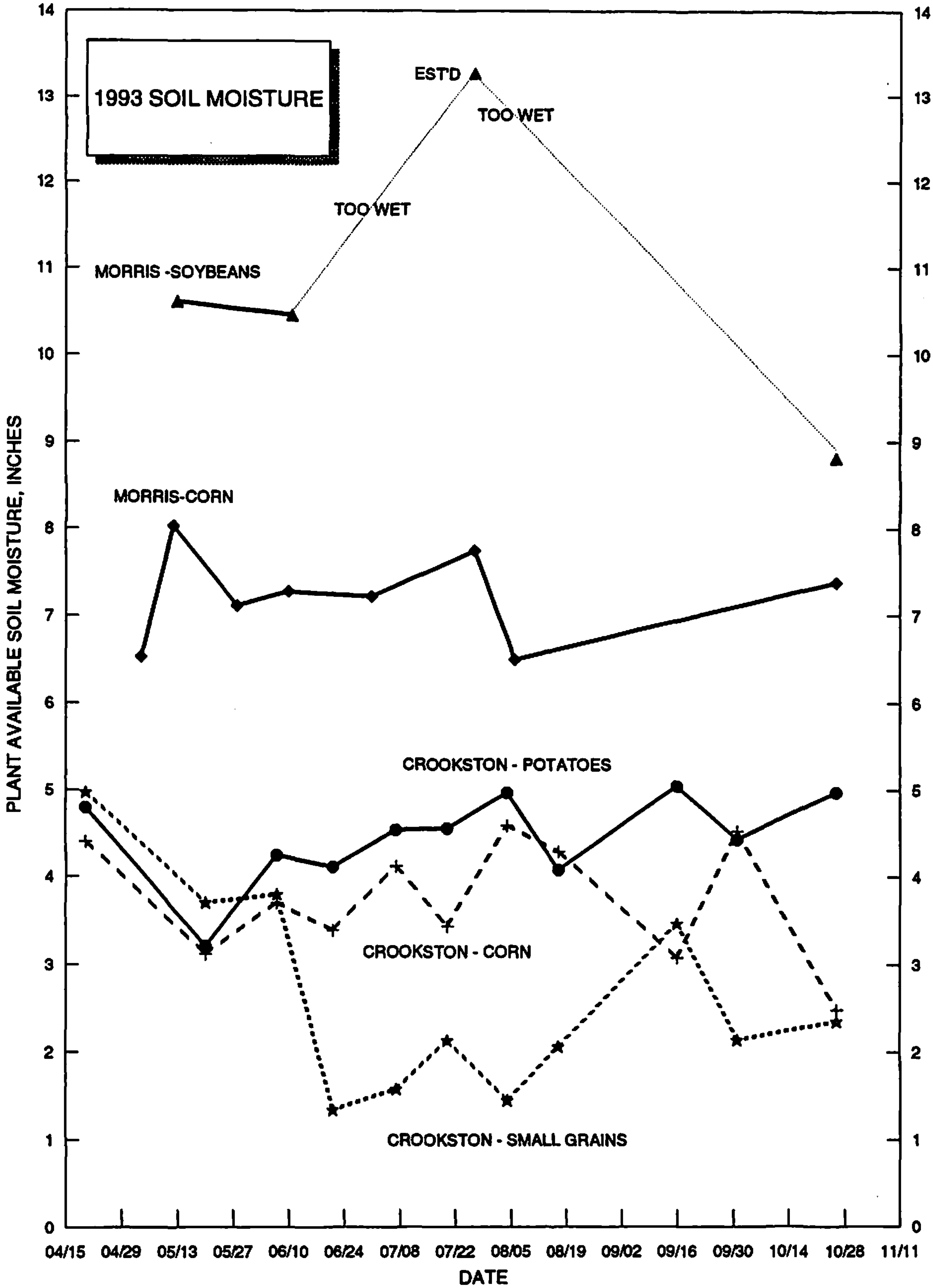

Fig. 3. Comparison of the total plant available soil moisture in a 5-foot column of soil under the indicated crops at the Crookston and Morris Agricultural Experiment Stations. At Morris, the soybean field was frequently too wet to obtain acceptable samples.

SOIL FREEZE-THAW OCCURRENCES[1]

D. G. Baker and D. L. Ruschy[2]

The fluctuation of temperature above, then below the freezing point and returning above the freezing level (or vice versa), constituting a freeze-thaw (or a thaw-freeze) occurrence, has long been considered an important measure of physical weathering. With the volume expansion of water upon freezing and the attendant relaxation of the pressure upon thawing, the freeze-thaw phenomenon is a natural physical force to be reckoned with. It is of importance to soil scientists as a result of its effect upon soil structure, to engineers for its effect upon highways and other structures resting in or on the soil, to geologists for its effect upon the weathering of rocks and minerals and the alteration of landscape features, and to agriculturists for its effect upon biological systems.

The statistics of the freeze-thaw phenomenon, essentially a surface feature, are difficult to determine from the usual climatological data for two reasons: a) the frequency of observation and the height of the standard air temperature measurement. Only at experimental sites and first order National Weather Service stations are observations made more frequently than the daily maximum and minimum measurements common to the cooperative network stations. And only at certain experimental sites are temperatures sometimes measured at heights other than the approximately 160-cm (63-in.) of the standard temperature shelter.

A comparison between air and soil temperature made at the St. Paul campus climatological observatory permit the determination of the best method to estimate the frequency of soil freeze-thaws when only daily maximum and minimum air temperatures are available. The estimated average monthly frequencies on a north to south transect from International Falls to Des Moines are shown in Fig. 5. All stations show the expected maximum frequency in the fall and spring maximums. At all stations except International Falls the maximums occur in November and March. Due to the lower temperatures and longer winter season at International Falls, the maximum occur in October and April. The January frequency of freeze-thaws increases north to south paralleling the increase in temperatures in the same direction.

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[1]Support for this project was provided by the Agricultural Experiment Station.

[2]Dr. Baker and D. Ruschy are professor and junior scientist, respectively, Soil Science Dept., University of Minnesota, St. Paul.

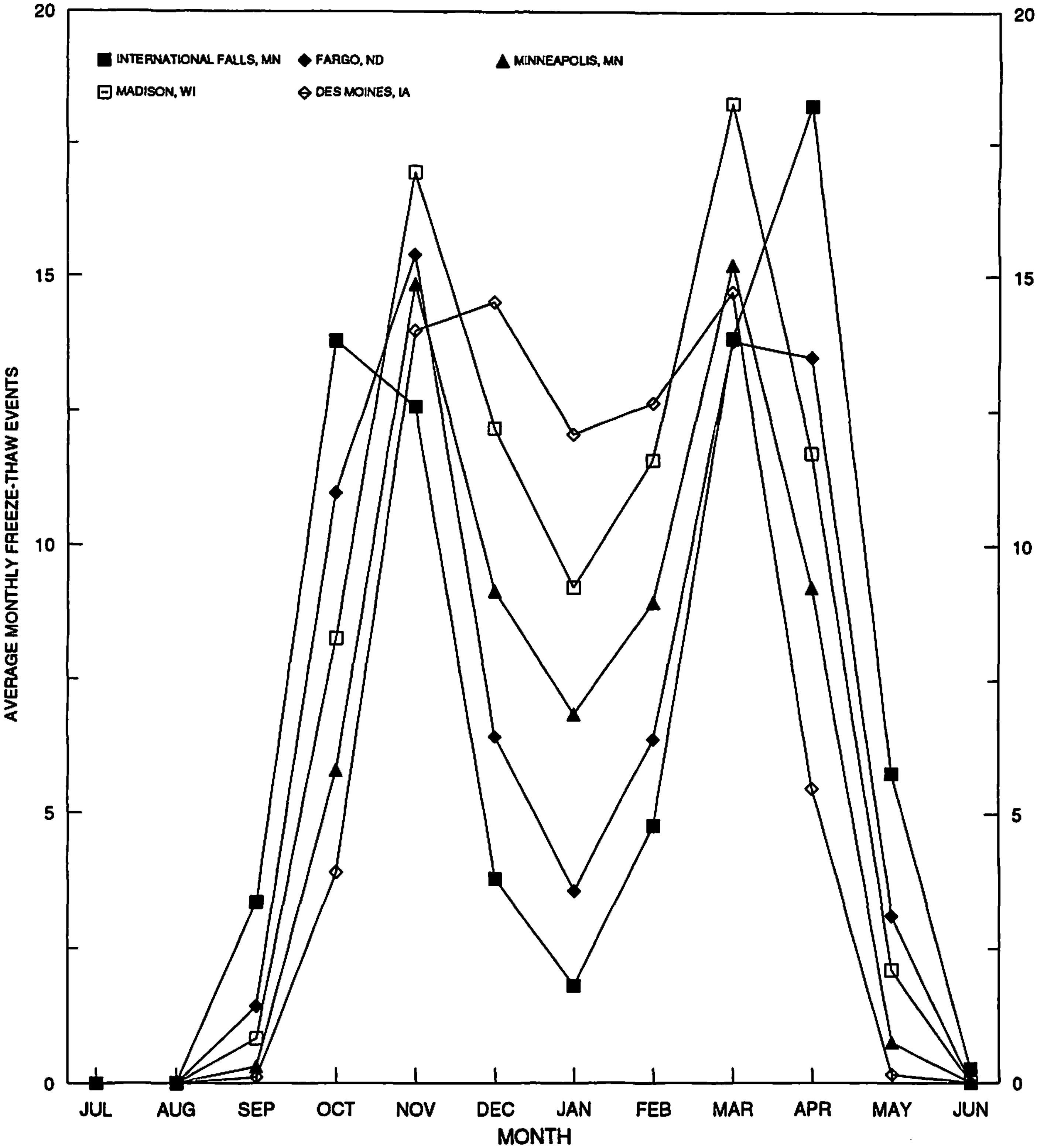

Fig. 5. Mean montly freeze-thaw cycles calculated from air temperatures in a north to south transect from International Falls to Des Moines. The method used to count the cycles most nearly represents the freeze-thaw cycles in soil bare of vegetation as determined at the St. Paul Campus Climatological Observatory using 7 years of data.

VARIABILITY OF CLIMATE[1]

D. G. Baker and D. L. Ruschy[2]

We are all aware of the vagaries of the weather from day to day and of the climate from year to year. And, anyone involved in agriculture is aware of the extremes, both good and bad, that can descend upon us. The bad events are rather well known to us and include the drought years of 1934, 1936 and 1976 and the heat wave and drought of 1988. Other years could be included. It is not as easy to name the good years since they don't seem to impress us as much - it is easier to remember catastrophes apparently.

There was a series of years that occurred from about 1956 to 1973 in which the climate from year to year was remarkably consistent and without major surprises. It was easy to forecast the next year's yield, since it seemed to increase in a regular fashion of 1-3 bu/A of corn per year, for example. Within a season the weather was such that the full effect of the applied technology (fertilizers and other chemicals, new and improved machinery, better seed, etc.) showed up in the nearly constantly improving yields. This time of an historically unique period of low climate variation was an important but little appreciated period that was termed the "benign climate".

In Fig. 4 is shown the remarkable decrease in interannual variability centered around 1952-1964 in the Eastern Minnesota record. It is even more apparent and over a more extended period when the average of 36 stations across the U.S. is calculated. Thus, it is confirmed as more than a chance occurrence at the single Minnesota station.

It is our contention that this agriculturally favorable period was in part responsible for the general euphoria that became a part of the general mood of the U.S. and of American agriculture in particular. The duration of this period was about a generation in length. It misled a number of the farmers who entered agriculture at that time into believing that the good weather and climate was the natural course of events; they hadn't experienced the bad times (climatic as well as economic) that their parents had experienced. As a result, farming looked extremely profitable and land prices began to rise.

However, by 1974 the precipitation totals began to decrease culminating in the drought of 1976. It was not realized by most that the variability of the climate had changed sharply, and from this point on equalled the variability experienced in earlier years; the variability common to most of the record. The recent and all too brief "benign climate" period was unique, and not the norm. Unfortunately, land prices and interest rates continued to increase while, in contrast to the "benign period", the yields were far more variable from year to year.

With the end of the benign period, yields became much more variable, and in consequence it became more difficult to carry the higher expenses that many had assumed in the benign period. The effect of the disappearance of this period was not realized immediately, but by about 1980 the end came with a rapid drop in land prices - a real deflation or depression in agriculture.

In summary, the "benign climate" was in part responsible for the good times agriculture experienced during about 1956-1973 that led less experienced farmers into assuming a debt burden that could be supported only with its continuation. The ending of this unique climatic period, which was largely unrecognized, was responsible in part for the sudden deflation and the agricultural depression that began in 1980. Thus, this series of events makes it very apparent that relatively minor climatic events - even very subtle events that are difficult to detect - can have far reaching consequences affecting the economic and social fabric of our nation.

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[1]Support for this project was provided by the Agricultural Experiment Station.

[2]D. Baker and D. Ruschy are professor and junior scientist, respectively, Soil Science Department at the University of Minnesota, St. Paul, MN 55108.

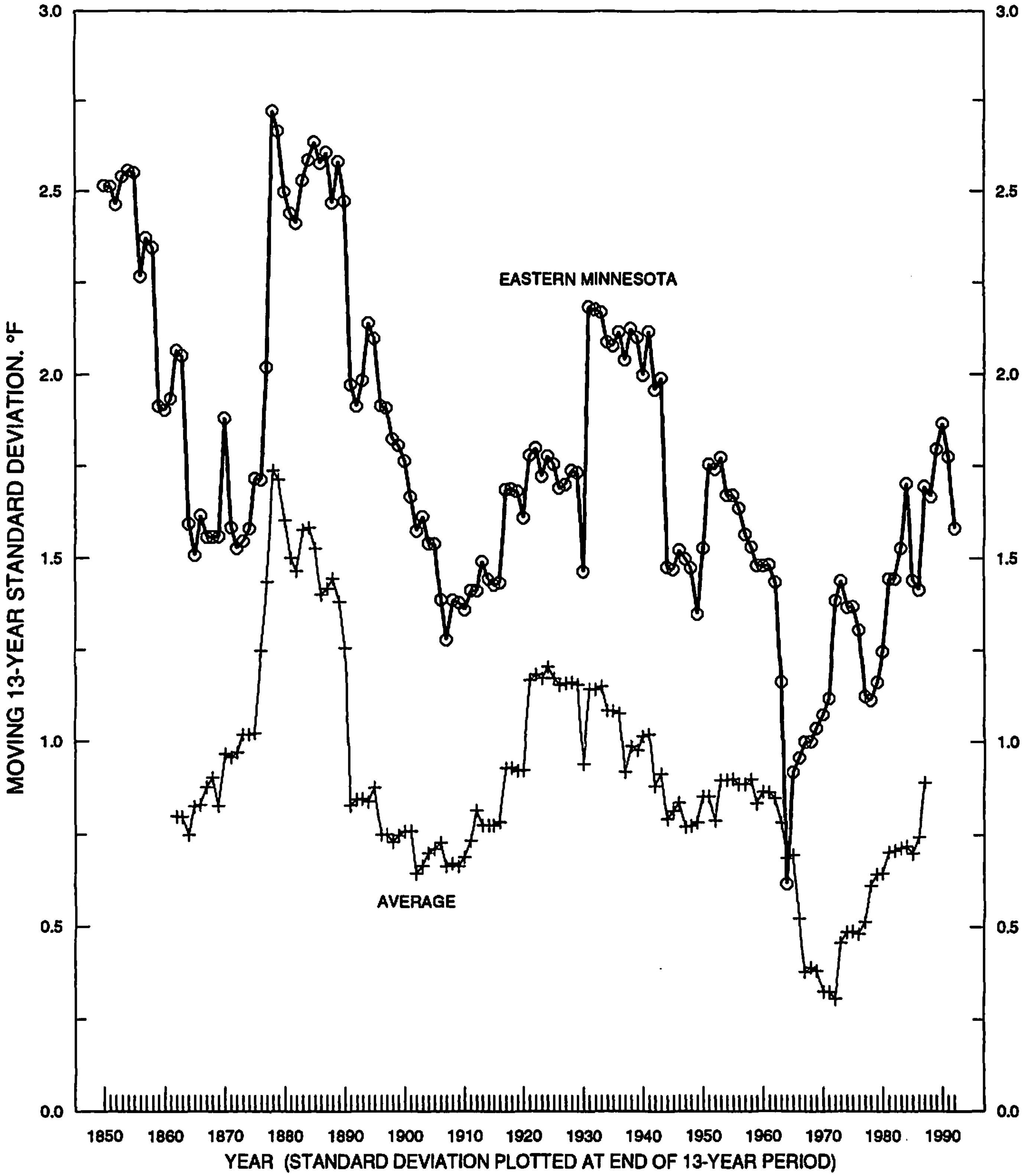

Fig. 4. Running standard deviations of 13-year periods of the average annual temperature at the Eastern Minnesota station and the average of 36 United States' stations. Note the minimum standard deviation in the mid-1960's and the early 1970's in the two records and the much higher variation both before and after the "benign climate" period.

NITROGEN MANAGEMENT FOR IRRIGATED POTATOES: EFFECTS OF NITROGEN TIMING AND SOURCE ON SOIL NITRATE MOVEMENT AND PETIOLE SAP NITRATE INTERPRETATION - 1993[1]

Carl Rosen, Mohamed Errebhi, John Moncrief, Satish Gupta, H. H. Cheng, and Dave Birong[2]

ABSTRACT: The third year of a four year study was conducted at the Sand Plain Research Farm in Becker, MN to evaluate the effects of various N management strategies on nitrogen use and nitrate movement under irrigated potatoes. A second objective was to continue with calibration of a quick petiole nitrate sap test for determining nitrogen status of the crop and predicting nitrogen needs. Tuber yield increased with increasing N rate up to 240 lb N/A, with the greatest increase occurring between the 0 and 120 lb N/A rate. At equivalent N rates, use of post-hilling N applications tended to result in larger tubers compared to applying all the N up to hilling. Hollow heart increased with increasing N rate, but was not affected by post-hilling N application. Higher concentrations of nitrate in soil water at the 4 ft depth were found in the row compared to between the row for most treatments. Leaching of N was related more to rate of N applied than timing of application. Final tuber yields with urea as the N source were similar to those with ammonium nitrate as the N source, although early plant growth with ammonium nitrate was greater than with urea. The early response to ammonium nitrate may have been due to cooler temperatures, which may have inhibited conversion of ammonium to nitrate when urea was used. Petiole nitrate increased with increasing N rate and with post-hilling N applications. For all treatments that did not involve post-hilling N, petiole nitrate decreased through the season. The quick tests used reflected the changes in petiole nitrate with N treatment. Sap nitrate concentrations determined with the Cardy meter tended to be 50 to 100 ppm higher than readings from the Hach or Wescan instruments.

Potatoes grown on sandy soils under irrigation are usually provided with high rates of nitrogen (N) to promote growth and yield. Concern about ground water quality, however, has raised questions about the fate of N 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 relatively high rates of N to maintain profitable production. Proper N management is critical to minimize losses of N from the root zone and maintain yields. The objectives of this study were to characterize the pattern of soil nitrate-N movement during irrigated potato production under defined nitrogen management regimes and to develop diagnostic tools for quick and accurate prediction of the need for N by potato during the growing season. The results presented below are the third year of a four year study.

EXPERIMENTAL PROCEDURES

The experiment was conducted in Becker, MN at the Sand Plain Research Farm on a Hubbard loamy sand soil. The previous crop was rye. Selected soil chemical properties prior to planting were as follows (0-6"): pH, 6.8; organic matter, 2.5%; phosphorus, 31 ppm; potassium, 95 ppm; sulfur, 1 ppm. Residual nitrate-N in the top 3 feet of soil was 13 lb/A. Prior to planting, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. Russet Burbank "B" size potatoes were planted April 20, 1993 at a spacing of 36" between rows and 10" within the row. Phosphate (0-46-0) and potash (0-0-60) fertilizer were applied in the band at planting at a rate of 80 lb P_2O_5/A and 200 lb K_2O/A to all plots. The fertilizer was banded 3" to each side and 2" below the tuber. Individual plot size consisted of six, 30 ft rows. The middle two rows (3 and 4) were harvest rows and rows 2 and 5 were sample rows. Ten treatments were tested to evaluate the effects of various N management practices on potato productivity, N use/uptake, soil nitrate movement, and petiole N status during the course of the season. The 10 specific treatments were as follows:

			N Application Rate (lb N/A)				
N Source	Planting	Emergence	Hilling	Post-Hilling	Post-Hilling	Post-Hilling	Post-Hilling
1) Control	0	0	0	0	0	0	0
2) Urea	40	100	100	0	0	0	0
3) Urea	20	70	70	20	20	20	20
4) Urea	20	70	70	0	0	0	0
5) Ammonium nitrate	40	100	100	0	0	0	0
6) Ammonium nitrate	20	70	70	20	20	20	20
7) Ammonium nitrate	20	70	70	0	0	0	0
8) Ammonium nitrate	40	40	40	0	0	0	0
9) Ammonium nitrate	40	40	40	0	20	20	20
10) Ammonium nitrate	40	40	40	20	20	20	20

[1]Funding for this project was provided by the Legislative Commission on Minnesota Resources. We thank Glenn Titrud for assistance in plot maintenance.
[2]Assoc. Prof., Grad. Res. Asst., Ext. Soil Sci., Prof., Prof., and Asst. Sci., respectively, Dept. Soil Sci.

Nitrogen applied at planting was banded with the P and K fertilizer. Nitrogen applied at emergence (May 26) was banded 1" deep and 8" from each side of the plant. At hilling (June 11), the N fertilizer was sidedressed on the surface on either side of the plant and then incorporated during the hilling process. Post-hilling applications to treatments #3, 6, and 10 were applied on June 18, July 2, July 13 and July 19. Applications were made by broadcasting 50% ammonium nitrate and 50% urea over the plot by hand and then irrigating in. Post-hilling applications to treatment #9 were June 25, July 2, and July 13.

The experimental design was a randomized complete block with 4 replications. Rainfall was supplemented with overhead irrigation to supply water needs according to the checkbook method. Rainfall during the growing season totaled 31 inches and was supplemented with 5.9 inches of irrigation. The nitrate-N concentration in the irrigation water averaged 8 to 10 ppm. Given that 5.9 inches of irrigation were applied, approximately 14 lbs of additional N was provided with the irrigation water. Figure 1 shows the weekly precipitation (rainfall + irrigation) through the growing season.

Recently matured potato leaves (4th leaf from the growing terminal) were collected every 10-14 days starting one day before hilling for nitrate-N determinations. Thirty leaves were collected from each plot. Leaflets were removed, half of the petioles were crushed with a Hach press, and the remaining petioles were dried in an oven at 140°F. The expressed sap was immediately frozen until analyses could be performed.

Two instruments designed for quick tests were compared: the Hach nitrate electrode and the Horiba/Cardy nitrate electrode. In addition to the quick test procedures, nitrate in sap and nitrate in dried petioles were determined conductimetrically using a Wescan nitrogen analyzer.

Specific methods for analyses were as follows:

Hach Test - The instrument was calibrated using two standard solutions. One ml of expressed sap was mixed with 25 ml of 0.075 molar aluminum sulfate solution. The electrode was immersed in the solution and a reading was recorded. The reading was related to concentration of nitrate-N in the sap by using a standard curve.

Horiba/Cardy Test - The instrument was calibrated using two standard solutions, 34 and 450 ppm nitrate-N. A few drops of nondiluted sap were placed on the electrode membrane and a direct reading of nitrate-N was recorded.

Wescan Sap Test - The instrument was calibrated using five standard solutions. One ml of expressed sap was mixed with water to a volume of 100 ml in a volumetric flask. Diluted solutions were run through the instrument and the reading recorded was related to the concentration of nitrate-N in the sap using a standard curve.

Wescan Petiole Nitrate Test - The instrumental set up was the same as for the sap test. Dried petioles were ground and 0.1 g of ground tissue was weighed and mixed with 20 ml of water. Samples were shaken for 30 minutes and then filtered. The reading recorded was related to concentration of nitrate-N in dried tissue using a standard curve.

Nitrate-N was determined in soil samples collected one week after harvest. Samples consisted of 3 cores from an individual plot taken to a depth of 3 feet at 1 foot increments. All samples were brought back to the lab and air dried. Nitrate and ammonium were extracted with 2 N KCl using a 5 g to 25 ml soil:extractant ratio. Results are expressed as pounds of nitrate-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.

Suction tubes, consisting of a porous ceramic cup and 1.5" diameter PVC tubes, were installed one week after planting in one of the sample rows and between the rows at the 4 ft depth. Nitrate-N in soil water was determined in samples collected every 1-2 weeks from the suction tubes.

Three plants from the other sample row from each plot were harvested on June 22 to determine the effects of the N treatments on initial growth. Samples were dried, weighed, and ground. Total N was determined using the salicylic Kjeldahl method. At harvest, vines were cut and weighed 5 days prior to harvest. Potatoes were mechanically harvested on September 15. Subsamples of vines and tubers were collected to determine dry matter and N accumulation. Tubers were evaluated for hollow heart and specific gravity was determined.

RESULTS

Rainfall and Soil Nitrate Movement. Weekly precipitation over the course of the season is presented in Figure 1. Leaching events (> 2" rainfall/day) only occurred three times, at 58, 111, and 130 days after planting. Seasonal nitrate-N concentrations in soil water extracted with the suction tubes at the 4 ft depth in and between the row for each treatment are shown in Figures 2 to 11. Although nitrate-N in the soil water was measured, these numbers do not represent the concentration of nitrate in the ground water. Nor do they indicate the amount of nitrate lost to the ground water. The only way these data can be interpreted is in a more qualitative sense. That is, a higher peak for one treatment compared to another at a given time, indicates that losses of nitrate were relatively greater, but does not indicate how much greater. These data, therefore, can be used to determine which treatments minimized nitrate movement out of the root zone.

The control treatment, where no fertilizer N was applied, had nitrate-N concentrations that increased to 20 ppm during the first 12 weeks of the growing season (Figure 2). This nitrate originated from organic matter mineralization that occurs following tillage.

Differences in nitrate movement due to N sources (urea vs. ammonium nitrate) were not that apparent (Figs. 3, 4, 5 vs. 6, 7, 8) possibly due to the fact that leaching was not a problem until later in the growing season. Higher concentrations of nitrate were generally found in the row compared to between the row with little difference between nonpost-hilling and post-hilling applications at equivalent rates. Exceptions were post-hilling treatments 9 and 10, where high in row nitrate levels were found (Figs 10 and 11). Reasons for this higher level for these treatments are unclear. Higher rates of N generally resulted in higher nitrate concentrations in and between the row (Figs. 4, 7, 8 vs. 2, 3, 6, 7, 10) regardless of timing. By the end of the season after harvest, nitrate-N in soil water tended to increase for all treatments. Even though winter rye was planted, nitrate may have already moved beyond where the rye roots could take it up.

One week after harvest, extractable soil nitrate was higher in the N fertilized plots compared to the 0 N control, but there was little difference in soil nitrate concentrations among the N fertilized treatments (Table 1).

Tuber Yield, Specific Gravity, Hollow Heart, and Vine Yield. The effects of the various N treatments on tuber yield, specific gravity, hollow heart, and vine yield are presented in Table 3. Total yield increased with N rate with most of the yield increase occurring between the control treatment and 120 lb N/A (treatment 8). The 7-14 oz tuber size increased significantly with N rate. Vine yield also increased with increasing N rate. Specific gravity of tubers from the control treatment was generally higher than in those receiving N. Specific gravity decreased with increasing N rate. At similar N rates and timing of application, there was little difference between urea and ammonium nitrate on vine and tuber and vine yields. Specific gravity was similar for the urea and ammonium nitrate treatments when applied at equal rates. The post-hilling N application treatments 3 and 6 resulted in equal total yields compared to 240 lbs N/A applied through hilling (treatments 2 and 5). Post-hilling treatments resulted in greater yield of 7 - 14 oz potatoes compared to all the N applied up to hilling. Specific gravity was not affected by post-hilling N applications. Additional N after hilling resulted in larger tubers compared to the lower rates applied up to hilling; however, specific gravity was lower with the post-hilling N applications. Hollow heart tended to increase with increasing N rate but was not significantly affected by timing of N application.

Treatment Effects on Early Plant Growth. Increasing nitrogen rate resulted in more tubers per plant, greater dry matter accumulation, and higher N concentrations in plants sampled one week after hilling (Table 2). Ammonium nitrate did result in more tubers, and greater dry matter accumulation in vines and roots, and higher tissue N concentrations compared to urea. These results suggest that ammonium nitrate may be beneficial for early harvested potatoes. As expected all N applied up to hilling resulted in higher tissue N concentrations than post-hilling treatments since all the post-hilling N applications had not yet been applied.

Dry Matter and Nitrogen Accumulation. Dry matter and N accumulation, as well as concentrations of N in vines and tubers at harvest, are presented in Table 4. As expected, dry weight, N concentrations in vines and tubers, and N accumulation increased with increasing N rate. At equivalent N rates, post-hilling N applications increased N concentrations in vines and tubers compared to all N applied up to hilling, but did not significantly increase total N uptake. Dry matter accumulation was slightly lower with post-hilling N applications, which accounted for the lack of an effect on n uptake despite higher N concentrations with post-hilling applications. Nitrogen uptake and dry matter production were not affected by N source (urea vs. ammonium nitrate).

Nitrate-N Concentrations in Petiole Samples. The N status of the plant (sampled every 10-14 days starting one day before hilling), as measured by conventional petiole analysis and sap analysis, is presented in Table 5. On all sampling dates, nitrate on a dry weight or sap basis increased with increasing N rate. On the first sampling date, petiole nitrate concentrations were lower with the urea N source than with ammonium nitrate. After this date, petiole nitrate levels were not generally affected by N source. The lower level of petiole nitrate early may have been due to cooler weather inhibiting conversion of ammonium to nitrate for the urea N source. Differences in petiole nitrate due to post-hilling applications were not apparent until July 21. Sap Nitrate-N concentrations determined with the Cardy meter were 50 to 100 ppm higher than the those determined with the Hach or Wescan instruments.

SUMMARY

The 1993 season at Becker was a moderate year for nitrate leaching. Nitrogen rate significantly affected nitrate losses under irrigated potatoes. Greatest losses were observed as N rate increased. Post-hilling applications of N also reduced N losses compared to similar rates of N applied before hilling. Potato yield was primarily affected by N rate. The greatest yield increase was obtained between the 0 and 120 lb N/A increment. Petiole sap nitrate tests using portable nitrate electrodes appear to have promise for determining N status of the crop; however, using the N status to predict N needs will require additional calibration research to evaluate timing and rates of post-hilling application to maximize yield.

Table 1. Effect of nitrogen treatments on soil nitrate-N in the top 3 ft. (pounds per acre ± one standard deviation) at the end of the growing season. Becker, MN.

Treatment N source	Treatment N timing	0 to 1 foot	1 to 2 foot	2 to 3 foot	Field total
		Pounds per acre			
1. Control	(0 N/A)	3.47 ± 2.06	3.28 ± 1.77	1.11 ± 0.41	7.86 ± 3.55
2. (46-0-0)	(40,100,100)[1]	9.98 ± 4.28	7.91 ± 6.21	1.68 ± 1.13	19.57 ± 10.49
3. (46-0-0)	(20,70,70)+80[2]	9.80 ± 4.01	8.33 ± 2.62	1.32 ± 0.63	21.95 ± 2.76
4. (46-0-0)	(20,70,70)	8.02 ± 5.02	8.17 ± 1.85	1.58 ± 0.30	17.77 ± 6.08
5. (34-0-0)	(40,100,100)	12.31 ± 5.25	6.77 ± 3.95	1.03 ± 0.68	20.11 ± 9.05
6. (34-0-0)	(20,70,70)+80[2]	9.82 ± 5.96	9.33 ± 4.35	1.74 ± 0.58	20.89 ± 10.21
7. (34-0-0)	(20,70,70)	10.27 ± 4.95	11.46 ± 3.48	2.07 ± 0.64	23.80 ± 6.92
8. (34-0-0)	(40,40,40)	7.50 ± 5.65	6.26 ± 3.34	1.89 ± 0.77	15.65 ± 9.31
9. (34-0-0)	(40,40,40)+60[3]	7.10 ± 4.08	5.81 ± 2.98	1.35 ± 0.76	14.26 ± 6.06
10. (34-0-0)	(40,40,40)+80[2]	12.21 ± 5.41	7.73 ± 3.52	2.26 ± 1.20	22.20 ± 9.41

[1] = Planting, emergence, and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis.

Table 2. Effect of nitrogen treatments on fresh weight of vines, tubers, and hollow heart. Becker, MN.

Treatment N source	Treatment N timing	Fresh weight: Vines (Tons/A)	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total	Specific Gravity	Hollow Heart-% incidence
			cwt/A							
1. Control	(0 N/A)	0.78	11.9	16.9	132.8	65.1	4.4	231.2	1.0874	2.0
2. (46-0-0)	(40,100,100)[1]	3.42	59.0	28.3	144.9	167.9	55.2	455.2	1.0825	10.0
3. (46-0-0)	(20,70,70)+80[2]	5.00	35.4	22.4	143.8	196.3	53.8	451.8	1.0831	14.7
4. (46-0-0)	(20,70,70)	1.91	63.3	28.0	156.5	160.6	28.0	436.5	1.0873	17.0
5. (34-0-0)	(40,100,100)	4.88	63.2	28.9	148.3	192.6	42.2	475.3	1.0828	12.0
6. (34-0-0)	(20,70,70)+80[2]	5.54	36.6	26.0	139.9	200.7	55.7	458.8	1.0812	10.0
7. (34-0-0)	(20,70,70)	1.51	66.3	31.6	153.1	169.6	21.8	442.5	1.0850	12.0
8. (34-0-0)	(40,40,40)	0.76	61.6	26.7	175.0	144.5	10.0	417.8	1.0885	6.0
9. (34-0-0)	(40,40,40)+60[3]	2.76	51.6	33.5	153.9	175.0	32.4	446.4	1.0843	15.0
10. (34-0-0)	(40,40,40)+80[2]	3.16	47.0	28.9	155.9	163.4	53.1	448.3	1.0810	5.0
Significance		**	**	NS	*	**	**	**	**	NS
BLSD (0.05)		1.44	20.1	--	27.1	28.6	16.8	24.0	0.0030	--
Contrasts										
Lin Rate N (1, 5, 7, 8)		**	**	*	NS	**	**	**	**	*
Quad Rate N (1, 5, 7, 8)		*	**	NS	*	**	NS	**	NS	NS
Post-hilling (2, 5) vs (3, 6)		*	**	NS	NS	++	NS	NS	NS	NS
(2, 3, 4) vs (5, 6, 7)		NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment 3 vs 4		**	**	NS	NS	*	**	NS	NS	NS
Treatment 6 vs 7		**	**	NS	NS	*	**	NS	*	NS
Treatment 9 vs 10		NS	**	NS	NS	NS	*	NS	*	++

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3. Effect of nitrogen treatments on root and vine dry matter, tuber number and dry matter; sampled June 22, 1993 - Becker, MN.

Treatment			Tubers	dry matter				N concentration		
	N source	N timing		Tuber	Vine	Root	Total	Tuber	Vine	Root
			-#/plant-	g/plant				% N		
1.	Control	(0 N/A)	3.83	2.2	8.3	1.8	12.3	1.48	3.01	1.49
2.	(46-0-0)	(40,100,100)[1]	5.25	7.0	31.5	2.8	41.3	1.98	4.88	2.41
3.	(46-0-0)	(20,70,70)+80[2]	5.55	5.8	32.4	2.8	41.0	2.17	5.22	2.58
4.	(46-0-0)	(20,70,70)	5.83	5.5	28.7	2.4	36.6	1.92	4.88	2.36
5.	(34-0-0)	(40,100,100)	6.33	5.2	41.7	3.2	50.0	2.00	5.25	2.40
6.	(34-0-0)	(20,70,70)+80[2]	7.08	6.3	35.4	3.3	45.1	2.29	5.67	2.70
7.	(34-0-0)	(20,70,70)	8.33	8.3	35.1	3.2	47.4	1.80	5.06	2.43
8.	(34-0-0)	(40,40,40)	5.66	5.7	38.4	3.2	47.3	1.94	4.63	2.43
9.	(34-0-0)	(40,40,40)+60[3]	6.25	7.3	35.1	3.0	45.3	1.87	4.58	2.19
10.	(34-0-0)	(40,40,40)+80[2]	8.33	9.7	38.9	3.3	51.8	2.17	5.26	2.34
Significance			NS	NS	**	**	**	**	**	**
BLSD (0.05)			--	--	5.4	0.6	7.5	0.25	0.20	0.22
Contrasts										
Lin Rate N (1, 5, 7, 8)			*	NS	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			NS	NS	**	*	**	**	**	**
Post-hilling (2, 5) vs (3, 6)			NS	NS	NS	NS	NS	**	**	*
(2, 3, 4) vs (5, 6, 7)			++	NS	**	**	**	NS	**	NS
Treatment 3 vs 4			NS	NS	NS	NS	NS	*	**	++
Treatment 6 vs 7			NS	NS	NS	NS	NS	**	**	*
Treatment 9 vs 10			NS	NS	NS	NS	NS	*	**	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 4. Effect of nitrogen on N content, concentration, and dry matter production. Becker, MN

Treatment			Nitrogen content			N concentration		Dry matter		
	N source	N timing	Vines	Tubers	Total	Vine	Tubers	Vines	Tubers	Total
			lbs/A			% N		Tons/A		
1.	Control	(0 N/A)	4.7	51.1	55.8	1.28	1.01	0.18	2.52	2.70
2.	(46-0-0)	(40,100,100)[1]	25.6	131.3	157.0	1.42	1.37	0.88	4.83	5.70
3.	(46-0-0)	(20,70,70)+80[2]	26.2	138.4	164.6	1.85	1.53	0.71	4.50	5.22
4.	(46-0-0)	(20,70,70)	13.7	112.4	126.2	1.03	1.16	0.67	4.84	5.51
5.	(34-0-0)	(40,100,100)	22.8	137.6	160.4	1.58	1.40	0.73	4.94	5.66
6.	(34-0-0)	(20,70,70)+80[2]	31.0	143.8	174.8	2.05	1.50	0.76	4.81	5.58
7.	(34-0-0)	(20,70,70)	16.6	119.5	136.2	1.18	1.24	0.71	4.78	5.49
8.	(34-0-0)	(40,40,40)	8.2	94.7	102.9	0.80	1.02	0.52	4.67	5.19
9.	(34-0-0)	(40,40,40)+60[3]	17.8	123.2	141.0	1.54	1.31	0.58	4.73	5.31
10.	(34-0-0)	(40,40,40)+80[2]	24.6	141.6	166.2	1.73	1.52	0.71	4.68	5.39
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			8.7	16.6	18.4	0.28	0.18	0.26	0.37	0.42
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	++	**	**	**	**
Quad Rate N (1, 5, 7, 8)			NS	**	**	NS	NS	NS	**	**
Post-hilling (2, 5) vs (3, 6)			NS	NS	NS	**	*	NS	NS	++
(2, 3, 4) vs (5, 6, 7)			NS	NS	NS	++	NS	NS	NS	NS
Treatment 3 vs 4			**	**	**	**	**	NS	NS	NS
Treatment 6 vs 7			**	*	**	**	**	NS	NS	NS
Treatment 9 vs 10			NS	*	*	NS	*	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 5. Effect of nitrogen treatments on nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment			June 10				June 24			
	N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	1676	211	159	122	1035	160	100	88
2.	(46-0-0)	(40,100,100)[1]	21779	1438	1260	1135	20688	1650	1288	1295
3.	(46-0-0)	(20,70,70)+80[2]	20844	1325	1209	1110	21662	1625	1308	1324
4.	(46-0-0)	(20,70,70)	22260	1538	1369	1187	20579	1600	1324	1241
5.	(34-0-0)	(40,100,100)	24332	1575	1425	1301	24584	1650	1261	1295
6.	(34-0-0)	(20,70,70)+80[2]	25143	1688	1469	1376	23198	1625	1346	1376
7.	(34-0-0)	(20,70,70)	24814	1625	1490	1380	21414	1600	1233	1249
8.	(34-0-0)	(40,40,40)	24106	1563	1376	1261	14265	1225	931	936
9.	(34-0-0)	(40,40,40)+60[3]	22730	1550	1303	1205	15054	1200	956	1089
10.	(34-0-0)	(40,40,40)+80[2]	24274	1538	1360	1255	19149	1525	1209	1204
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			1884	217	128	86	1817	156	124	126
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Post-hilling (2, 5) vs (3, 6)			NS	NS	NS	NS	NS	NS	NS	NS
(2, 3, 4) vs (5, 6, 7)			**	**	**	**	**	NS	NS	NS
Treatment 3 vs 4			NS	++	*	NS	NS	NS	NS	NS
Treatment 6 vs 7			NS	NS	NS	NS	++	NS	NS	++
Treatment 9 vs 10			NS	NS	NS	NS	**	**	**	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 5 cont. Effect of nitrogen treatments on nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment			July 8				July 21			
	N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	215	73	49	37	995	158	115	93
2.	(46-0-0)	(40,100,100)[1]	21451	1388	1295	1276	17670	1425	1356	1339
3.	(46-0-0)	(20,70,70)+80[2]	22951	1438	1385	1362	22257	1575	1475	1442
4.	(46-0-0)	(20,70,70)	17099	1200	1117	1099	4367	458	383	365
5.	(34-0-0)	(40,100,100)	22120	1488	1306	1342	17216	1375	1235	1217
6.	(34-0-0)	(20,70,70)+80[2]	21320	1375	1286	1235	18624	1375	1369	1359
7.	(34-0-0)	(20,70,70)	15678	1150	1067	1033	3853	503	431	401
8.	(34-0-0)	(40,40,40)	5986	550	458	434	384	136	67	44
9.	(34-0-0)	(40,40,40)+60[3]	15401	1275	1134	1099	15864	1350	1249	1223
10.	(34-0-0)	(40,40,40)+80[2]	16466	1175	1079	1032	13931	1300	1171	1128
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			1768	153	127	127	1867	164	121	120
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Post-hilling (2, 5) vs (3, 6)			NS	NS	NS	NS	**	NS	*	*
(2, 3, 4) vs (5, 6, 7)			NS	NS	NS	NS	*	NS	NS	NS
Treatment 3 vs 4			**	**	**	**	**	**	**	**
Treatment 6 vs 7			**	*	**	**	**	**	**	**
Treatment 9 vs 10			NS	NS	NS	NS	++	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis.

Table 5. Effect of nitrogen treatments on nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

	Treatment		Date							
			June 10				June 24			
	N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	1676	211	159	122	1035	160	100	88
2.	(46-0-0)	(40,100,100)[1]	21779	1438	1260	1135	20688	1650	1288	1295
3.	(46-0-0)	(20,70,70)+80[2]	20844	1325	1209	1110	21662	1625	1308	1324
4.	(46-0-0)	(20,70,70)	22260	1538	1369	1187	20579	1600	1324	1241
5.	(34-0-0)	(40,100,100)	24332	1575	1425	1301	24584	1650	1261	1295
6.	(34-0-0)	(20,70,70)+80[2]	25143	1688	1469	1376	23198	1625	1346	1376
7.	(34-0-0)	(20,70,70)	24814	1625	1490	1380	21414	1600	1233	1249
8.	(34-0-0)	(40,40,40)	24106	1563	1376	1261	14265	1225	931	936
9.	(34-0-0)	(40,40,40)+60[3]	22730	1550	1303	1205	15054	1200	956	1089
10.	(34-0-0)	(40,40,40)+80[2]	24274	1538	1360	1255	19149	1525	1209	1204
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			1884	217	128	86	1817	156	124	126
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Post-hilling (2, 5) vs (3, 6)			NS	NS	NS	NS	NS	NS	NS	NS
(2, 3, 4) vs (5, 6, 7)			**	**	**	**	**	NS	NS	NS
Treatment 3 vs 4			NS	++	*	NS	NS	NS	NS	NS
Treatment 6 vs 7			NS	NS	NS	NS	++	NS	NS	++
Treatment 9 vs 10			NS	NS	NS	NS	**	**	**	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 5 cont. Effect of nitrogen treatments on nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

	Treatment		Date							
			July 8				July 21			
	N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	215	73	49	37	995	158	115	93
2.	(46-0-0)	(40,100,100)[1]	21451	1388	1295	1276	17670	1425	1356	1339
3.	(46-0-0)	(20,70,70)+80[2]	22951	1438	1385	1362	22257	1575	1475	1442
4.	(46-0-0)	(20,70,70)	17099	1200	1117	1099	4367	458	383	365
5.	(34-0-0)	(40,100,100)	22120	1488	1306	1342	17216	1375	1235	1217
6.	(34-0-0)	(20,70,70)+80[2]	21320	1375	1286	1235	18624	1375	1369	1359
7.	(34-0-0)	(20,70,70)	15678	1150	1067	1033	3853	503	431	401
8.	(34-0-0)	(40,40,40)	5986	550	458	434	384	136	67	44
9.	(34-0-0)	(40,40,40)+60[3]	15401	1275	1134	1099	15864	1350	1249	1223
10.	(34-0-0)	(40,40,40)+80[2]	16466	1175	1079	1032	13931	1300	1171	1128
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			1768	153	127	127	1867	164	121	120
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Post-hilling (2, 5) vs (3, 6)			NS	NS	NS	NS	**	NS	*	*
(2, 3, 4) vs (5, 6, 7)			NS	NS	NS	NS	*	NS	NS	NS
Treatment 3 vs 4			**	**	**	**	**	**	**	**
Treatment 6 vs 7			**	*	**	**	**	**	**	**
Treatment 9 vs 10			NS	NS	NS	NS	++	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 5 cont. Effect of nitrogen treatments on nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment			Date							
			August 4				August 18			
	N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	67	94	44	12	20	58	37	3
2.	(46-0-0)	(40,100,100)[1]	9704	851	737	704	2486	250	202	182
3.	(46-0-0)	(20,70,70)+80[2]	15053	1263	1174	1120	5660	604	501	522
4.	(46-0-0)	(20,70,70)	1836	334	246	227	168	78	55	23
5.	(34-0-0)	(40,100,100)	8487	891	782	749	2587	245	196	182
6.	(34-0-0)	(20,70,70)+80[2]	15929	1188	1071	1046	5563	530	431	441
7.	(34-0-0)	(20,70,70)	1510	270	205	168	209	78	57	26
8.	(34-0-0)	(40,40,40)	161	101	55	18	151	66	40	10
9.	(34-0-0)	(40,40,40)+60[3]	9181	828	775	732	1474	205	171	154
10.	(34-0-0)	(40,40,40)+80[2]	16651	1150	1053	1033	3386	378	302	299
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			2080	106	96	98	1571	115	98	108
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			**	**	**	**	++	++	NS	++
Post-hilling (2, 5) vs (3, 6)			**	**	**	**	**	**	**	**
(2, 3, 4) vs (5, 6, 7)			NS	NS	NS	NS	NS	NS	NS	NS
Treatment 3 vs 4			**	**	**	**	**	**	**	**
Treatment 6 vs 7			**	**	**	**	**	**	**	**
Treatment 9 vs 10			**	**	**	**	*	**	*	*

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

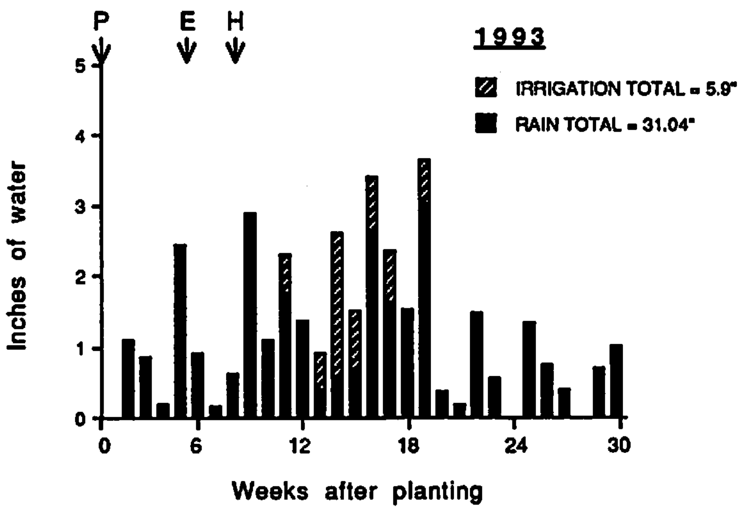

Figure 1. Rainfall and irrigation at Becker, MN during the 1993 growing season. P, H and E = planting, emergence and hilling, respectively.

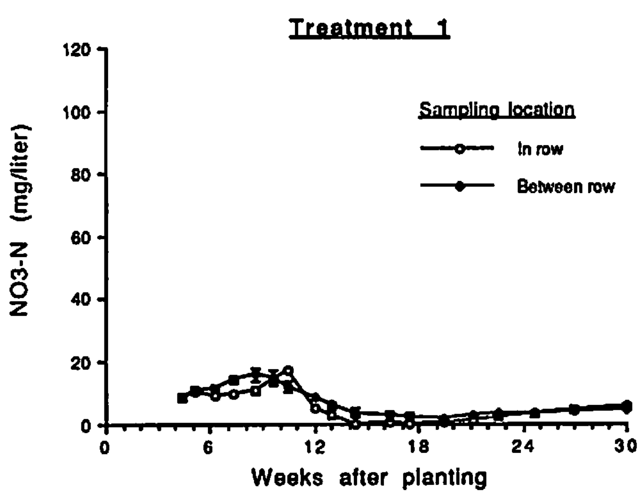

Figure 2. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: no nitrogen. Error bar represents SE of the mean.

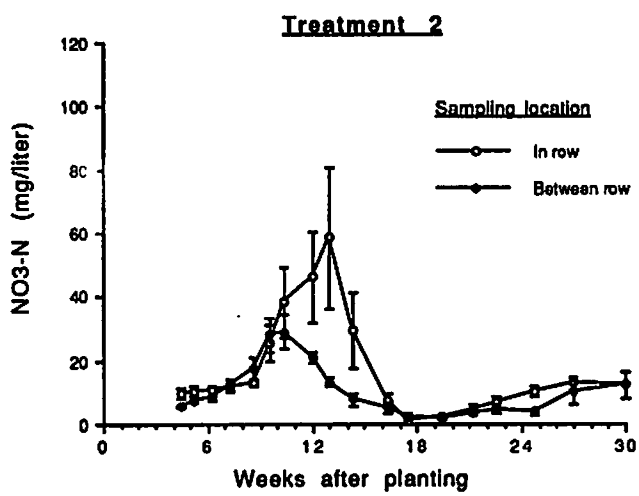

Figure 3. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (46-0-0). Error bars represent SE of the mean.

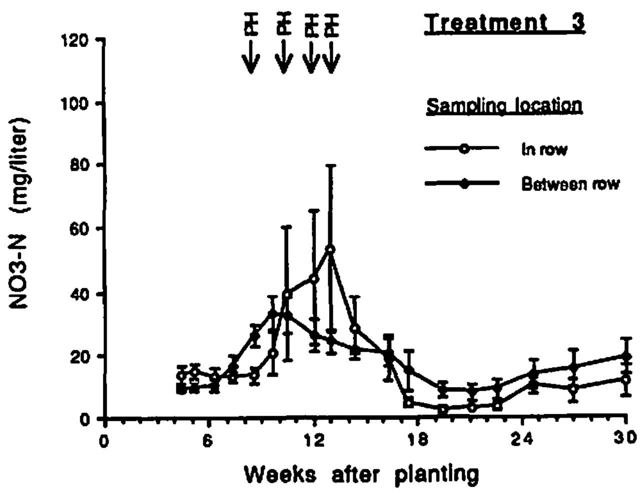

Figure 4. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 20 lb N/A at planting, 70 lb at emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (46-0-0). Error bars represent SE of the mean. PH = post-hilling application.

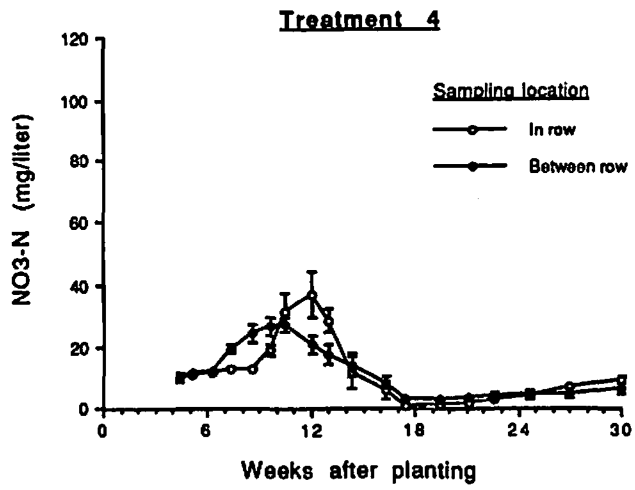

Figure 5. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 20 lb N/A at planting and 70 lb at emergence and hilling (46-0-0). Error bars represent SE of the mean.

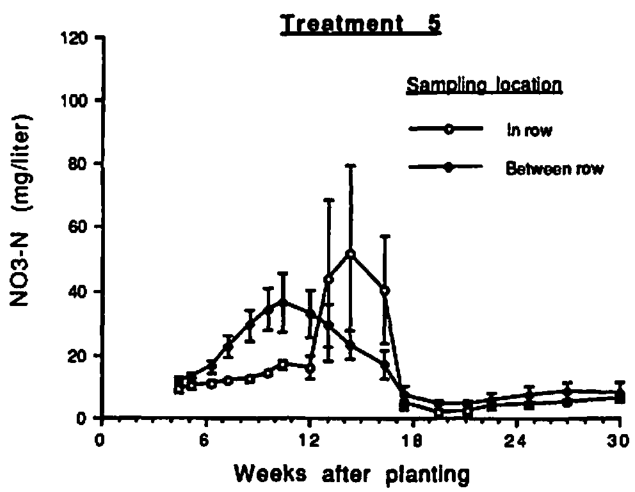

Figure 6. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

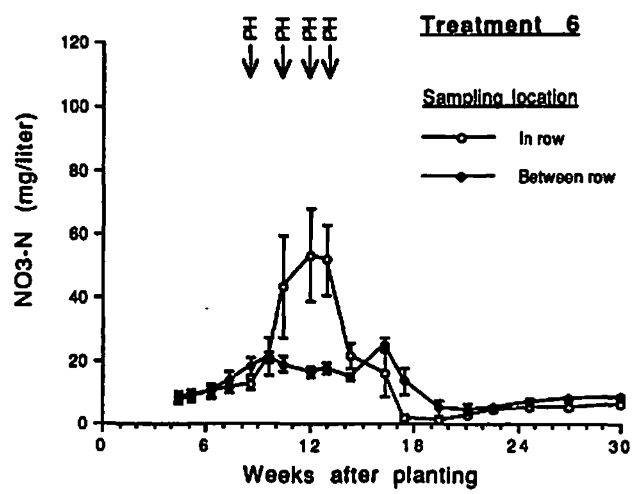

Figure 7. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 20 lb N/A at planting, 70 lb at emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (34-0-0). Error bars represent SE of the mean. PH = post-hilling application.

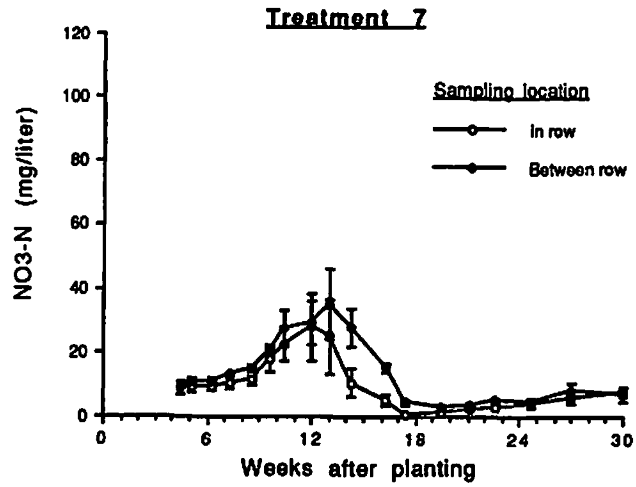

Figure 8. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 20 lb N/A at planting and 70 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

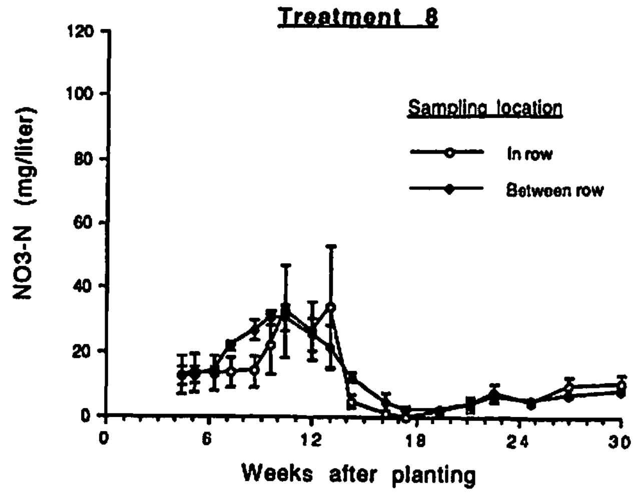

Figure 9. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling (34-0-0). Error bars represent SE of the mean.

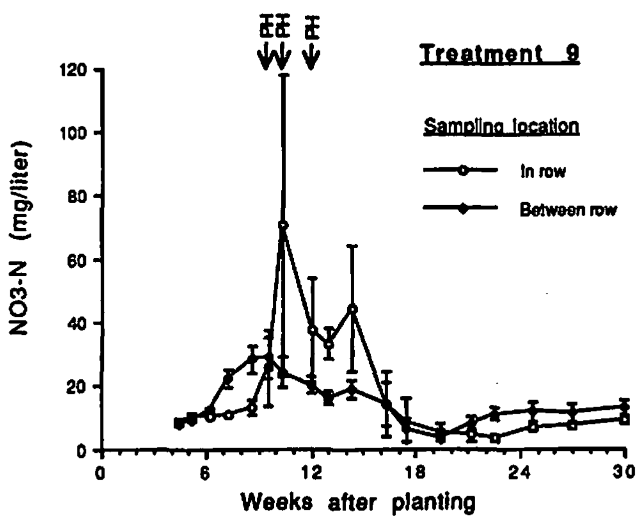

Figure 10. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling, plus three post hilling applications at 20 lb N/A each (34-0-0). Error bars represent SE of the mean. PH = post-hilling application.

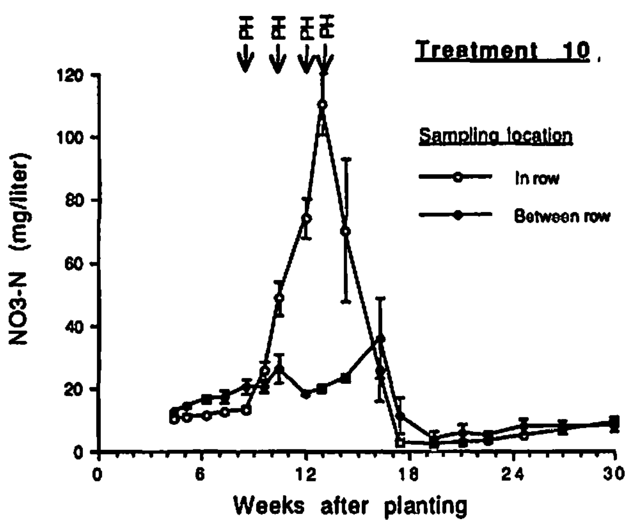

Figure 11. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1993 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling, plus four post-hilling applications at 20 lb N/A each (34-0-0). Error bars represent SE of the PH = post-hilling application.

PHOSPHORUS REQUIREMENTS FOR POTATOES ON SANDY SOILS - 1993

Carl Rosen, Dave Birong, and Glenn Titrud

ABSTRACT: Response of Russet Burbank and Norland potatoes to phosphate fertilizer on low and high P testing sites was evaluated. Phosphate fertilizer increased early tuber growth in both cultivars on low and high P testing soils. However, effects on final yield were not consistent. For Russet Burbank, P fertilizer had no effect on yields on high testing soils, but increased larger size tubers on low testing soils. For Norland, total tuber yield increased up to 150 lb P_2O_5/A in the low testing soil, with the greatest response to fertilizer occurring between the 0 to 50 lb P_2O_5. In the high testing soil, Norland tended to increase with phosphate fertilizer, up to 50 lb P_2O_5/A with an unusual increase when 250 lb P_2O_5/A was applied. Phosphate fertilizer increased phosphorus concentrations in petiole and leaf (leaflet plus petiole) tissue. However, phosphorus concentrations were 20-25% higher in leaf tissue compared to petiole tissue. Leaf tissue tended to be more sensitive than petiole tissue to phosphate fertilizer induced changes in micronutrient concentrations. In addition to increasing tissue P, phosphate fertilizer tended to increase tissue calcium, and decrease tissue copper.

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 even on soils testing above 25 ppm. The objective of this study, therefore, was to evaluate the response of early harvested Norland and late harvested Russet Burbank 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 soils 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	Rye	Alfalfa/rye
Soil pH (1:1 - soil:water)	5.7	6.0
Bray P1	57 ppm	21 ppm
K - NH4OAc	177 ppm	95 ppm

The high P site had a history of potatoes from 1986 to 1988 prior to rye from 1989 to 1992. The low P site was planted to alfalfa in 1986 and was plowed under in 1991. In 1992 the low P site was planted to rye. Prior to planting, 250 lb sul-po-mag and 100 lb K_2O (as 0-0-60) were broadcast and incorporated at both sites. Norland and Russet Burbank "B" size potatoes were planted on April 16, 1993 at a spacing of 36" between rows and 10" within the row. Each plot consisted of four, 20' rows. At planting, all plots received 50 lb N/A and 200 lb K_2O. Phosphate fertilizer (triple superphosphate, 0-46-0) treatments were as follows: 0, 50, 100, 150, 200, 250 lb P_2O_5/A. Phosphate fertilizer (along with nitrogen and potash) was applied as a band 3 inches to each side and 2 inches below the row. Post-planting nitrogen was applied at the rate of 85 lb N/A at emergence for Norland (May 20). For Russet Burbank, post-planting N included 85 lb N/A emergence (May 20) and 100 lb N/A at hilling (June 8). Within each site, cultivars were planted in two strips. From a statistical standpoint, therefore, each cultivar will be analyzed separately. Within each cultivar, 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 on June 29. On half of the samples the leaflets were removed and only the petioles were saved. Both whole leaf samples and petiole samples were dried and ground through a 30 mesh screen for subsequent elemental analyses. Whole plant samples (two plants per plot) were collected on June 28 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 September 9 and tubers were graded according to weight classes: <3 oz, 3-7 oz, 7-14 oz, and >14 oz. A subsample of tubers was saved for specific gravity determination and hollow heart incidence.

[1]We thank the Area II potato growers for providing funds to support this project.

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

RESULTS

Early plant growth: Dry weight of Russet Burbank vines, roots, and tubers sampled in June are presented in Tables 1 and 2. For the high P testing site, phosphate fertilizer increased dry weight of tubers, but not roots or vines. Tuber number was not affected by phosphate fertilizer application in the high testing site. For the low P testing site, phosphate fertilizer increased dry weight of vines, roots, and tubers. Tuber number was not affected by phosphate fertilizer. Dry weight of Norland vines, roots, and tubers sampled on June 28 are presented in Tables 3 and 4. For the high P testing site, phosphate fertilizer increased dry weight of tubers, but not roots or vines. Tuber number was not significantly affected by phosphate fertilizer application in the high testing site. For the low P testing site, phosphate fertilizer increased dry weight of vines and tubers. Tuber number was not affected by phosphate fertilizer.

Tuber yield: Tuber yield, size distribution, specific gravity, and hollow heart for Russet Burbank are presented in Tables 5 and 6. For the high P testing site, phosphate fertilizer had no effect on tuber yield or quality. In the low P testing site, significant yield increases were obtained in the greater than 14 oz size category. Knobby tubers also tended to increase with phosphate fertilizer. Tuber yield, size distribution, specific gravity, and hollow heart for Norland are presented in Tables 7 and 8. For the high P testing site, phosphate fertilizer increased tuber yield and decrease hollow heart incidence. The yield response up to 250 lb P_2O_5/A was unusual and not consistent with response up to 150 lb P_2O_5/A. In the low P testing site, phosphate fertilizer increased total yield up to 150 lb P_2O_5/A.

Leaf and petiole nutrient concentrations: Nutrient concentrations were determined in petiole and leaf (leaflets plus petioles) samples to determine how the type of tissue sampled affects diagnostic interpretations (Tables 9-16). Concentrations of phosphorus in both cultivars increased with increasing phosphate fertilizer rate in both petiole and leaf tissue in low and high P testing sites. Concentrations of P were approximately 25% higher in leaf tissue compared to petioles. Total N was not affected by phosphate fertilizer. In contrast, petiole nitrate-N tended to decrease with P treatment. Concentrations of nitrogen in leaves and nitrate in petioles were generally higher when alfalfa was the previous crop compared to rye even though the alfalfa had been plowed under two years before the experiment was initiated. Potassium concentrations in petioles were approximately twice as high as those in leaf tissue. Phosphate fertilizer did not consistently affect potassium concentrations in the tissues sampled. Calcium concentrations were similar in petiole and leaf tissue, while magnesium concentrations were lower in petiole tissue compared to leaf tissue. Calcium tended to increase with increasing phosphate fertilizer, probably due to the fact that 0-46-0 contains significant Ca. Iron concentrations were approximately twice as high in leaf tissue compared to petiole tissue. Phosphate fertilizer had no effect on leaf or petiole iron for either cultivar. Manganese concentrations were higher in leaf tissue than in petiole tissue. Phosphate fertilizer generally had no effect on manganese tissue concentrations. Petiole and leaf tissue had similar concentrations of zinc. Zinc concentrations were not consistently affected by phosphate fertilizer application. Copper concentrations were higher in leaf tissue than in petiole tissue. Phosphate fertilizer tended to decrease leaf and petiole copper concentrations in both low and high P sites. Petiole and leaf tissue had similar concentrations of boron. Increasing phosphate fertilizer had inconsistent effects on tissue boron. It is clear from these results that nutrient diagnostic criteria for petiole tissue will be different from the criteria used for leaf tissue.

Table 1. Effect of phosphate fertilizer on dry matter of Russet Burbank potato vines, roots, tubers, and number of tubers - sampled June 28, 1993. Previous crop - Rye; initial soil test P - 57 ppm.

Phosphate Treatment	Plant Part			
lb $P2O_5$	vines	roots	tubers	number of tubers
	grams/plant			per plant
0	62.00	14.20	20.25	12.38
50	69.38	14.95	26.00	11.13
100	73.38	14.26	29.00	9.88
150	74.25	14.91	27.75	10.75
200	67.50	14.30	29.75	9.88
250	70.88	14.40	20.25	10.38
Pr>F	0.91	0.69	0.57	0.89
Lin P_2O_5	NS	NS	NS	NS
Quad P_2O_5	NS	NS	++	NS
Cubic P_2O_5	NS	NS	NS	NS

NS = nonsignificant, ++ = significant at 10%.

Table 2. Effect of phosphate fertilizer on dry matter of Russet Burbank vines, roots, tubers, and number of tubers - sampled June 28, 1993. Previous crop - alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment lb P_2O_5	Plant Part vines	roots	tubers	number of tubers
	grams/plant			per plant
0	38.00	13.64	17.50	9.13
50	57.50	14.36	21.75	8.75
100	63.75	14.44	23.00	8.50
150	71.75	14.79	30.50	10.13
200	66.13	13.99	25.00	9.75
250	71.13	15.00	28.25	10.38
Pr>F	0.04	0.09	0.42	0.98
Lin P_2O_5	**	*	++	NS
Quad P_2O_5	++	NS	NS	NS
Cubic P_2O_5	NS	++	NS	NS

NS = nonsignificant; ++, *, ** = significant at 10%, 5% and 1%,respectively.

Table 3. Effect of phosphate fertilizer on dry matter of Norland potato vines, roots, tubers, and number of tubers - sampled June 28, 1993. Previous crop - Rye; initial soil test P - 57 ppm.

Phosphate Treatment lb $P2O_5$	Plant Part vines	roots	tubers	number of tubers
	grams/plant			per plant
0	43.25	14.42	47.00	9.00
50	46.50	14.68	59.00	14.50
100	62.13	15.61	73.00	13.00
150	58.63	15.31	66.75	13.63
200	54.25	14.99	64.25	12.50
250	56.75	15.40	61.75	14.63
Pr>F	0.26	0.63	0.33	0.45
Lin P_2O_5	NS	NS	NS	NS
Quad P_2O_5	NS	NS	++	NS
Cubic P_2O_5	NS	NS	NS	NS

NS = nonsignificant, ++ = significant at 10%.

Table 4. Effect of phosphate fertilizer on dry matter of Norland vines, roots, tubers, and number of tubers - sampled June 28, 1993. Previous crop - alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment lb P_2O_5	Plant Part vines	roots	tubers	number of tubers
	grams/plant			per plant
0	46.63	14.36	36.75	10.75
50	61.00	15.74	56.00	13.38
100	57.38	14.86	49.50	11.63
150	59.00	15.74	54.00	12.00
200	74.13	15.49	63.75	14.38
250	65.00	14.86	60.50	12.88
Pr>F	0.03	0.48	0.29	0.73
Lin P_2O_5	**	NS	*	NS
Quad P_2O_5	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS

NS = nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 5. Effect of phosphate fertilizer on yield and specific gravity of Russet Burbank potatoes. Previous crop - Rye; initial soil test P - 57 ppm.

Phosphate Treatment	Tuber Yield						Specific Gravity	Hollow Heart
		Tuber Size						
lb P_2O_5	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total		
	cwt/A							% incidence
0	58.6	30.8	179.1	133.3	6.7	408.6	1.0770	1.0
50	39.1	41.7	165.5	111.0	2.9	360.2	1.0794	2.0
100	54.6	34.7	148.7	157.0	8.0	403.0	1.0792	3.0
150	59.6	33.7	156.3	114.4	5.8	369.9	1.0755	0.0
200	50.0	36.9	176.1	130.9	7.9	401.8	1.0775	2.0
250	53.6	36.6	165.8	133.8	8.0	397.7	1.0774	6.0
Pr>F	0.81	0.57	0.53	0.19	0.90	0.23	0.33	0.63
Lin P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS
Quad P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant.

Table 6. Effect of phosphate fertilizer on yield and specific gravity of Russet Burbank potatoes. Previous crop - Alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment	Tuber Yield						Specific Gravity	Hollow Heart
		Tuber Size						
lb P_2O_5	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total		
	cwt/A							% incidence
0	33.1	30.9	185.6	138.9	8.7	397.2	1.0810	1.0
50	56.4	31.8	173.6	169.0	23.4	454.2	1.0799	0.0
100	66.7	26.9	202.2	148.8	23.6	468.2	1.0802	2.0
150	39.1	28.9	198.3	179.9	17.8	464.0	1.0794	0.0
200	46.4	32.6	175.0	164.5	13.1	431.7	1.0814	0.0
250	36.8	33.1	168.4	148.7	26.2	413.2	1.0802	4.0
Pr>F	0.08	0.46	0.74	0.68	0.08	0.73	0.90	0.24
Lin P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS
Quad P_2O_5	*	NS	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	++	NS	NS	NS	**	NS	NS	NS

NS = nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 7. Effect of phosphate fertilizer on yield and specific gravity of Norland potatoes. Previous crop - Rye; initial soil test P - 57 ppm.

Phosphate Treatment	Tuber Yield						Specific Gravity	Hollow Heart
		Tuber Size						
lb P_2O_5	Culls	<1.75"	1.75-2.5"	2.5-3.5"	>3.5"	Total		
	cwt/A							% incidence
0	3.4	29.2	177.2	27.5	19.4	257.0	1.0695	10.0
50	5.8	27.4	195.1	28.9	22.0	279.3	1.0686	7.5
100	3.9	26.3	210.2	23.8	18.6	282.9	1.0672	5.0
150	5.3	28.8	202.2	26.0	24.6	287.0	1.0703	7.5
200	4.5	31.2	184.2	41.3	26.0	287.1	1.0697	2.5
250	3.0	31.6	215.3	25.1	29.9	305.0	1.0685	0.0
Pr>F	0.59	0.79	0.28	0.32	0.82	0.46	0.87	0.55
Lin P_2O_5	NS	NS	NS	NS	NS	++	NS	++
Quad P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	++	NS	NS	NS	NS	NS

NS = nonsignificant; ++ = significant at 10%.

Table 8. Effect of phosphate fertilizer on yield and specific gravity of Norland potatoes. Previous crop - Alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment	Tuber Yield						Specific	Hollow
		Tuber Size						
lb P_2O_5	Culls	<1.75"	1.75-2.5"	2.5-3.5"	>3.5"	Total	Gravity	Heart
	cwt/A							% incidence
0	4.1	20.6	158.6	48.4	0.0	231.8	1.0640	7.5
50	5.3	26.6	177.9	49.3	0.9	259.9	1.0651	2.5
100	3.0	30.5	187.6	40.2	0.0	261.2	1.0681	12.5
150	1.8	27.2	186.3	54.7	3.4	273.2	1.0651	7.5
200	4.8	30.7	183.4	53.0	0.0	271.9	1.0652	2.5
250	5.6	26.8	188.0	50.3	0.0	270.7	1.0660	2.5
Pr>F	0.08	0.53	0.54	0.84	0.52	0.25	0.23	0.27
Lin P_2O_5	NS	NS	NS	NS	NS	*	NS	NS
Quad P_2O_5	*	NS	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant; * = significant at 5%.

Table 9. Effect of phosphate fertilizer on elemental composition of recently expanded Russet Burbank potato leaves, sampled June 29, 1993. Previous crop - rye; initial soil test P - 57 ppm.

Phosphate Treatment	Element									
lb P_2O_5	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
0	4.92	0.30	4.80	0.60	0.44	100	170	19	7.8	23
50	4.80	0.32	4.34	0.46	0.36	88	128	19	7.5	21
100	5.08	0.33	4.72	0.53	0.40	97	167	19	7.5	22
150	4.92	0.34	4.51	0.58	0.41	93	122	19	6.3	22
200	4.93	0.36	4.47	0.55	0.40	98	138	20	6.8	22
250	4.95	0.36	4.83	0.53	0.39	96	141	19	6.5	22
Pr>F	0.54	0.00	0.74	0.27	0.49	0.48	0.63	0.88	0.29	0.77
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	NS
Cubic P_2O_5	NS	NS	NS	*	NS	NS	NS	NS	NS	NS

NS = nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 10. Effect of phosphate fertilizer on elemental composition of Russet Burbank petioles sampled June 29, 1993. Previous crop - rye; initial soil test P - 57 ppm.

Phosphate Treatment	dry wt. petiole	Element								
lb P_2O_5	NO_3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	ppm	%				ppm				
0	18975	0.23	12.2	0.52	0.34	48	140	24	2.5	23
50	14753	0.26	11.2	0.48	0.30	44	101	23	2.4	22
100	16242	0.27	11.6	0.50	0.31	47	126	25	3.6	25
150	17498	0.30	12.1	0.56	0.35	46	93	24	2.3	23
200	16686	0.29	11.6	0.57	0.35	43	109	23	2.0	23
250	14269	0.30	12.1	0.53	0.28	44	123	23	1.6	24
Pr>F	0.02	0.02	0.70	0.52	0.39	0.52	0.51	0.91	0.63	0.23
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	NS
Cubic P_2O_5	**	NS	NS	NS	*	NS	NS	NS	NS	NS

NS = nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 11. Effect of phosphate fertilizer on elemental composition of recently expanded Russet Burbank potato leaves sampled June 29, 1993. Previous crop - alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment lb P_2O_5	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
0	5.13	0.28	4.42	0.62	0.52	93	100	18	9.3	24
50	5.11	0.29	4.32	0.65	0.53	95	96	17	8.1	23
100	5.11	0.33	4.14	0.60	0.51	94	82	19	8.5	21
150	5.21	0.34	4.06	0.64	0.53	96	96	19	7.3	21
200	5.08	0.35	4.08	0.63	0.51	95	81	19	7.4	20
250	4.91	0.34	3.91	0.60	0.49	90	93	18	6.9	20
Pr>F	0.58	0.00	0.14	0.94	0.78	0.48	0.48	0.08	0.00	0.00
Lin P_2O_5	NS	**	**	NS	NS	NS	NS	NS	**	**
Quad P_2O_5	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% and 1%, respectively.

Table 12. Effect of phosphate fertilizer on elemental composition of Russet Burbank petioles sampled June 29, 1993. Previous crop - alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment lb P_2O_5	dry wt. petiole NO_3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	-ppm-	%				ppm				
0	19651	0.20	10.7	0.58	0.44	46	71	21	4.4	24
50	18512	0.22	10.9	0.61	0.48	54	70	25	4.8	27
100	18037	0.24	11.0	0.60	0.47	48	64	20	3.3	24
150	18752	0.27	10.7	0.64	0.49	52	63	23	4.2	25
200	18385	0.29	10.5	0.61	0.48	48	66	19	2.3	22
250	17090	0.30	10.3	0.65	0.52	49	60	21	3.2	24
Pr>F	0.26	0.00	0.03	0.58	0.45	0.24	0.23	0.25	0.41	0.20
Lin P_2O_5	++	**	**	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 = nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 13. Effect of phosphate fertilizer on elemental composition of recently expanded Norland potato leaves, sampled June 29, 1993. Previous crop - rye; initial soil test P - 57 ppm.

Phosphate Treatment lb P_2O_5	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
0	4.38	0.32	5.79	0.82	0.37	103	119	22	10.4	31
50	4.14	0.30	5.45	0.84	0.36	109	114	19	8.2	31
100	4.16	0.30	5.41	0.84	0.35	106	128	18	8.4	31
150	4.34	0.34	5.57	0.91	0.39	106	109	19	7.6	32
200	4.31	0.34	5.70	0.90	0.37	112	118	18	7.4	33
250	4.35	0.35	5.70	1.00	0.41	113	122	18	6.9	31
Pr>F	0.51	0.08	0.82	0.00	0.24	0.67	0.92	0.04	0.01	0.27
Lin P_2O_5	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 = nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 14. Effect of phosphate fertilizer on elemental composition of Norland petioles sampled June 29, 1993. Previous crop - rye; initial soil test P - 57 ppm.

Phosphate Treatment lb P_2O_5	dry wt. petiole NO_3-N	P	K	Ca	Mg	Element Fe	Mn	Zn	Cu	B
	ppm	%				ppm				
0	4298	0.23	12.0	0.75	0.24	60	70	22	2.8	23
50	3191	0.23	11.6	0.76	0.23	59	64	18	2.2	23
100	2530	0.24	12.2	0.81	0.25	59	89	20	3.3	27
150	3582	0.29	11.1	0.82	0.27	59	66	18	2.3	24
200	2786	0.34	12.3	0.84	0.27	79	72	18	2.2	26
250	3584	0.32	11.7	0.87	0.27	63	65	20	3.2	27
Pr>F	0.63	0.00	0.65	0.62	0.99	0.51	0.68	0.31	0.02	0.03
Lin P_2O_5	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 = nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 15. Effect of phosphate fertilizer on elemental composition of recently expanded Norland potato leaves sampled June 29, 1993. Previous crop - alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment lb P_2O_5	N	P	K	Ca	Mg	Element Fe	Mn	Zn	Cu	B
	%					ppm				
0	5.24	0.35	4.86	1.00	0.54	104	83	24	12.8	28
50	5.04	0.35	5.22	1.10	0.57	100	92	22	11.5	30
100	4.71	0.35	5.42	1.04	0.51	105	94	21	10.8	31
150	5.10	0.38	5.18	1.20	0.66	109	94	23	10.7	31
200	4.79	0.38	5.25	1.11	0.56	105	88	26	10.4	31
250	4.91	0.39	5.06	1.09	0.55	104	87	22	9.8	31
Pr>F	0.44	0.24	0.55	0.31	0.44	0.77	0.78	0.74	0.03	0.31
Lin P_2O_5	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 10%, 5% and 1%, respectively.

Table 16. Effect of phosphate fertilizer on elemental composition of Norland petioles sampled June 29, 1993. Previous crop - alfalfa/rye; initial soil test P - 21 ppm.

Phosphate Treatment lb P_2O_5	dry wt. petiole NO_3-N	P	K	Ca	Mg	Element Fe	Mn	Zn	Cu	B
	-ppm-	%				ppm				
0	11129	0.30	12.5	0.75	0.39	67	47	26	4.9	27
50	8736	0.28	12.0	0.86	0.47	60	52	27	5.3	28
100	5387	0.31	12.1	0.82	0.36	57	62	24	5.5	29
150	7254	0.31	10.9	0.83	0.44	57	49	23	4.8	27
200	6273	0.40	11.9	0.88	0.43	57	53	28	5.1	29
250	5844	0.39	11.6	0.87	0.42	59	49	24	4.4	28
Pr>F	0.16	0.00	0.17	0.26	0.84	0.43	0.71	0.61	0.91	0.19
Lin P_2O_5	*	**	++	++	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 10%, 5% and 1%, respectively.

EVALUATION OF POTASSIUM SOURCES FOR POTATO PRODUCTION ON SANDY SOILS[1]

Carl Rosen and Dave Birong[2]

ABSTRACT: A field experiment was conducted at the Sand Plain Research Farm in Becker, MN to evaluate the effects of potassium chloride, potassium sulfate, and potassium nitrate as a potassium source on potato yield, nutrient composition, petiole sap nutrient levels, and tuber quality under irrigated conditions. Potatoes at this site did not respond to potassium fertilizer or potassium fertilizer source. A reevaluation of potassium fertilizer recommendations for irrigated potatoes is warranted. The Horiba/Cardy potassium meter underestimated sap potassium concentrations compared to conventional laboratory methods.

Potatoes have a relatively high demand for potassium with up to 220 lb K/A removed in the tuber at harvest. Few studies have been conducted on sandy soils to determine potato response to potassium fertilizer sources. The objective of this study was to evaluate various potassium sources on potato yield and quality as well as to determine the effects of these sources on petiole nutrient composition on a sap and dry weight basis. The use of hand held nitrate and potassium electrodes were used to determine sap NO_3-N and K levels.

PROCEDURES:

The field experiment was conducted under irrigation at the Sand Plains Research Farm in Becker, MN. The soil at this location is classified as a Hubbard loamy sand and had the following soil test values prior to planting (0-6"): pH - 5.4; Bray P1 - 28 ppm; NH_4OAc K - 91 ppm. The previous crop was rye. The cultivar 'Russet Burbank' was planted April 21, 1993. There were five treatments arranged in a randomized complete block design with four replications. The five treatments were: 1) control 2) 250 lb K_2O/A as KCl - applied as a band at planting, 3) 250 lb K_2O/A as K_2SO_4 - applied as a band at planting, 4) 250 lb K_2O/A as KNO_3 - half applied at emergence and half applied at hilling, and 5) 250 lb K_2O/A as KNO_3 - 100 lbs applied at emergence, 75 lbs applied at hilling, and 75 lbs applied 3 weeks post-hilling. All plots received 80 lbs P_2O_5/A as triple superphosphate, 40 lbs N/A as urea and 300 lb/A Epsom salts as a band at planting. At emergence and hilling urea was applied at the rates of 80 and 100 lbs N/A for treatments 1, 2, and 3. Similar total rates of N were applied for treatments 4 and 5, except urea application was reduced to account for the N applied with potassium nitrate. The total N applied for all treatments was 220 lbs N/A. A breakdown of the five treatments are:

	K	Time of application								
Trmt	source	Planting		Emergence		Hilling		3 weeks post-hilling		Total N applied
		N rate	K rate	N rate	K rate	N rate	K rate	N rate	K rate	--- lb N/A ---
1.	--	40	0	80	0	100	0	0	0	220
2.	KCl	40	250	80	0	100	0	0	0	220
3.	K_2SO_4	40	250	80	0	100	0	0	0	220
4.	KNO_3	40	0	40	125	60	125	0	0	220
5.	KNO_3	40	0	48	100	52	75	0	75	220

Herbicides, linuron (1 lb/A ai) and Dual (1.5 lb/A ai), were applied on May 5. The N application at emergence was on May 27 and the hilling application was on June 11. Post-hilling N applications were made on July 1 and July 20. Irrigation was supplied according to the checkbook method for potato. Petiole samples were collected on June 10, July 8, and August 4 for nutrient analyses. Half the petioles were dried and the other half were crushed to express the sap. Nitrate-N in sap was determined using the Horiba/Cardy nitrate meter, the Hach electrode and the Wescan laboratory method. Potassium in sap was determined using the Horiba/Cardy potassium meter and with the ICP after dilution 1:100 (sap:water). Other elements in the sap were determined with the ICP. Nutrient concentrations (except nitrate) in petioles on dry weight basis were determined on ashed samples using ICP procedures. Nitrate on a dry weight basis was determined in water extracts using the Wescan N analyzer. Potassium source effects on early plant growth were evaluated by harvesting two plants per plot on June 29. Harvested plants were separated into roots, vines and tubers, dried and then weighed. Plots were harvested on September 9 and tubers were separated according to size. Subsamples of tubers were also collected for specific gravity determination and hollow heart incidence.

RESULTS:

Vine growth in June tended to be lower with potassium sulfate as the potash source compared to potassium chloride and potassium nitrate (Table 1). Root and tuber dry weight and number of tubers were not affected

[1] Partial support for this project was provided by Cedar Chemical Corp.

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by treatment. Potato yield and size distribution were not affected by treatment (Table 2). Lack of response to potash was most likely due to the relatively high soil test K. The recommendation for potash at this soil test level is 200 lb K_2O/A. Based on these results, this recommendation needs to be reevaluated. Tubers in the 0 potash control had the highest specific gravity, but also had the highest incidence of hollow heart.

Petiole nutrient concentrations on a dry weight and sap basis for three sampling dates are presented in Tables 3-8. Nitrate concentrations in petioles expressed on a dry weight or sap basis were lower when potassium chloride was applied compared to the other K sources and the control at all sampling dates. Nitrate concentrations in sap measured by the Horiba/Cardy meter tended to be higher than those measured by the Hach or Wescan methods. In contrast, potassium concentrations in sap measured by the Horiba potassium meter were lower than those measured by the ICP. The exact cause for these differences are not known and need to be further investigated. Potassium fertilizer increased petiole K on a sap and a dry weight basis. At the early sampling date, petiole K was higher in potassium chloride and potassium sulfate treatments compared to potassium nitrate. However, potassium nitrate was not applied until emergence, and by the last two sampling dates there was no difference in petiole K among potassium sources. These results indicate that potassium nitrate sidedressed after planting can still supply sufficient quantities of potassium for plant growth. Potassium fertilizer decreased petiole Ca and Mg, but not to levels where deficiency would be expected. Sap concentrations of P, Ca, Mg and S were low relative to K. Concentrations of micronutrients in sap were generally below detection limits. A much lower dilution rate than 1:100 would be needed to detect sap micronutrients. On a dry weight basis, petiole P was not affected by potassium source except at the first sampling date where the potassium sulfate treatment resulted in lower P concentrations. Fe, Cu, Zn, and B concentrations in petioles were generally not affect by treatment. Petiole Mn tended to be lower when potassium nitrate was the K source.

Table 1. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on potato dry matter of vines, roots, tubers, and number of tubers - sampled June 22,1993.

K source	Time of application: Planting	Emergence	Hilling	3wk PH[1]	Vines	Roots	Tubers	Number of tubers
	K rate (lb K/A)				g/plant			per plant
--	0	0	0	0	37.9	13.6	13.0	8.8
KCl	250	0	0	0	44.4	13.9	10.3	8.8
K_2SO_4	250	0	0	0	36.4	13.4	5.5	6.9
KNO_3	0	125	125	0	44.1	13.7	11.3	8.8
KNO_3	0	100	75	75	40.0	13.5	6.3	6.8
Significance					++	NS	NS	NS
LSD (5% level)					7.4	--	--	--

NS = nonsignificant; ++ = significant at 10%.
[1]wk PH = weeks post hilling.

Table 2. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on potato yield, hollow heart, and specific gravity. (Becker, 1993)

K source	Time of application: Planting	Emergence	Hilling	3wk PH[1]	Tuber size: Knobs	<3 oz	3-7 oz	7-14 oz	<14 oz	Total	Specific Gravity	Hollow Heart
	K rate (lb K/A)				cwt/A							%
--	0	0	0	0	32.4	35.4	206.0	130.1	21.7	425.6	1.0888	6.0
KCl	250	0	0	0	37.7	31.8	193.4	156.1	18.9	437.9	1.0832	0.0
K_2SO_4	250	0	0	0	33.1	28.5	163.7	169.9	42.5	437.6	1.0842	0.0
KNO_3	0	125	125	0	38.7	29.8	186.4	168.0	19.3	422.1	1.0863	2.0
KNO_3	0	100	75	75	48.1	35.0	197.1	150.1	18.9	449.6	1.0849	2.0
Significance					NS	NS	NS	NS	NS	NS	**	++
LSD (5% level)					--	--	--	--	--	--	0.0026	4.9

NS = nonsignificant; **, ++ = significant at 1% and 10%, respectively.
[1]wk PH = weeks post hilling.

Table 3. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on nitrate nitrogen content of petioles, and elemental concentrations in petioles, sampled June 10, 1993.

K source	Time of application: Planting	Emergence	Hilling	3wk PH[1]	dry weight petiole NO_3-N	Elemental Concentration in Petioles: P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	------- K rate (lb K/A)	---------			ppm	--------- %			---------	----------- ppm				-----------
--	0	0	0	0	25,501	0.51	8.8	0.97	0.72	113	56	47	3.9	24
KCl	250	0	0	0	20,879	0.50	12.5	0.65	0.39	116	94	57	5.2	25
K_2SO_4	250	0	0	0	25,740	0.44	10.8	0.60	0.41	122	78	56	4.6	24
KNO_3	0	125	125	0	25,170	0.54	9.3	0.85	0.70	115	57	52	4.7	24
KNO_3	0	100	75	75	26,044	0.49	9.3	0.86	0.69	113	55	51	4.7	24
Significance					**	*	**	**	**	NS	**	NS	NS	NS
LSD (5% level)					2,127	0.05	0.6	0.05	0.07	--	15	--	--	--

NS = nonsignificant; **, * = significant at 1% and 5%, respectively.
[1]wk PH = weeks post hilling.

Table 4. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on nitrate nitrogen and potassium concentration in petiole sap, as determined by various procedures, and elemental concentrations in petiole sap, sampled June 10, 1993.

K source	Time of application: Planting	Emergence	Hilling	3wk PH[1]	Horiba K	Horiba NO_3-N	Hach NO_3-N	Wescan NO_3-N	Elemental Concentration in Sap: P	K	Ca	Mg	S
	------- K rate (lb K/A)	---------			---------------			ppm	---------------				
--	0	0	0	0	2925	1288	1289	1220	106	3734	211	252	46
KCl	250	0	0	0	3575	970	934	864	88	4333	36	106	38
K_2SO_4	250	0	0	0	3525	1575	1447	1345	99	4830	45	148	48
KNO_3	0	125	125	0	3275	1475	1474	1354	110	4195	176	250	40
KNO_3	0	100	75	75	3250	1450	1461	1367	104	4092	187	250	42
Significance					**	**	**	**	*	**	**	**	**
LSD (5% level)					83	85	58	52	13	273	38	34	4

NS = nonsignificant; **, * = significant at 1% and 5%, respectively.
[1]wk PH = weeks post hilling.

Table 5. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on nitrate nitrogen content of petioles, and elemental concentrations in petioles, sampled July 8, 1993.

K source	Time of application: Planting	Emergence	Hilling	3wk PH[1]	dry weight petiole NO_3-N	Elemental Concentration in Petioles: P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	------- K rate (lb K/A)	---------			ppm	--------- %			---------	----------- ppm				-----------
--	0	0	0	0	24,473	0.31	6.6	0.82	0.96	60	122	24	29.4	29
KCl	250	0	0	0	20,102	0.31	9.8	0.65	0.52	54	118	25	19.2	26
K_2SO_4	250	0	0	0	23,441	0.29	9.1	0.68	0.56	50	126	25	13.4	26
KNO_3	0	125	125	0	22,031	0.32	9.8	0.71	0.60	48	79	28	21.1	28
KNO_3	0	100	75	75	23,824	0.30	9.7	0.67	0.62	50	80	26	13.1	26
Significance					**	NS	**	*	**	NS	**	NS	NS	NS
LSD (5% level)					1,361	--	0.8	0.09	0.12	--	21	--	--	--

NS = nonsignificant; **, * = significant at 1% and 5%, respectively.
[1]wk PH = weeks post hilling.

Table 6. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on nitrate nitrogen and potassium concentration in petiole sap, as determined by various procedures, and elemental concentrations in petiole sap, sampled July 8, 1993.

K	Time of application				Horiba	Horiba	Hach	Wescan	Elemental Concentration in Sap				
source	Planting	Emergence	Hilling	3wk PH[1]	K	NO_3-N	NO_3-N	NO_3-N	P	K	Ca	Mg	S
	------- K rate (lb K/A) ---------				ppm								
--	0	0	0	0	2825	1488	1395	1490	61	3184	185	412	58
KCl	250	0	0	0	3325	1375	1120	1271	66	4473	39	220	51
K_2SO_4	250	0	0	0	3300	1588	1307	1413	60	4345	46	221	64
KNO_3	0	125	125	0	3275	1500	1164	1250	67	4273	18	195	50
KNO_3	0	100	75	75	3225	1563	1308	1394	61	4333	33	234	48
Significance					++	++	**	*	NS	**	**	**	++
LSD (5% level)					394	163	122	176	--	375	40	72	13

NS = nonsignificant; **, * = significant at 1% and 5%, respectively.
[1]wk PH = weeks post hilling.

Table 7. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on nitrate nitrogen content of petioles, and elemental concentrations in petioles, sampled August 4, 1993.

K	Time of application				dry weight petiole	Elemental Concentration in Petioles								
source	Planting	Emergence	Hilling	3wk PH[1]	NO_3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	------- K rate (lb K/A) ---------				ppm	--------- % ---------				----------- ppm -----------				
--	0	0	0	0	17,540	0.25	4.8	0.99	1.38	44	160	13	10.9	30
KCl	250	0	0	0	10,488	0.23	8.6	0.76	0.68	37	176	14	9.2	29
K_2SO_4	250	0	0	0	12,910	0.20	8.5	0.78	0.69	35	166	13	4.6	29
KNO_3	0	125	125	0	7,636	0.18	8.5	0.84	0.68	32	98	10	8.2	30
KNO_3	0	100	75	75	7,853	0.18	8.3	0.85	0.67	38	85	12	6.4	30
Significance					**	**	**	**	**	++	*	++	NS	NS
LSD (5% level)					3,323	0.04	1.1	0.09	0.23	8	64	3	--	--

NS = nonsignificant; **, *, ++ = significant at 1%, 5%, and 10%, respectively.
[1]wk PH = weeks post hilling.

Table 8. Comparative effects of potassium chloride, potassium sulfate, and potassium nitrate on nitrate nitrogen and potassium concentration in petiole sap, as determined by various procedures, and elemental concentrations in petiole sap, sampled August 4, 1993.

K	Time of application				Horiba	Horiba	Hach	Wescan	Elemental Concentration in Sap				
source	Planting	Emergence	Hilling	3wk PH[1]	K	NO_3-N	NO_3-N	NO_3-N	P	K	Ca	Mg	S
	------- K rate (lb K/A) ---------				ppm								
--	0	0	0	0	3025	1288	1383	1362	73	3296	313	670	67
KCl	250	0	0	0	4050	948	960	865	65	4997	25	284	54
K_2SO_4	250	0	0	0	3850	1218	1190	954	64	5081	43	287	63
KNO_3	0	125	125	0	4000	1025	914	825	60	5680	42	328	69
KNO_3	0	100	75	75	3800	1020	914	835	60	5346	28	291	70
Significance					**	*	**	**	NS	**	**	**	NS
LSD (5% level)					306	259	190	292	--	411	100	124	--

NS = nonsignificant; **, * = significant at 1% and 5%, respectively.
[1]wk PH = weeks post hilling.

TILLAGE INDUCED MICRORELIEF IMPACTS ON NITRATE MOVEMENT IN SOILS BECKER MN CORN 1993[1]

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

Abstract: Many nitrogen management practices such as rate, timing, source, placement and the use of additives can influence fertilizer use efficiency and potential groundwater contamination. The objectives of this experiment were to evaluate the impact of fertilizer placement within different tillage systems on grain yield, fertilizer N use efficiency and movement through the soil profile. Below average yields resulted from the unusually cool wet season. Spring plow treatments, in general, provided higher yields within a given treatment than either chisel or ridge tillage systems. Grain yield was increased with each increment of fertilizer N applied, although the rate of response was highest within the plow system. Placement of fertilizer N had no influence on grain yield in the plow and ridge-till system, but placement of N close to the row in the chisel system increased grain yield. Early sidedressed applications of N resulted in significant N loss and reduced yields in all tillage systems.

Experimental Procedures

A field site was located at the Sand Plains Research Farm at Becker MN in fall of 1991. During 1992 and 1993 the following experiment was conducted and treatments were applied to the same plot area. The experiment consisted of 39 treatments with four replications arranged in a split plot design with tillage as the main plot. The 39 treatments consisted of three tillage systems (chisel, ridge till, and plow), a control plot (zero N) plus three nitrogen rates (60, 120 and 180 lbs/A), two subsurface band placement methods (7.5 or 15 inches from the row) and two times of fertilizer N application (early=3-leaf or late=8-leaf).

All fertilizer was applied as 28% N solution. The early N application was made on May 20 and the late application on June 28. All N was injected 2-4 inches deep on 30" centers. Soil samples were collected from the knife bands five times during the year. Soil samples were obtained from a depth of 0-2' in 6 inch increments from the control and the 180 lbs N/A rate. Soil samples were collected on May 25 (3-leaf), June 22 (8-leaf, early N application), July 2 (8-leaf, late N application), July 28 (silking) and August 30 (dent). All soil samples were analyzed for nitrate and ammonium N.

Prior to tillage 300 lbs/A 0-0-22 and 165 lbs/A 0-0-60 were broadcasted and incorporated by the different tillage systems. Corn (DeKalb 485, 100 day R.M.) was planted on April 29 in 30 inch rows at a population of 30,700 seeds/A. Starter fertilizer (7-21-7) was applied at 10 gal/A as a band below the seed. Counter 15 G at 8 lbs/A was banded in the row at planting. For weed control a tank mix of Dual (2 lbs/A) + Atrazine (1.25 lbs/A) was applied on April 30.

Plant samples were collected from the control and all N treated plots on June 22 (8-leaf), July 29 (silking) and October 4 (physiological maturity). Total dry matter production, N concentration, and total N uptake were determined on the first two sampling dates. Plant samples obtained at physiological maturity were separated into grain and stover. Separate determinations were made for dry matter production and N concentrations. Grain yields were adjusted to 15.5% moisture.

The irrigation program was started on July 19 and continued through September 7 with 5.4 in. of water applied through irrigation. An additional 23.41 in. of water was obtained during the season as rainfall, with 6.75 in. received between 3 leaf and 8 leaf.

General Results

Results are summarized in Tables 1-4. Grain yields at Becker were below average in 1993 as a result of the cool wet growing season. The wet growing season also created conditions for significant N loss, especially with early season N applications. Grain yields were increased approximately 80 bu/A over the controls when 180 lbs N/A was applied. Overall grain yield and response to fertilizer N was highest within the plow treatment, while chisel and ridge systems provided similar but lower yield responses to applied N. Delayed application of fertilizer N reduced N loss and resulted in approximately a 20 bu/A increase in yield within each tillage system. The increased yields with delayed N applications reflects the N loss from leaching that occurred with early season N application. Placement position of N fertilizer had no influence on grain yield on the plow and ridge till systems, but the placement of N close to the row with the chisel treatment increased yields an average of 11 bu/A across all rate and time comparisons.

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1. Funding provided by Cooperative State Research Service (CSRS) and the Minnesota Agricultural Experiment Station. Appreciation is also expressed to DEKALB Plant Genetics for supplying seed.

2. Professor and Assistant Scientist respectively, Dept. of Soil Science, University of MN.

Table 1. Influence of N-rate, tillage, placement and time of application on grain yields and dry matter production at harvest. Becker, MN 10/4/1993.

Tillage	N-Rate	Placement	Time	Grain Yields	Dry Matter Production Stover	Grain	Total
	#/A			Bu/A	---------T/A------------		
Chisel	Control	---	-	61.8	2.37	1.46	3.83
	60	1	1	72.3	2.59	1.71	4.31
	60	1	2	114.8	3.12	2.72	5.84
	60	2	1	68.1	2.64	1.61	4.26
	60	2	2	104.9	3.13	2.48	5.61
	120	1	1	119.9	3.02	2.84	5.85
	120	1	2	137.4	3.07	3.25	6.32
	120	2	1	105.4	3.21	2.49	5.71
	120	2	2	104.7	2.87	2.48	5.34
	180	1	1	150.8	3.67	3.57	7.23
	180	1	2	125.5	2.84	2.97	5.81
	180	2	1	130.7	3.30	3.09	6.40
	180	2	2	142.3	3.29	3.37	6.65
Ridge	Control	---	-	60.6	2.20	1.43	3.64
	60	1	1	79.0	2.93	1.87	4.80
	60	1	2	106.8	2.95	2.53	5.48
	60	2	1	67.0	2.51	1.59	4.09
	60	2	2	104.2	2.79	2.47	5.26
	120	1	1	95.1	3.34	2.25	5.59
	120	1	2	132.0	2.97	3.12	6.09
	120	2	1	112.1	3.05	2.65	5.70
	120	2	2	137.4	2.99	3.25	6.24
	180	1	1	134.8	3.17	3.19	6.36
	180	1	2	141.9	3.24	3.36	6.60
	180	2	1	118.6	3.18	2.81	5.98
	180	2	2	151.9	3.37	3.59	6.96
Plow	Control	---	-	55.2	2.28	1.31	3.59
	60	1	1	80.7	3.12	1.91	5.03
	60	1	2	115.0	3.40	2.72	6.12
	60	2	1	81.7	2.79	1.93	4.73
	60	2	2	131.6	3.62	3.11	6.73
	120	1	1	129.2	4.08	3.06	7.13
	120	1	2	134.7	3.20	3.19	6.39
	120	2	1	112.2	3.81	2.66	6.47
	120	2	2	137.7	3.29	3.26	6.54
	180	1	1	141.7	3.70	3.35	7.05
	180	1	2	139.9	3.26	3.31	6.57
	180	2	1	142.1	3.57	3.36	6.93
	180	2	2	151.0	3.38	3.57	6.96

Placement 1 = 7.5 and 2 = 15 inches from the row.
Time 1 = 3-leaf and 2 = 8-leaf

Table 2. Influence of N-rate, tillage, placement and time of application on stover and grain N content and total N removal at harvest. Becker, MN 10/4/1993.

Tillage	N-Rate	Placement	Time	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
	#/A			-------%------		---------#/A----------		
Chisel	Control	---	-	0.52	0.92	24.8	26.9	51.6
	60	1	1	0.54	0.91	27.7	31.3	58.9
	60	1	2	0.66	1.06	41.7	57.7	99.4
	60	2	1	0.52	0.85	27.6	27.5	55.1
	60	2	2	0.84	1.01	52.8	50.3	103.1
	120	1	1	0.64	0.99	38.3	56.2	94.5
	120	1	2	0.84	1.19	51.8	77.6	129.4
	120	2	1	0.63	0.98	40.6	49.2	89.8
	120	2	2	0.79	1.10	45.5	54.5	100.0
	180	1	1	0.81	1.24	61.0	89.0	150.0
	180	1	2	0.74	1.19	42.8	70.5	113.3
	180	2	1	0.67	1.09	44.5	67.6	112.1
	180	2	2	1.10	1.23	72.6	82.6	155.2
Ridge	Control	---	-	0.62	0.92	27.6	26.4	54.0
	60	1	1	0.50	0.94	29.2	35.4	64.6
	60	1	2	0.80	1.02	47.4	51.4	98.8
	60	2	1	0.56	0.95	28.4	30.3	58.7
	60	2	2	0.71	1.03	40.0	51.1	91.1
	120	1	1	0.55	1.01	36.8	45.8	82.6
	120	1	2	0.79	1.13	47.2	70.5	117.7
	120	2	1	0.77	1.05	47.2	55.4	102.6
	120	2	2	0.79	1.14	47.6	73.9	121.4
	180	1	1	0.73	1.16	46.1	74.1	120.1
	180	1	2	0.75	1.20	48.8	80.6	129.5
	180	2	1	0.63	1.02	39.5	57.4	96.9
	180	2	2	0.80	1.19	53.7	85.5	139.2
Plow	Control	---	-	0.59	0.87	27.0	22.9	49.9
	60	1	1	0.57	0.93	34.8	35.3	70.2
	60	1	2	0.72	0.95	48.6	51.5	100.1
	60	2	1	0.45	0.87	25.0	33.5	58.5
	60	2	2	0.76	0.97	55.1	60.8	115.9
	120	1	1	0.66	1.02	54.0	62.3	116.4
	120	1	2	0.75	1.16	47.5	74.4	121.9
	120	2	1	0.63	1.01	48.3	53.9	102.2
	120	2	2	0.93	1.15	61.0	75.1	136.1
	180	1	1	0.60	1.14	44.7	76.3	121.0
	180	1	2	0.86	1.23	56.2	81.6	137.7
	180	2	1	0.70	1.07	50.0	71.6	121.6
	180	2	2	0.84	1.24	57.4	88.6	146.1

Placement 1 = 7.5 and 2 = 15 inches from the row.
Time 1 = 3-leaf and 2 = 8-leaf

Table 3. Continued from table 1. Split Plot Statistical Analysis

N-Rate X Tillage X Placement X Time	Grain Yields	Dry Matter Production Stover	Grain	Total
	Bu/A	---------T/A-----------		
Tillage				
Chisel	114.7	3.06	2.71	5.77
Ridge Till	115.0	3.04	2.72	5.76
Plow	124.7	3.43	2.85	6.38
P-Value	99	99	99	99
BLSD (.05)	3.5	0.09	0.08	0.14
N-Rate #/A				
60	93.8	2.96	2.22	5.18
120	121.4	3.24	2.87	6.11
180	139.2	3.33	3.29	6.25
P-Value	99	90	99	99
BLSD (.05)	3.4		0.08	0.14
N-Rate X Tillage	38	90	38	84
Placement				
1. 7.5 inches	119.5	3.20	2.82	6.03
2. 15 inches	116.8	3.15	2.76	5.91
P-Value	90	73	90	90
Tillage X Placement	99	57	99	65
N-Rate X Placement	79	61	79	75
N-Rate X Tillage X Placement	99	26	99	92
Time				
1. 3 leaf	107.8	3.20	2.55	5.75
2. 8 leaf	128.5	3.15	3.04	6.19
P-Value	99	74	99	99
Tillage X Time	99	76	99	96
N-Rate X Time	99	99	99	99
N-Rate X Tillage X Time	99	99	99	99
Placement X Time	99	99	99	99
Tillage X Placement X Time	65	49	65	71
N-Rate X Placement X Time	99	62	99	99
N-Rate X Tillage X Placement X Time	99	95	99	99

Table 4. continued from Table 2: Split Plot Statistical Analysis

N-Rate X Tillage X Placement X Time	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
	-------%------		---------#/A----------		
Tillage					
Chisel	0.73	1.07	45.5	59.4	105.6
Ridge Till	0.69	1.07	42.6	59.2	101.9
Plow	0.70	1.06	48.5	63.7	112.2
P-Value	48	30	87	97	94
BLSD (.05)				2.8	
N-Rate #/A					
60	0.63	0.95	38.1	43.0	81.2
120	0.73	1.07	47.1	62.3	109.5
180	0.77	1.16	51.4	77.1	128.5
P-Value	99	99	99	99	99
BLSD (.05)	0.04	0.02	3.2	2.5	4.5
N-Rate X Tillage	74	90	91	43	92
Placement					
1. 7.5 inches	0.69	1.08	44.7	62.2	106.9
2. 15 inches	0.73	1.05	46.4	59.3	105.8
P-Value	94	99	78	99	41
Tillage X Placement	20	64	33	99	62
N-Rate X Placement	32	77	35	34	94
N-Rate X Tillage X Placement	90	32	67	99	97
Time					
1. 3 leaf	0.62	1.01	40.2	52.8	93.0
2. 8 leaf	0.80	1.12	50.9	68.7	119.7
P-Value	99	99	99	99	99
Tillage X Time	52	33	15	94	47
Placement X Time	95	91	99	99	99
Tillage X Placement X Time	99	9	96	43	79
N-Rate X Time	70	75	99	99	99
N-Rate X Tillage X Time	8	90	36	99	91
N-Rate X Placement X Time	86	99	95	99	99
N-Rate X Tillage X Placement X Time	99	38	99	98	99

LONG-TERM NITROGEN MANAGEMENT EFFECTS ON CORN YIELD[1]

D.J. Fuchs and D.R Huggins[2]

ABSTRACT

Nitrogen management considerations for corn production include application rate, timing, form, and placement. A continuous corn study at the Southwest Experiment Station, Lamberton was initiated in 1960 on a Normania loam. The study was conducted to aid N management decisions regarding N rate (0 to 160 lb N/ac), form (urea or ammonium nitrate), application time (fall, spring or sidedressed), and placement (fall surface broadcast before and after moldboard plowing). Wet, cold weather conditions in the fall of 1992 and continuing in 1993 favored sidedressed applications of N as compared to fall applied N. Corn yields with urea applications of 80 lb N/ac were 40 bu/ac greater with sidedressed as compared to fall applied N. Maximum corn yields (100 bu/ac) were obtained with NH_4NO_3 applications of 160 lb N/ac, however, this was not significantly greater than yields obtained with 80 lb N/ac of urea. The 33 year yield average (no yields were taken in 1976) indicate that corn yields respond the greatest to N rate with a slight advantage to spring and sidedressed Aapplied N and little yield difference between N forms.

METHODS AND MATERIALS

The Corn N management study was initiated in 1960 and the same treatments were applied through 1993. The study is located at the Southwest Experiment Station on a tiled Normania loam. Each plot is 20 by 77.5 feet with the four replications arranged in a randomized block. After ear corn removal and stalk cutting, treatments with fall N are either surface broadcast before or after moldboard plowing to a depth of 12 inches. Spring N treatments are broadcast before seedbed preparations in late April or early May. Corn is planted in 30-inch rows, and starter fertilizer is banded at a rate of 14-41-15 lbs/ac (N-P_2O_5-K_2O). Sidedress N treatments are broadcast in June and incorporated during cultivation. Additional management information for 1993 is provided in Table 1. In the fall of 1993, the experiment was modified to include anhydrous ammonia, a 120 lb N/ac rate, a corn/soybean rotation, and a complete experimental design.

RESULTS

Cool, wet weather conditions during the fall of 1992 and the 1993 growing season favored spring and sidedressed applied N as compared to fall N applications (Table 2). Corn yields with urea applications of 80 lb N/ac were 40 bu/ac greater with sidedressed as compared to fall applied N. Maximum corn yields (100 bu/ac) were obtained with sidedressed NH_4NO_3 applications of 160 lb N/ac, however, this was not significantly greater than yields obtained with 80 lb N/ac of sidedressed urea. Corn yields with 160 lb N/ac of fall applied urea were statistically equal to yields with 40 lb N/ac of sidedressed NH_4NO_3 (Table 2). The 33 year yield average (no yields were taken in 1976) indicate that corn yields respond the greatest to N rate with a slight advantage to spring and sidedressed applied N and little yield difference between N forms (Table 3).

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[1] Funding provided by Agricultural Experiment Station

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

Table 1. Plot management information for 1993.

Item	Type	Rate	Date
Secondary Tillage	Disc	1 pass	5/5
	Digger	1 pass	5/6
Seed	Pioneer	29,000 seeds/ac	5/6
Fertilizer	Starter	14-36-13 lbs/ac (N-P_2O_5-K_2O)	5/6
Herbicides	Lasso	3.0 lbs/ac (ai)	5/6
	Bladex	2.0 lbs/ac (ai)	
Insecticides	Counter	1.0 lbs/ac (ai)	5/6
Row Cultivation		2 passes	6/28, 7/21
Rotary Hoe		1 pass	5/14

Table 2. Corn yields in 1993.

Application Time	Nitrogen Form and Application Rate					
	NH_4NO_3 (lb N/ac)			UREA (lb N/ac)		
	40	80	160	40	80	160
	bu/ac					
Fall Incorp.	43	53	76	47	54	82
Fall Surface	51	nd†	nd	46	nd	nd
Spring preplt.	53	67	nd	52	66	nd
Sidedress	73	78	100	56	94	nd
Control: 42 bu/ac						

†nd=no data (treatments not in experiment).
LSD $_{0.05}$ = 14.5 bu/ac.

Table 3. Long-term corn yields (1960-1993).

Application Time	Nitrogen Form and Application Rate					
	NH_4NO_3 (lb N/ac)			UREA (lb N/ac)		
	40	80	160	40	80	160
	bu/ac					
Fall Incorp.	83	102	111	90	102	112
Fall Surface	87	nd†	nd	88	nd	nd
Spring preplt.	92	106	nd	92	108	nd
Sidedress	97	104	116	96	112	nd
Control: 63 bu/ac						

†nd=no data (treatments not in experiment).
LSD $_{0.05}$ = 3.8 bu/ac.

NITRATE LOSSES TO TILE DRAINAGE, RESIDUAL SOIL N, AND N UPTAKE AS AFFECTED BY CROPPING SYSTEMS[1]

Lamberton, 1993

G. W. Randall, D. R. Huggins, D. J. Fuchs,
M. P. Russelle, and J. L. Anderson

ABSTRACT: Four cropping systems (continuous corn, a corn-soybean sequence, alfalfa, and CRP) were established in 1988 to determine biomass yields, N uptake, residual soil NO_3 and NO_3 and pesticide losses to tile drainage water as influenced by cropping system. Crop yields in this sixth year of the study were below average due to the very wet and cool conditions. Nitrogen uptake by the continuous corn, corn-Sb, soybean, and alfalfa crops totaled 96, 95, 167 and 243 lb/A, respectively. Residual soil NO_3-N remaining in the 0-5' profile in October totaled 62, 43, 53, 25 and 21 lb/A for the continuous corn, corn-soybean, soybean-corn, alfalfa and CRP systems, respectively. Available water in the 0-5' profile in late October with the row-crop systems ranged between 7.1 and 8.1 inches while the perennial crops had 6.8" (alfalfa) and 7.5" (CRP). Tile water drainage from the row-crop systems ranged from 17.4 to 19.2 acre-inches while 12.7 and 20.1 acre-inches drained from the alfalfa and CRP systems, respectively. Flow-weighted NO_3-N concentrations ranged from 13 to 20 mg/L for the 5-month drainage period with the corn and soybean systems but averaged <2 mg/L with the alfalfa and CRP systems. Nitrate-N losses ranged from only 1.5 lb/A with the CRP system and 3.2 lb/A with alfalfa to 81 lb/A with continuous corn.

Nitrate and pesticide losses to tile drainage water have been monitored in the last few years for continuous corn systems at the Lamberton and Waseca branch experiment stations. However, very little information exists on the N and pesticide losses from other cropping systems, especially those involving alfalfa or CRP grass:legume plantings. The purpose of this study was to determine the effect of four cropping systems on the:

1) above-ground biomass yields, N concentrations in the biomass, and N removal,
2) residual NH_4 and NO_3 in the 0 to 10' soil profile after harvest, and
3) NO_3 losses in the tile drainage water.

Background

Fifteen tile drainage plots each measuring 45' x 50', surrounded with plastic sheeting to a depth of 6', were installed in 1972 at the Southwest Experiment Station at Lamberton. Nitrogen rates from 18 to 400 lb N/A were applied annually to corn from 1973 through 1979 on this Nicollet clay loam. Since 1979, continuous corn without N in 1980-1985 and with only 50 lb N/A in 1986-87 was grown to "erase" the effects of the previous treatments.

Experimental Procedures

Four cropping systems [continuous corn, corn-soybean sequence, continuous alfalfa, and continuous CRP (Conservation Reserve Program) species] were established on these drainage plots in the spring of 1988. Each cropping system was randomly assigned to the drainage plots in a randomized, complete-block design with three replications. The detailed experimental procedures are shown in Table 1.

Soil samples taken from the 0 to 8" layer in 1988 indicated high soil test P&K values. Consequently, no broadcast nor starter fertilizer was used for the corn, soybeans or CRP systems. Potassium was broadcast at a rate of 120 lb K_2O/A following the first cutting of alfalfa. Samples taken to a 5-foot depth in late-April (Table 3) were used to determine the N fertilizer rates needed for corn. The 140-lb N rate used for continuous corn and the 95-lb N rate for corn after soybeans was based on the NO_3 concentration in the 0 to 24" layer and a yield goal of 140 bu/A according to AG-FO-3790 (1993).

Results and Discussion

Weather

Climatic conditions during the 1993 growing season were cooler and wetter than normal (Table 2). Rainfall over the 7-month growing season was 10" above normal with greatest departure from normal in May and June. Monthly temperature averages were markedly below normal in August and September while the 7-month seasonal average was 5° F below normal. These conditions resulted in below normal corn and soybean yields and average alfalfa yield.

Spring Soil Nitrate

Residual NO_3 in the 0 to 5-foot soil profile in late-April was average to low for both the corn-soybean and soybean-corn systems and medium-high for the continuous corn system (Table 3). Nitrate-N distribution was relatively uniform in the top three feet of the continuous corn plots

[1] Funding provided by the North Central Regional Research Comm. (NC-201), Southwest Experiment Station, and the Southern Experiment Station.

but increased approximately two-fold in the 3 to 5' layer. This was similar to 1992. Residual NO_3-N following soybeans in 1992 was highest in the 0-1' and 4-5' layers and lowest between 2 and 3'. In the soybean-corn sequence (corn in 1992), very low NO_3-N levels occurred in the 1 to 3' layer with the highest concentration in the 4-5' layer. Residual soil NO_3 in the corn-soybean system (soybean in 1992) increased dramatically (74%) between the October '92 sampling and the April '93 sampling. Slight changes between the fall and spring NO_3-N data were seen in the continuous corn and soybean-corn systems. This suggests little over-winter loss of NO_3 in this year.

Crop Yields

Crop yields shown in Table 4 were below the yield goal for corn and below the expected yields for soybean and alfalfa. Although corn yields were about 8 bu/A higher following soybean compared to continuous corn, N uptake was not different between the two systems. Nitrogen uptake by soybean and alfalfa was 72 and 148 lb/A higher, respectively, compared to corn. The CRP plots continued to be completely dominated by grasses (primarily brome grass), similar to 1992 and N uptake in the above-ground dry matter was small.

Fall Soil Nitrate

Soil NO_3 levels throughout the 10-foot profile were markedly lower for those cropping systems dominated by alfalfa and CRP compared to the corn and soybean systems (Table 5). Ranking from highest to lowest was: CC > Sb-C> C-Sb>A=CRP. Nitrate-N concentrations were often highest in the 0-1' profile, usually lowest between 1 and 3' and were somewhat higher again below 3'. Distribution below 4' was very uniform for the CC and C-Sb systems but increased below 6' with the Sb-C system. The alfalfa and CRP systems exhibited very low NO_3-N concentrations between 1 and 9' with a slight increase in the 9-10' layer. Amounts of soil NO_3 in the top five feet in October were 44% lower than in April for the continuous corn and corn-soybean systems with no difference between sampling dates for the soybean-corn system. Absolute differences between the dates of sampling were -48 to -34, and -3 lb NO_3-N/A for the CC, C-Sb and Sb-C systems, respectively.

Soil Moisture

Soil moisture in the 0 to 5' profile in October was higher than in previous years and was affected by the cropping system (Table 6). Available soil water was lowest for the alfalfa and highest for continuous corn.

Tile Flow

Tile line discharge occurred from mid-March through early August with the alfalfa and CRP systems and from late March through early August (with minimal drainage from two plots again in November) from the corn and soybean systems. Drainage averaged 18.5" for the systems containing corn and soybean compared to 12.7" for alfalfa (Table 7). This was the first year where drainage from the CRP system was markedly higher than from alfalfa. Flow-weighted NO_3-N concentrations for the season were highest for the CC system and were approximately 20x higher than the alfalfa and CRP systems. Nitrate-N concentrations from the C-Sb and Sb-C systems averaged about 7 mg/L less than from the CC system. Temporal changes in NO_3-N concentrations did occur in 1993. Flow-weighted NO_3-N concentrations for each month show lowest concentrations for the year in the very first water samples collected (March) for the corn and soybean systems while concentrations in the first samples under alfalfa and CRP were highest for the year. Highest monthly F-W concentrations for the corn and soybean systems were found in April with a slight decline thereafter. Losses of NO_3-N in the tile drainage for the 1993 season ranged from 26 to 35 times higher for the corn-soybean sequences and CC systems compared to the two perennial crop systems. Losses averaged 80 lb/A for the two systems where corn was grown in 1993, 59 lb/A for soybean, and only 2.3 lb/A for the alfalfa and CRP systems. These data indicate that N removal (alfalfa) and N cycling (CRP) along with high ET demand of the perennial crops are resulting in minimal NO_3 loss. Thus, we can speculate that NO_3 loss from native prairies to ground water prior to the adoption of cropping and tillage practices in southern Minnesota would have been extremely small.

Conclusions

The wetter and colder than normal conditions in 1993 resulted in poor crop yields in this sixth year of the study. Nitrogen removal by soybean and alfalfa was 1.8x and 2.5x as high, respectively, as with continuous corn. After four moist years, the grass species again dominated the CRP system. Over winter, "loss" of soil NO_3 was very low. Residual soil NO_3 in the fall, although not as high as in some previous years, was approximately 2x higher with the row crop systems compared to the perennial crop systems. Tile flow occurred over a 5-month period for all crop systems. Drainage averaged 18.5 acre-inches from the row crop systems and totaled 20.1" for CRP and only 12.7" for alfalfa. Nitrate-N concentrations also were 16 to 25x higher with the row-crop systems. Nitrate-N losses to the drainage water totaled 81 lb/A from the continuous corn system and 78 lb/A from the corn-soybean rotation that received fertilizer N in 1992. Nitrate-N losses from the soybean-corn system were markedly lower (59 lb/A) due primarily to lower NO_3-N concentrations. Less than 4 lb NO_3-N/A were lost in the drainage water from the alfalfa and CRP systems.

Table 1. Experimental procedures used in 1993 for the nitrate-pesticide movement study at Lamberton.

Cropping System	Procedures
Cont. Corn and Corn-"Sb"	
Hybrid	Pioneer 3563
Planting rate and date	29000 ppA on 5/14
Insecticide	Counter (1 lb/A)
Herbicides	Lasso (4 lb/A) + Bladex (3 lb/A)
Date	Both applied on 5/14 after field cultivation and then incorporated with field cultivator.
N rate (Cont. corn only)	140 lb N/A as urea
Date	6/28 and cultivated in the same day
Cultivation date(s)	6/15 and 6/28
Harvest date	10/13
Fall tillage (kind and date)	Moldboard plow 11/11
Corn - "Sb"	
N rate	95 lb N/A as urea on 6/28
Soybeans	
Secondary tillage	Field cultivated 2X (5/14)
Variety	Hardin
Planting rate and date	150,000 seeds/A on 5/14
Row width	30"
Herbicides	
Lasso: Rate and date	4.0 lb/A on 5/14, incorporated with a field cultivator
Pursuit: Rate and date	0.063 lb/A plus surfactant + UAN on 7/12
Cultivation date(s)	6/15
Harvest date	10/5
Fall Tillage	None
Alfalfa	
K_2O date	6/29
Harvest date(s)	6/14, 7/26 and 9/2
Harvest area	3' x 20'
CRP	
Harvest date	9/24

Table 2. Growing season monthly air temperature averages and precipitation amounts during 1993 and the long-term normals for Lamberton.

Month	Avg. Temperature 1993	Avg. Temperature Normal	Precipitation 1993	Precipitation Normal
	°F		inches	
April	41	46	2.55	2.69
May	56	59	7.09	3.28
June	64	68	8.14	3.76
July	69	72	5.23	3.84
Aug.	60	70	5.29	2.97
Sept.	54	60	2.55	3.24
Oct.	46	48	1.01	2.04
7-mo avg.	56	61		
Total	-	-	31.86	21.82

Table 3. Residual NO_3-N in the 0 to 5' soil profile of the cropping systems in April, 1993.

Depth	Cropping System in 1993		
	Cont. Corn	Corn-Sb	Soybean-C
feet	lb NO_3-N/A		
0 - 1	16.1	18.9	11.3
1 - 2	13.2	13.5	6.3
2 - 3	18.7	10.7	6.0
3 - 4	33.1	14.0	11.7
4 - 5	29.2	19.6	15.1
Total (0-5')			
Apr.'93	110.3	76.7	50.4
Oct. '92	95.3	44.1	59.2
% Change over winter	+16	+74	-15

Table 4. Crop yields, N concentration, and N uptake at Lamberton in 1993.

Cropping System	Yield	N Concentration	N Uptake
		%	lb/A
Cont. Corn			
Grain (bu/A)	97.6	1.22	66.7
Stover (lb DM/A)	4708.	0.62	29.2
Total			95.9
Corn-Sb			
Grain (bu/A)	105.3	1.08	63.7
Stover (lb DM/A)	5020.	0.62	31.1
Total			94.8
Soybean-C			
Seed (bu/A)	34.0	5.89	120.2
Stover (lb DM/A)	5021.	0.93	46.7
Total			166.9
Alfalfa			
1st Cut Forage (lb DM/A)	5000	2.60*	130.0
2nd Cut Forage (lb DM/A)	1520	2.71	41.2
3rd Cut Forage (lb DM/A)	2640	2.71	71.5
Total	4.58 T/A		242.7
CRP			
Grass (lb DM/A)	4570	0.71	32.4

* Approximation

Table 5. Soil profile NO_3-N concentrations and amounts in October, 1993 as influenced by cropping system at Lamberton.

	Cont. Corn			Corn-Sb		
Depth	Avg.	SE	Avg.	Avg.	SE	Avg.
feet	------ ppm ------		lb/A	------ ppm ------		lb/A
0 - 1	6.1	3.42	24.3	3.7	0.38	14.9
1 - 2	0.6	0.20	2.5	1.0	0.22	3.9
2 - 3	1.2	0.32	4.9	0.9	0.23	3.6
3 - 4	2.9	0.37	11.5	2.1	0.26	8.3
4 - 5	4.7	1.47	18.8	3.1	0.37	12.3
5 - 6	4.7	0.81	18.8	2.9	0.35	11.6
6 - 7	4.1	0.78	16.3	3.0	0.47	12.1
7 - 8	4.3	1.47	17.3	2.5	0.32	10.0
8 - 9	4.8	1.70	19.2	2.3	0.26	9.3
9 - 10	4.1	1.07	16.3	2.0	0.20	8.0
Totals						
0 - 5			62.0			43.0
5 - 8			52.4			33.7
8 - 10			35.5			17.3
0 - 10			149.7			94.0

	Soybean-C			Alfalfa		
Depth	Avg.	SE	Avg.	Avg.	SE	Avg.
feet	------ ppm ------		lb/A	------ ppm ------		lb/A
0 - 1	5.0	0.67	19.9	2.9	0.47	11.5
1 - 2	2.0	0.54	7.9	1.2	0.30	4.9
2 - 3	2.2	0.47	8.8	0.9	0.35	3.6
3 - 4	2.1	0.22	8.3	0.6	0.00	2.4
4 - 5	2.1	0.09	8.5	0.7	0.07	2.7
5 - 6	2.4	0.26	9.7	1.3	0.58	5.3
6 - 7	2.9	0.18	11.5	0.4	0.12	1.6
7 - 8	3.3	0.35	13.2	0.7	0.24	2.7
8 - 9	3.1	0.23	12.5	1.2	0.09	4.7
9 - 10	4.6	0.64	18.5	1.6	0.03	6.5
Totals						
0 - 5			53.4			25.1
5 - 8			34.4			9.6
8 - 10			31.0			11.2
0 - 10			118.8			45.9

	CRP		
Depth	Avg.	SE	Avg.
feet	----------- ppm ----------		lb/A
0 - 1	3.3	1.63	13.2
1 - 2	0.9	0.32	3.6
2 - 3	0.4	0.09	1.5
3 - 4	0.4	0.06	1.6
4 - 5	0.4	0.03	1.5
5 - 6	0.4	0.03	1.5
6 - 7	0.4	0.12	1.5
7 - 8	0.8	0.35	3.2
8 - 9	1.5	0.62	6.1
9 - 10	2.0	0.46	8.1
Totals			
0 - 5			21.4
5 - 8			6.2
8 - 10			14.2
0 - 10			41.8

Table 6. Gravimetric water content of the 0-10' profile and "available" water in the 0-5' profile in October, 1993 as influenced by cropping system

Profile depth	Cropping system				
	Cont. Corn	Corn-Sb	Soybean-C	Alfalfa	CRP
feet	Water Content (%)				
0 - 1	22.8	24.0	23.7	20.7	24.5
1 - 2	20.7	20.4	21.6	20.8	20.9
2 - 3	19.3	18.4	19.8	19.2	19.8
3 - 4	21.0	18.7	18.5	18.7	18.9
4 - 5	22.8	19.4	19.3	18.9	19.5
5 - 6	22.0	19.9	20.3	19.4	17.6
6 - 7	21.4	20.1	20.1	19.6	19.1
7 - 8	20.8	19.9	20.0	19.4	20.0
8 - 9	22.5	19.6	20.1	19.9	21.7
9 - 10	20.0	19.8	20.7	19.6	20.9
"Available" Water 0-5' (inches)	8.06	7.08	7.39	6.77	7.50

Table 7. Tile discharge, flow-weighted NO_3-N concentration, and NO_3-N loss via the tile lines as influenced by cropping system.

Month	Cont. Corn	Corn-Sb	Soybean-C	Alfalfa	CRP
	Tile Flow (acre-in)				
March	0.06	0.24	0.36	0.42	2.69
April	1.95	2.54	2.53	2.62	3.83
May	3.52	4.87	3.69	2.20	2.90
June	9.36	9.45	10.10	6.02	9.23
July	2.35	2.13	2.09	1.35	1.41
August	0.10	0.01	0.04	0.05	0.01
November	0.02	0.00	0.01	0.00	0.00
Total	17.36	19.24	18.82	12.66	20.07
	Flow-weighted NO_3-N Conc. (ppm)				
March	11.6	9.2	9.1	2.3	0.5
April	27.1	19.4	16.3	2.3	0.4
May	23.0	19.3	15.1	1.2	0.3
June	18.7	18.3	13.5	0.6	0.2
July	17.8	16.5	12.5	1.0	0.3
August	20.9	16.0	11.3	1.7	0.3
November	23.3	-	14.2	-	-
Season Avg.	20.3	14.1	13.1	1.3	0.3
	NO_3-N Loss (lb/A)				
March	0.2	0.3	0.6	0.18	0.35
April	12.0	10.0	9.3	1.26	0.31
May	18.4	21.5	12.6	0.61	0.17
June	40.0	38.5	30.8	0.77	0.52
July	9.6	8.0	5.9	0.32	0.10
August	0.5	0.0	0.1	0.01	0.00
November	0.1	0.0	0.0	0.00	0.00
Total	80.8	78.3	59.3	3.15	1.45

ORGANIC CROP ROTATION STUDY ON THE KOCH FARM AT THE SOUTHWEST EXPERIMENT STATION, LAMBERTON

S.R. Quiring, D.R. Huggins, D.J. Fuchs, J.H. Ford[1]

ABSTRACT

Crop rotations can increase crop yields and improve weed control, and are considered to be fundamental to organic production systems. This study, initiated in 1990, was designed to evaluate the effects of crop rotation and poultry manure on crop yields in organic systems. Crop rotation consistently increased corn yields but had little effect on soybean or oat yields. Corn yields were increased with manure applications each year. Oat and soybean yields were increased by manure applications in 1990 and 1993. The reported results are preliminary, and the value and meaning of the study will increase with time.

INTRODUCTION

This study was designed to evaluate the effects of crop rotation, with and without fertilizer (poultry manure), on plant growth, crop yield, and weed control. Crop rotations consist of 1 to 4 years with continuous corn, corn/soybeans, corn/soybean/oats, corn/soybean/oat/alfalfa. The site, located on the Koch farm next to the Southwest Experiment Station, has a history of low synthetic fertilizer and herbicide use, and high weed pressure. Soil tests from the fall of 1988 showed Bray 1 phosphorus at 10 ppm and potassium tests of 171 ppm. This study was started in 1990 following soybeans with the first yields taken in the fall of 1990. There are no chemical weed control practices used, only mechanical weed control methods.

METHODS and MATERIALS

The study design is a randomized complete block, 60' x 155', replicated 4 times, with split plot restrictions. Main plots consist of crop rotation, with each crop represented in each year, and subplots consist of control (no manure) and composted poultry manure applications. The manure rate is based on soil test results from the previous fall sampling and University of Minnesota Extension recommendations. Soil samples for phosphorus and potassium were taken to a depth of 1 foot with 8 composite cores per plot. Soil nitrate samples were taken in 1 foot increment down to 5 feet with 2 cores per plot.

Three different analyses of composted poultry manure have been used: N-P_2O_5-K_2O analyses of 4-6-4, 4-4-2, and 3-5-3. The form and rate were selected to meet the crop requirement of the most limiting nutrient (P or N). The manure was broadcast on the plot and incorporated prior to secondary tillage in the spring.

After planting oats, and oats underseeded with alfalfa, plots were harrowed and the oats underseeded with alfalfa were also packed. This was done to increase weed control and soil to seed contact. The corn and soybean plots were rotary-hoed 5 to 7 days after planting depending on weed stage and rotary-hoed again, if weather conditions and crop emergence permitted. Cultivation of corn and soybean was done as necessary to obtain maximum weed control. Tillage and cultivation in like crops in all rotations are treated the same. All treatments except oat underseeded with alfalfa were moldboard plowed in the fall.

Total weed counts were taken in all plots in 1992 and 1993. All weed species were identified and counted in each sample. In 1992, two random samples four feet long were taken in corn and soybeans for grassy weeds. In oats and alfalfa two 1 foot squares per plot were collected. The whole plot area was sampled for broadleaf weeds in oat and alfalfa plots and one row 155' long was counted in corn and soybean. In 1993, two rows 155' long were sampled for broadleaf weeds in corn and soybean and the whole plot was sampled in oat and alfalfa. Grassy weeds were counted using three samples, four feet long, in corn and soybean and five 1 foot squares in oat and alfalfa.

RESULTS

Manure applications significantly increased corn yields in every year of the study (Fig. 1). Oat and soybean yields were increased significantly by applied manure in 1990 and 1993 and alfalfa yields responded positively to manure in 1991 - 1993 (Fig. 4). Continuous corn rotation yields were reduced, with or without manure, compared to corn yields in the other rotations (Fig. 1). The four years of soybean yield data showed no significant crop rotation effect on yield. Oat yields were reduced by interseeded alfalfa. Broadleaf weed populations were less than grassy weed populations and more variable across all crop rotations (Fig. 5). In each year grassy weed counts were higher in treatments without manure as compared to treatments with manure. Increased crop competition in manured treatments could have decreased weed populations. Grassy weeds were suppressed in corn and soybean where rotary hoe and cultivation treatments were used. Weed numbers in oat plots could be greater due to the earlier planting dates, lack of post-plant cultural weed control measures, and an absence of competition after the crop was removed (Fig. 5).

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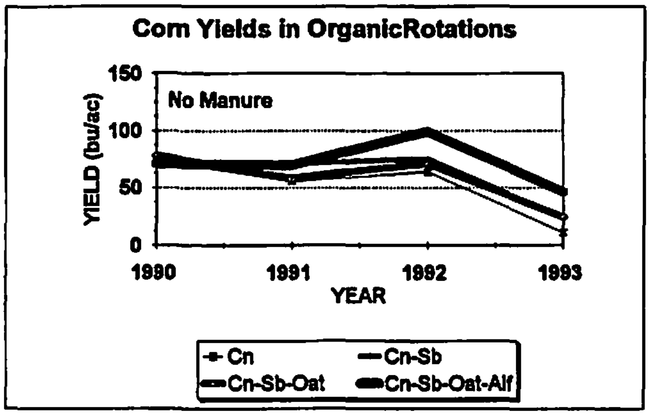
Fig. 1 Corn Yields by Rotation



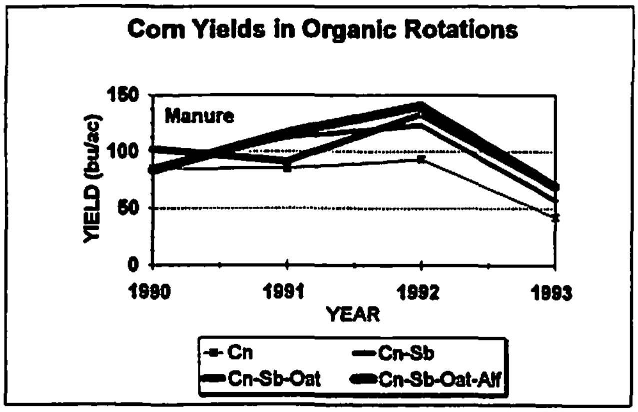
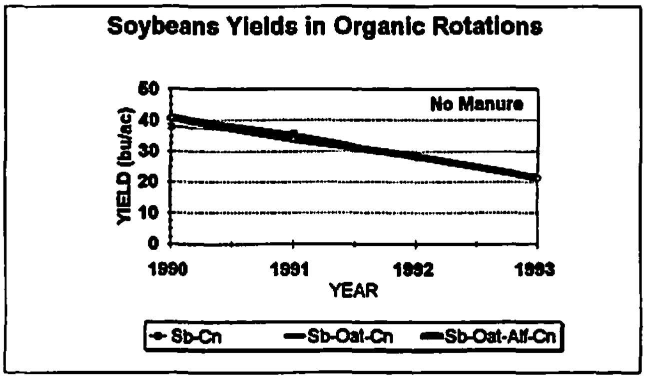


Fig. 2 Soybean Yields by Rotation



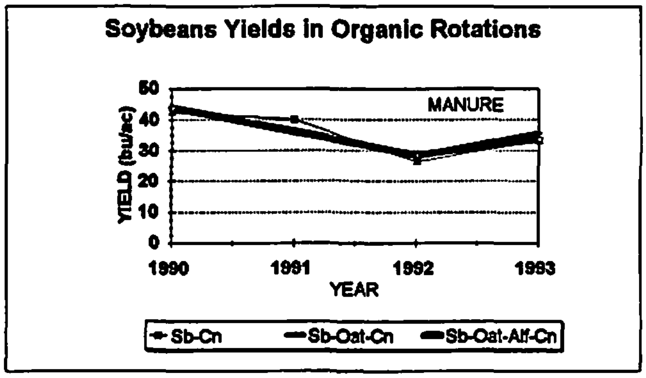


Fig. 3 Oat Yields by Rotation

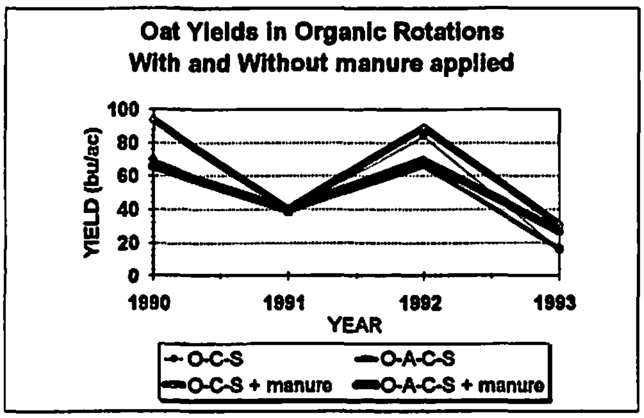


Fig. 4 Alfalfa Yields

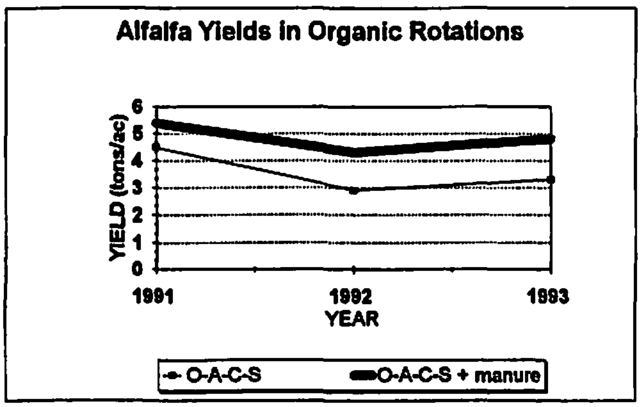
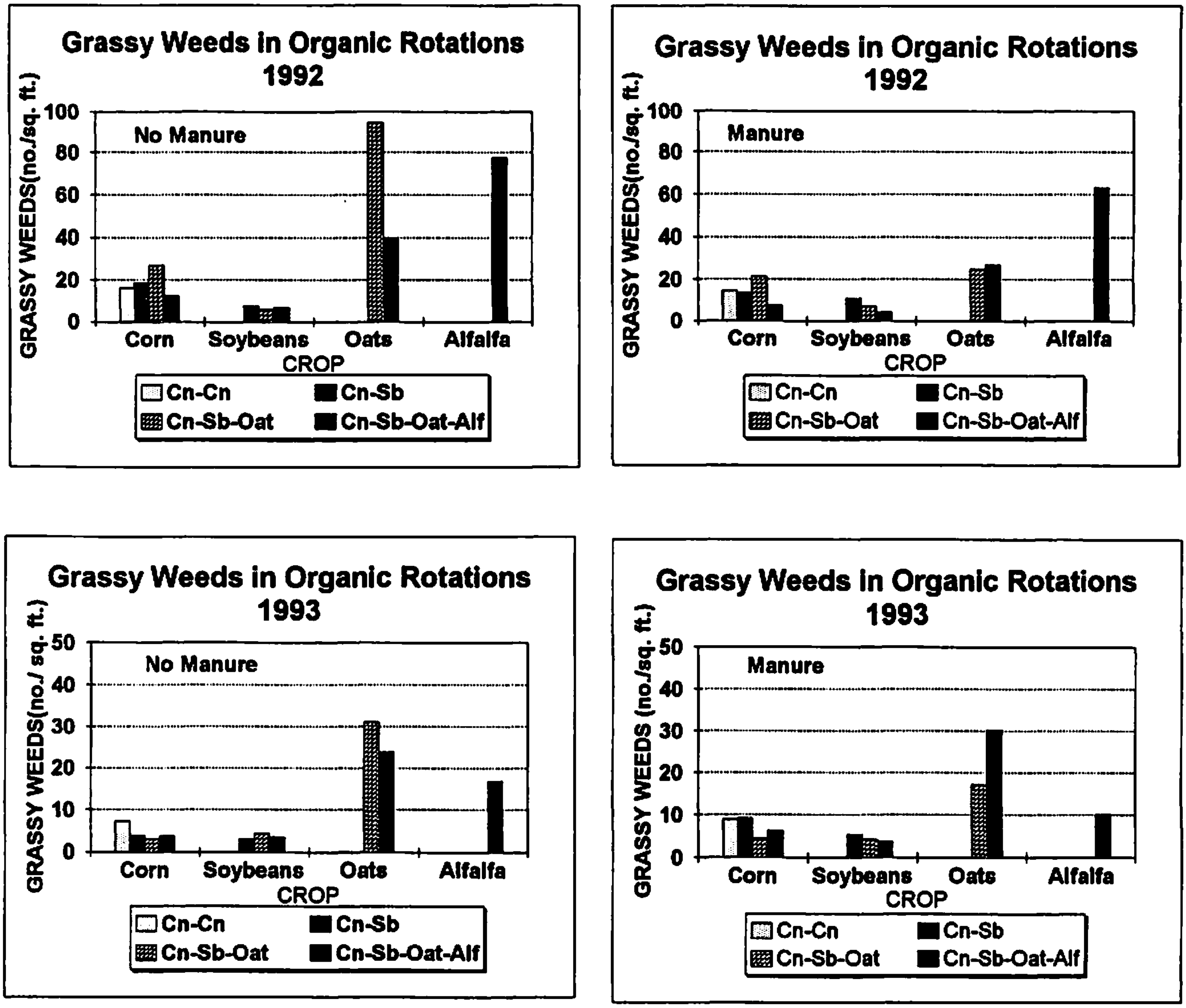


Fig. 5 Number of Grassy Weeds



VARIABLE INPUT CROP MANAGEMENT SYSTEMS: EVALUATION OF PRODUCTIVITY, PROFITABILITY AND ENERGY EFFICIENCY[1]

D.R. Huggins, D.J. Fuchs, J.H. Ford and K.D. Olson[2]

Abstract

Development of cropping systems that use purchased and on-farm inputs efficiently is an important goal of agricultural sustainablity. Our objectives are to develop and evaluate cropping systems that minimize energy and chemical inputs while maintaining a profitable and environmentally safe agriculture. Cropping systems with low-purchased input, high purchased input, organic inputs and minimal input were established with two crop rotations (corn-soybean; corn-soybean-oat-alfalfa) and two prior levels of external (off-farm) input (low and high) in 1989. Corn yields were sensitive to external inputs of fertilizer and pesticides with high inputs consistently producing greater yields than low input systems. Crop rotation effects were strongly expressed with low input systems but were virtually eliminated as purchased inputs increased. Soybean yields were greatly affected by prior input level with organic treatments yielding greater than high input treatments where high inputs were previously applied. Economic analysis indicated that transition from a high to a low input system was not accompanied by a dramatic drop in income.

Introduction

In 1988, the University of Minnesota gained access to a unique and significant research site called the 'Koch Farm'. The Koch Farm and was a minimum input farm for at least 35 years prior to 1988. No insecticide had been used on this land, herbicide use was very minimal, and neither synthetic or natural fertilizer had been applied.

The overall objectives of the Variable Input Crop Management Study (VICMS) was to determine how to replace off-farm inputs and energy with on-farm resources, and includes the evaluation of cropping systems with variable off-farm inputs.

Materials and Methods

The study began in 1989 with treatments including 2 prior levels of external (off-farm) input: 1) **VICMS I** (Variable Input Crop Management System) located on the Koch farm with 30 years of minimal inputs. Soil test levels of P_2O_5 (Bray 1) were low (4 ppm), and weed pressure was high; and 2) **VICMS II** located on the Southwest Experiment Station with 30 years of high external inputs. Soil test levels of P_2O_5 (Bray 1) were high (30 ppm), and weed pressure low. Each study (VICMS I and VICMS II) has four different management systems (1) Minimum Input (MIN), (2) Organic (ORG), (3) Low Purchased Input (LPI), and (4) High Purchased Input (HPI) and two different rotations: (1) corn/soybean, and (2) corn/soybean/oat/alfalfa. For each rotation every crop is grown every year.

Minimum Input (MIN)

<u>Tillage and Planting</u>
Primary Tillage: Moldboard plow following corn and alfalfa. Chisel plow following soybean.
Secondary Tillage: As needed to control weeds before planting. Corn residue: disc then field cultivator; soybean residue: field cultivator.
Planting: Crops planted 1 to 2 weeks later than normal. Corn and soybean are planted on 30-inch rows. Oat is drilled and undersown with alfalfa.

<u>Fertilizer</u>
No fertilizer is applied.

<u>Weed Control</u>
Mechanical weed control only, included are rotary hoe (pre and post plant emergence in corn and soybean) and row cultivation (corn and soybean).

Organic (ORG)

<u>Tillage and Planting</u>
Primary Tillage: Moldboard plow following corn and alfalfa. Chisel plow following soybean.
Secondary Tillage: As needed to control weeds before planting. Corn residue: disc then field cultivator, soybean residue: field cultivator.

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[1] Support for this project was provided by a grant from the LCMR.

[2] D.R. Huggins, D.J. Fuchs and J. H. Ford are Assistant Professor, Scientist and Professor at the Southwest Experiment Station, Lamberton, MN 56152. K.D. Olson is Associate Professor at the Agricultural and Applied Economics Department at the University of Minnesota, St. Paul, MN 55108.

Planting: Crops planted 1 to 2 weeks later than normal. Corn and soybean are planted on 30-inch rows. Oat is drilled and undersown with alfalfa

Fertilizer
The 4-year rotation receives solid beef manure. The 2-year rotation receives liquid hog manure. Rates are based on soil tests and previous years' application manure analysis.

Weed Control
Mechanical weed control only, which includes the rotary hoe (pre- and post-plant emergence in corn and soybean) and row cultivation (corn and soybean).

Low Purchased Input (LPI)

Tillage and Planting
Primary Tillage: Chisel plow following corn, moldboard plow following alfalfa, no tillage following soybean (with secondary tillage before planting).
Secondary Tillage: one pass before planting (implement, disc or field cultivator, dependent on crop residue and soil conditions).
Planting: Crops planted as soon as practical in 30 inch rows for corn and soybean, and oat is drilled with alfalfa undersown.

Fertilizer
P & K fertilizers are applied in a 2 X 2 band for corn and soybean. Nitrogen is applied in 2 by 2 band in corn. Fertilizer is broadcast applied on the oat and alfalfa. Fertilizer rates are based on soil tests (NPK), previous crop and a realistic yield goal.

Weed Control
Mechanical weed control with rotary hoe and row cultivation. Herbicides are banded in corn and soybean, and broadcast in oat and alfalfa.

High Purchased Input (HPI)

Tillage and Planting
Primary Tillage: Moldboard plow following corn and alfalfa, chisel plow following soybean.
Secondary Tillage: One pass or two passes before planting (implement, disc or field cultivator, dependent on crop residue and soil conditions).
Planting: Crops planted as soon as practical in 30 inch rows for corn and soybean, and oat is drilled with alfalfa undersown.

Fertilizer
N, P, and K fertilizers are broadcast on all crops. Fertilizer rates are based on soil tests (NPK), previous crop, and an optimistic yield goal (10 percent above realistic yield goal).

Weed Control
Mechanical weed control with row cultivator (1 to 2 passes). Herbicides are broadcast applied for all crops.

Soil P_2O_5 and K_2O tests from the fall of 1992 for VICMS I and VICMS II are presented in Figure 1. Nutrients applied from 1989 to 1992 are presented in Figure 1. Grassy weed counts for 1992 are shown in Figure 2 for VICMS I and VICMS II. Yields for each crop from 1989 to 1993 are presented in Figure 3.

Enterprise budgets were developed annually on a per acre basis from inputs and results of the experiment (Figure 4, Table 1 and 2). Product prices were obtained from annual reports (1989-1992) of the Southwest Minnesota Farm Business Management Association and represent averages received by members. Economic cost estimates of farming operations included overhead costs, operating expenses, and labor costs (Fuller et al., 1992). Market prices were used for inputs except herbicides which were from Durgan et al. (1992).

Energy budgets were developed annually on a per acre basis and expressed as diesel gallons (1 gal. diesel = 34,849 kcal) (Figure 4, Table 1 and 2). Fuel requirements for machinery operation were from Fuller et al. (1992).

Energy for machinery manufacture and repair was assumed to be 1/2 that required for operating fuel (Griffith and Parsons, 1983). Energy inputs were included for the production, formulation, and transport of N, P, and K fertilizers (Lockeretz, 1980) and pesticides (Pimentel, 1980)(Figure 4, Table 1 and 2).. Energy returns were based on yields and calculated for corn (Pimentel and Burgess, 1980), soybean (Scott and Krummel, 1980), oat (Weaver, 1980), and alfalfa (Heichel and Martin, 1980).

Results

Productivity Evaluation

Soil test P_2O_5 levels for VICMS I were less than half of VICMS II for all management systems, even with large additions of P_2O_5 fertilizer in the HPI system (Figure 1). Soil test K_2O levels were similar for both VICMS I and VICMS II for all management systems.

Grassy weed pressure was generally higher on VICMS I than VICMS II and with MIN and ORG treatments as compared to LPI and HPI (Figure 2).

Corn yields were higher in LPI and HPI systems than ORG and MIN for both previous levels of external inputs (Figure 3). Rotation effects on corn yields were not apparent until 1992 and were more strongly expressed with the MIN and ORG systems.

Soybean yields were greater in ORG and MIN systems as compared to LPI and HPI during the first 3 years on VICMS II (Figure 3). Yield decline in 1992 and 1993 was associated with increased weed pressure. Yearly fluctuations in soybean yield were greater for MIN and ORG systems than LPI and HPI systems (VICMS I) and corresponded with yearly weed pressure dynamics (1992>1989>1991>1990).

Oat yields were least affected by previous levels of external input (Figure 3). Yields were influenced primarily by weather and associated disease problems (lodging and cereal rusts).

Alfalfa yields on VICMS II were similar for each management system from 1990-1993. Alfalfa yields on VICMS I were similar to VICMS II with the exception of MIN system where yields have declined since 1990.

Economic and Energy Evaluation

Variable levels of total listed costs and energy use were achieved by the systems (Figure 4). Fertilizer and pest control inputs provided the greatest differences. Input differences between VICMS I and II were due to greater initial fertility status and less weed pressure in VICMS II. The HPI system generally achieved the greatest gross income and energy yield, but at the greatest cost in terms of dollars and energy (Figure 4 and Tables 1 and 2). The HPI system appears to have reached a plateau where further expenditures in dollars or energy would not increase either gross income or energy yield. Systems with lower costs per unit can withstand poor prices better than systems with higher costs per unit. The costs per unit on VICMS II are consistently less than VICMS I and reflect the different history of inputs. The four year rotation on VICMS II has consistently lower costs per unit than the two year rotation. Preliminary economic conclusions indicate VICMS II returns were greater than those on VICMS I.

The systems are still evolving from a management standpoint as well as from an environmental interaction perspective. Even though the results are preliminary they do serve as a comparison among systems during the transition period. Higher productivity, profitability, and energy efficiency were obtained on VICMS II where weed control and fertility levels were initially high. Adopting ORG or LPI systems to fields with high weed pressure and low fertility levels will be difficult. Differences between the four and two year crop rotations were more noticeable for the MIN and ORG systems than the LPI and HPI systems. Weed and fertility management are areas that require improvement if the ORG and LPI systems are to become more viable. Differences between VICMS I and VICMS II for the various management systems appear to be diminishing with time. The LPI and ORG systems are the most difficult to manage and the most promising for reducing off-farm inputs. However, yields must be increased without significantly increasing cash and energy inputs if they are to become more viable.

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ACKNOWLEDGMENTS

The authors recognize and thank R.K. Crookston, Head and Professor of Agronomy, Univ. of MN; W.W. Nelson, Emeritus Professor of Soil Science, Univ. of MN; members of the 'Koch Farm' Committee; and staff at the Southwest Experiment Station who played a large role in the design and implementation of this experiment

Figure 1. Soil tests and fertilizer additions.

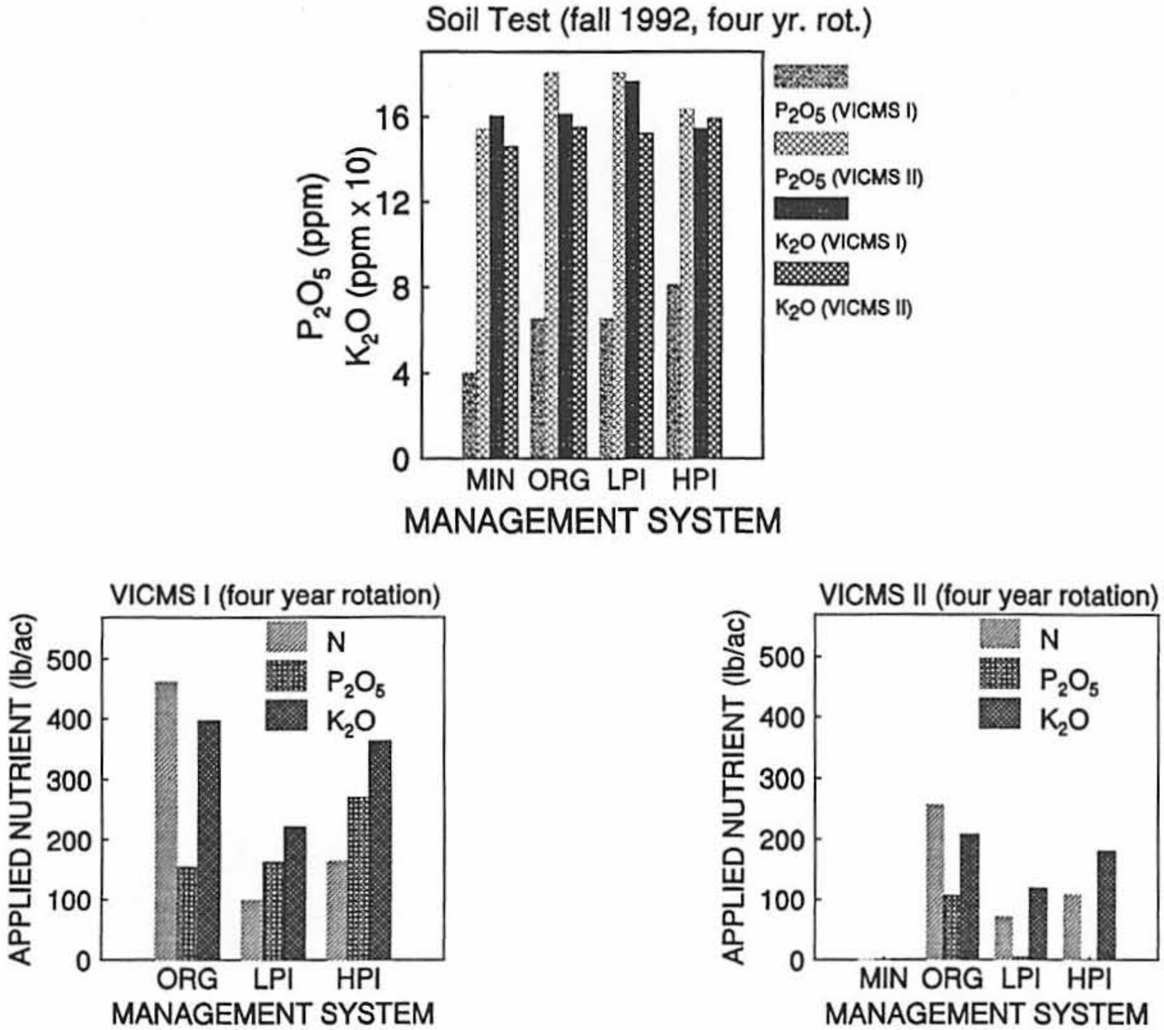


Figure 2. Grassy weed count in 1992.

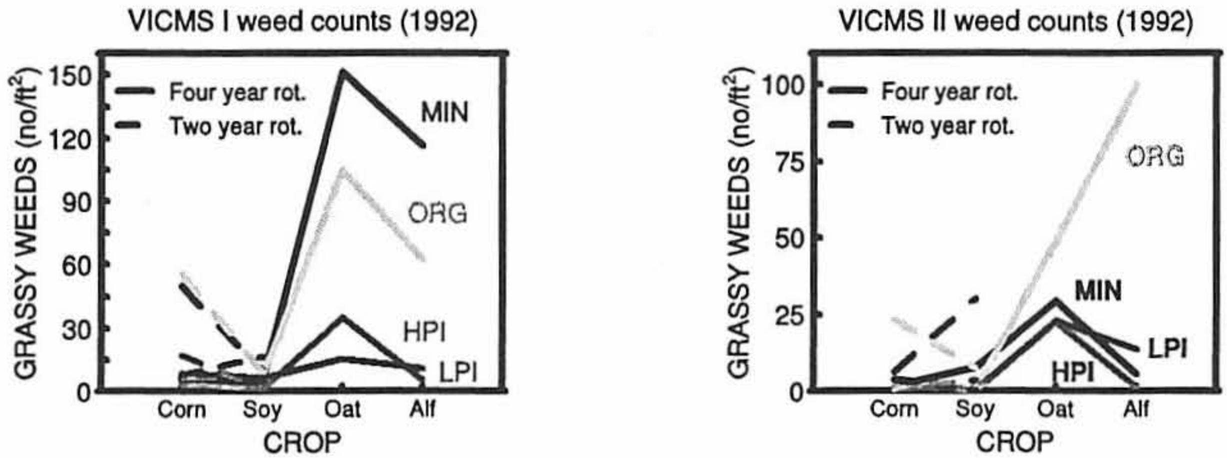


Figure 3. Crop yields.

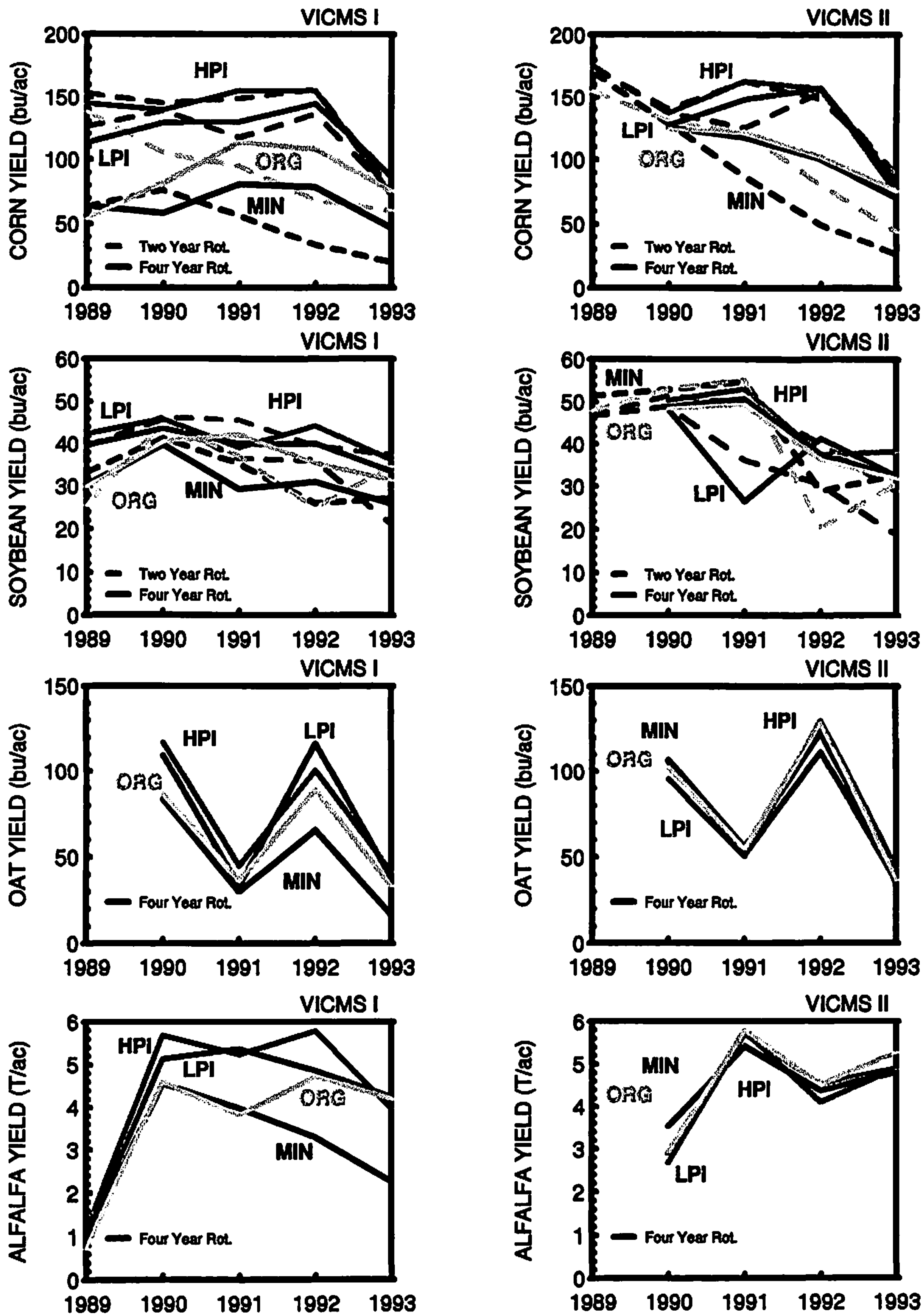


Figure 4. Economic and energy analysis 1989 - 1992.

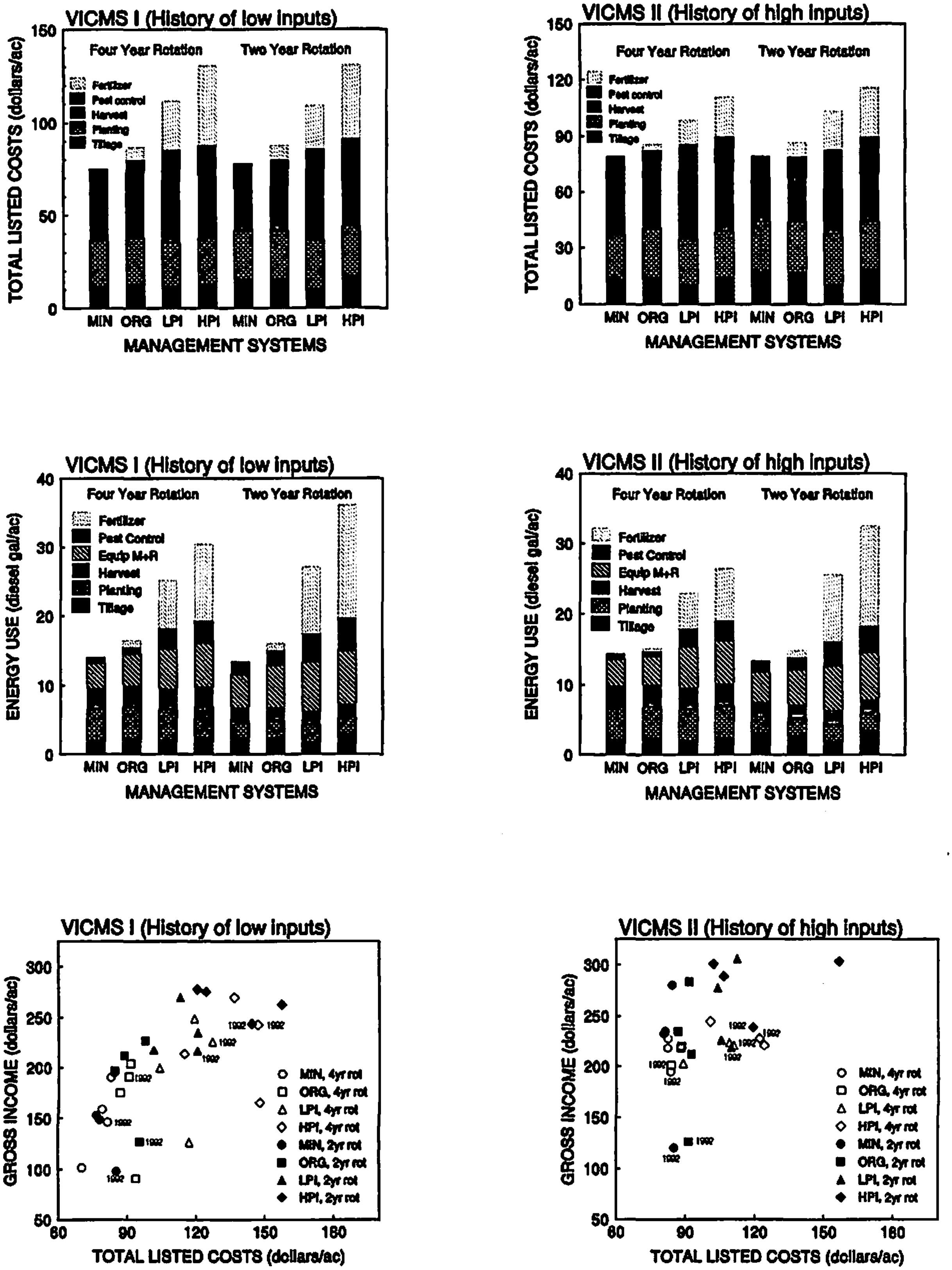
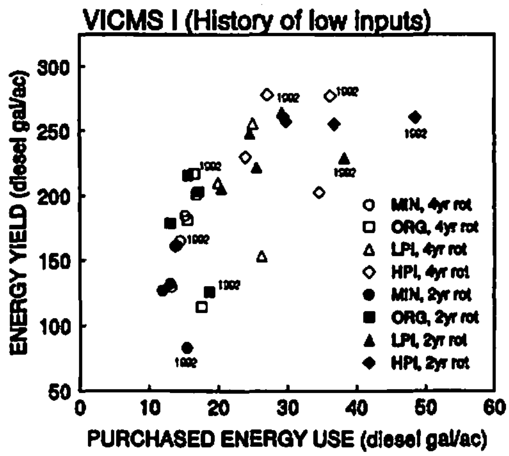


Figure 4 (cont.). Economic and energy analysis 1989 - 1992.



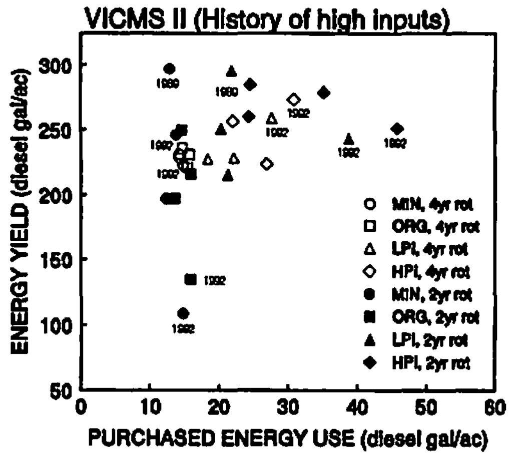


Table 1. VICMS I direct cash costs per unit (1989-1992).

	Four-Year Rotation			
Management	Corn	Soybean	Oat	Alfalfa
	($/bu)			($/ton)
MIN	1.38	2.05	0.90	43.50
ORG	1.25	2.24	0.75	52.64
LPI	1.02	2.56	1.18	56.12
HPI	1.14	2.40	1.18	57.43
	Two-Year Rotation			
MIN	1.77	2.14		
ORG	1.13	2.47		
LPI	1.03	2.42		
HPI	1.15	2.36		

Table 2. VICMS II direct cash costs per unit (1989-1992).

	Four-Year Rotation			
Management	Corn	Soybean	Oat	Alfalfa
	($/bu)			($/ton)
MIN	0.85	1.55	0.56	27.43
ORG	0.87	1.67	0.56	30.57
LPI	0.83	2.09	0.88	36.72
HPI	0.92	1.69	0.98	41.79
	Two-Year Rotation			
MIN	1.10	1.57		
ORG	1.04	2.31		
LPI	0.85	2.31		
HPI	1.00	1.83		

TILLAGE MANAGEMENT FOR INCREASING CROP YIELDS AND DECREASING SOIL EROSION AT THE SOUTHWEST EXPERIMENT STATION[1]

D.J. Fuchs, M. Lindstrom, and D.R. Huggins[2]

Field research is needed to evaluate soil movement under different crop production practices and its consequent effect on crop yield. 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 1993, tillage treatments had a significant effect on soybean yield on all slope percentages. Yields with moldboard plow and chisel plow treatments were significantly greater than yields with ridge tillage in all cases. No other treatments significantly affected soybean yield.

MATERIALS AND METHODS

This study began in the spring of 1985 to examine the effect of slope percentage (1%, 4%, and 8%), tillage (ridge tillage, moldboard plow, and chisel), tillage/planting direction (up and down the slope, or contour to the slope), and slope position (top, middle, and bottom) on soil movement and yield in a corn and soybean rotation. The field experiments are located at three different sites with one site for each slope percentage. Treatments at the site with 8 percent slope are tillage, plant row direction, and position on the slope (top, middle, or bottom). Treatments at the site with 4 percent slope are tillage, and plant row direction while the site with 1 percent slope has only tillage treatment. Yields are measured every year. Base line data on soil movement was collected at the start of the experiment. The experiment was concluded in 1993, and soil movement was assessed by grass catch strips and infrared transit survey. Additional management information is provided in Table 1. Analysis of variance was performed for each slope percentage. If treatments were significantly different (0.05 level), means were separated using Fisher's $LSD_{0.05}$., and are included with the appropriate tables.

RESULTS

In 1993, soybean yields for the various tillage treatments were significantly different for each slope percentage. The moldboard plow and chisel plow yielded more than the ridge tillage treatments in all cases (Table 2-5). Yields with moldboard plowing were 5 percent greater than with chisel plowing and 22 percent greater than yields with ridge tillage on the 8 percent slope (Table 2 and 3). No significant yield difference occurred on the 8 percent slope due to row direction or position (Table 3).

On the 4 percent slope, soybean with moldboard plow yielded 20 percent and chisel plow 18 percent more than the ridge tillage treatment (Table 4). There was no significant effect of row direction on corn yield on the site with 4 percent slope. On the 1 percent slope, soybean with moldboard plow yielded 19 percent and chisel plow 18 percent more than the ridge tillage treatment (Table 5).

Table 1. Management Information for 1993.

Item	Type	Rate	Date
Primary Tillage[1]	CP and MP	Once	Fall 1992
Secondary Tillage	Disc	1 pass	5/21,5/25
Seed	Hardin	150,000 seeds/ac	5/26
Herbicides	Lasso and Sencor	3.0 lbs/ac (ai) 1.5 lbs/ac (ai)	5/26
Row Cultivation		Once	7/15
Ridging			7/27

[1] No primary or secondary tillage on ridge tillage plots.

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

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

Table 2. Soybean Yields on the 8 Percent Slope by Tillage.

Tillage[1]	Average yield	Standard deviation
	bu/ac	
Moldboard Plow	39.2	4.1
Chisel	37.4	3.6
Ridge Tillage	30.7	4.2

[1] $LSD_{(0.05)}$ = 2.2 bu/ac

Table 3. Soybean Yields on the 8 Percent Slope by Tillage-Row Direction-Slope Position.

Row direction	Tillage	Slope Position	Average yield	Standard deviation
			bu/ac	
Up & Down	Moldboard Plow	Top	39.1	3.2
		Middle	39.5	3.3
		Bottom	37.5	7.1
	Chisel Plow	Top	36.6	3.3
		Middle	37.3	1.7
		Bottom	37.6	1.9
	Ridge Tillage	Top	28.7	4.0
		Middle	27.1	4.9
		Bottom	31.3	4.3
Contour	Moldboard Plow	Top	37.7	4.1
		Middle	40.5	1.9
		Bottom	40.7	4.2
	Chisel Plow	Top	35.6	5.9
		Middle	36.8	3.0
		Bottom	40.2	3.7
	Ridge Tillage	Top	31.6	4.3
		Middle	33.7	1.8
		Bottom	32.0	2.9

Table 4. Soybean Yields on the 4 Percent Slope by Tillage-Row Direction Interaction.

Tillage	Avg. Yield[1]	Row Direction	Average yield	Standard deviation
	-- bu/ac--		bu/ac	
Moldboard Plow	40.9	Up & Down	40.8	1.0
		Contour	40.9	2.5
Chisel Plow	36.7	Up & Down	37.4	2.6
		Contour	35.9	5.4
Ridge Tillage	32.7	Up & Down	29.2	2.4
		Contour	36.1	5.9

[1] $LSD_{(0.05)}$ = 4.0 bu/ac

Table 5. Soybean Yields on the 1 Percent Slope by Tillage.

Tillage	Average yield[1]	Standard deviation
	—— bu/ac ——	
Moldboard Plow	38.8	4.8
Chisel Plow	38.2	2.8
Ridge Tillage	31.4	3.1

1 $LSD_{(0.05)}$ = 4.3 bu/ac

THE EFFECT OF TILLAGE SYSTEMS ON SOIL BULK DENSITY AND LONG-TERM CROP YIELDS AT THE SOUTHWEST EXPERIMENT STATION[1]

D.J. Fuchs, J.F. Moncrief, and D.R. Huggins[2]

ABSTRACT

The wet soil conditions for the past year and latter part of 1992 have increased the potential of soil compaction. This study was conducted in the fall of 1993 (10/18/93) to evaluate bulk density differences in a corn -soybean rotation, with each crop grown every year, with four tillage systems: 1) no-tillage, 2) ridge tillage, 3) Reduced tillage and 4) Conventional tillage. Within each tillage system, wheel traffic and no wheel traffic areas were sampled at the 0 to 6 inch and 6 to 12 inch depth increments. Results show relatively high bulk densities across all treatments, averaging 1.56 (g/cm^3). There was no significant difference in bulk densities between tillage systems. There were significantly greater bulk densities in wheel traffic areas, and at the 6 to 12 inch depth increment.

MATERIALS AND METHODS

The wet conditions that have occurred since the fall of 1992 may have predisposed the soils to increased compaction from harvest and planting equipment. This study was conducted in the fall of 1993 (10/18/93) to evaluate bulk density differences in a corn -soybean rotation, with each crop grown every year, with four tillage systems: 1) no-tillage, 2) ridge tillage, 3) Reduced tillage and 4) Conventional tillage. Three of the four tillage replications were sampled in the corn portion of the rotation. The no-tillage system has no primary tillage, secondary tillage or row cultivation. The ridge tillage system has no primary or secondary tillage, row cultivating and ridging were timed for optimum weed control and minimal crop damage. The reduced tillage system has chisel plowing after corn harvest and no-tillage after soybean harvest. Both crops receive secondary tillage in the spring before planting and row cultivation for weed control. The conventional tillage system has moldboard plowing after corn harvest and chisel plowing after soybean harvest. Both crops receive secondary tillage in the spring before planting and row cultivation for weed control. Within each tillage system, areas with and without wheel traffic were sampled at the 0 to 6 inch and 6 to 12 inch depth increments. Five soil cores (1.8-cm diam.) were taken for each treatment replication and composited. Soil samples were dried at 105 degrees C for 24 hours and then weighed to determine bulk densities and gravimetric water contents.

A preliminary soil bulk density sampling was conducted earlier (9/8/93) on three of the four tillage systems mentioned above. The tillage systems evaluated included: 1) no-tillage, 2) conventional tillage, and 3) reduced tillage. Also, within each tillage system, wheel traffic and no wheel traffic areas were sampled at the 0 to 6 inch and 6 to 12 inch depth increments. One replication of the both the corn and soybean crops were sampled. Bulk density and gravimetric water contents from the preliminary sampling and the October 18 sampling are presented in Tables 1 and 2. Corn and soybean yields from 1986 to 1993 are presented in Table 3 and 4.

RESULTS AND DISCUSSION

The preliminary sampling on 9/8/93 indicated high bulk density measurements for all treatments. Bulk densities were greater in wheel traffic areas and at the 6 to 12 inch depth (Table 1). The sampling on 10/18/93 verified the preliminary sampling with significant differences in bulk densities and gravimetric water contents between areas with and without wheel traffic, and between depth increments. Average wheel traffic areas had bulk densities 9.8 percent and water contents 6.8 percent greater than in non-wheel traffic areas. The 6 to 12 inch depth increment had bulk densities 4.2 percent greater than the 0 to 6 inch depth increment. The water content was 4.3 percent greater in the 0 to 6 inch depth increment than in the 6 to 12 inch depth increment (Table 2). There was a significant interaction between wheel traffic and depth increment. The 6 to 12 inch depth was less effected by wheel traffic than the 0 to 6 inch depth (Figure 1). Tillage had no significant effect on measured soil bulk density or water content.

Long-term yields indicate that conventional tillage has resulted in the greatest corn and soybean yields (Table 3 and 4). Past research has shown that the moldboard plow decreases soil bulk density in the soil surface more than chisel plowing or no-tilling. This may be one factor that contributes to yields being greater in conventional tillage, even though there was no significant difference in bulk densities between tillages in the fall of 1993.

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1 Funding provided by the Agricultural Experiment Station.

2 Scientist - U of MN, Southwest Experiment Station; Associate Professor - U of MN, St Paul, MN 55108; Assistant Professor - U of MN, Southwest Experiment Station, respectively.

Table 1. Preliminary bulk density and gravimetric water content measurements .

Tillage	Wheel Traffic	Depth	Bulk Density	Gravimetric Water
	(yes/no)	(in.)	(g/cm^3)	(g/g)
No-tillage	no	0-6	1.46	21.99
	no	6-12	1.59	24.20
	yes	0-6	1.57	21.99
	yes	6-12	1.66	23.78
Reduced	no	0-6	1.54	21.87
	no	6-12	1.66	21.86
	yes	0-6	1.65	20.97
	yes	6-12	1.69	21.66
Conventional	no	0-6	1.34	23.10
	no	6-12	1.55	22.42
	yes	0-6	1.58	22.48
	yes	6-12	1.67	22.69

Table 2. Bulk density and gravimetric water content measurements.

Tillage	Wheel Traffic[1]	Depth[2]	Bulk Density	Std. Dev.	Gravimetric Water	Std. Dev.
	(yes/no)	(in.)	(g/cm^3)		(g/g)	
No-tillage	no	0-6	1.44	0.03	26.82	0.45
	no	6-12	1.52	0.06	25.21	0.82
	yes	0-6	1.63	0.04	24.05	0.19
	yes	6-12	1.62	0.06	24.66	0.94
Ridge Tillage	no	0-6	1.38	0.05	26.83	1.00
	no	6-12	1.54	0.05	25.75	1.01
	yes	0-6	1.64	0.06	24.98	1.51
	yes	6-12	1.64	0.07	25.04	1.44
Reduced	no	0-6	1.47	0.07	27.45	1.18
	no	6-12	1.58	0.08	25.76	0.68
	yes	0-6	1.62	0.07	25.41	0.85
	yes	6-12	1.66	0.06	24.36	0.55
Conventional	no	0-6	1.43	0.01	27.96	1.48
	no	6-12	1.55	0.03	25.28	0.56
	yes	0-6	1.61	0.03	25.18	2.11
	yes	6-12	1.63	0.06	23.94	2.16

[1] $LSD_{(0.05)}$ = 0.02 (g/cm^3) and 0.61 (g/g) in comparison between wheel traffic and no wheel traffic for bulk density and gravimetric water content measurements, respectively.

[2] $LSD_{(0.05)}$ = 0.03 (g/cm^3) and 0.61 (g/g) in comparison between 0 to 6 in. depth and 6 to 12 in. depth increments for bulk density and gravimetric water content measurements, respectively.

Figure 1. Bulk densities measurements with and without wheel traffic by depth.

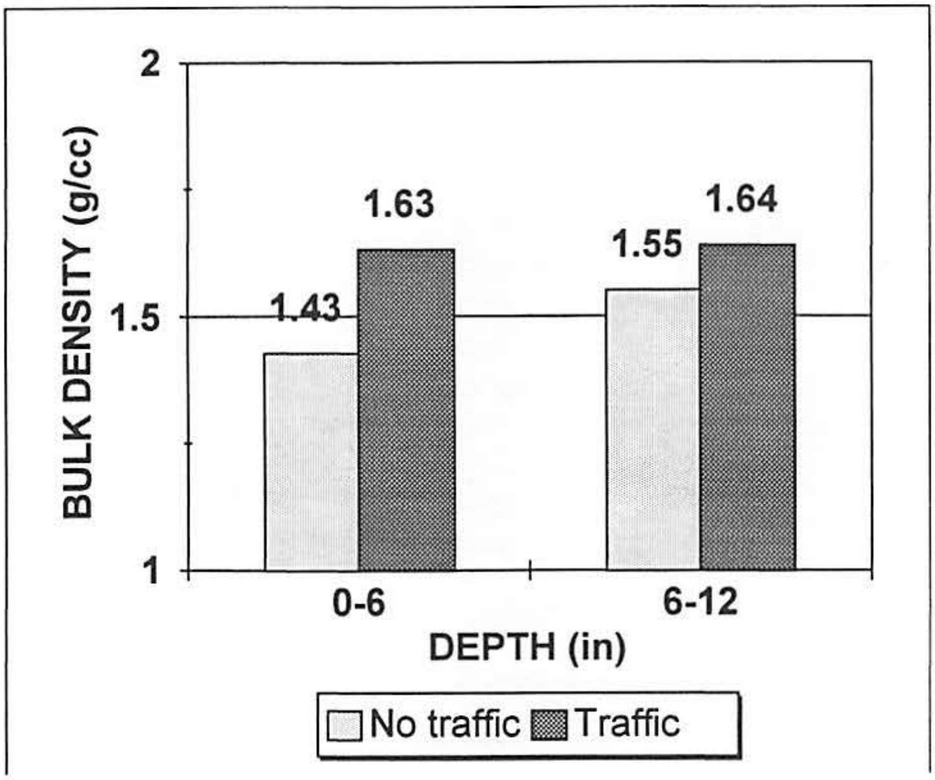

Table 3. Soybean yields 1986 - 1993.

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	Average
					(bu/ac)				
Notill	47.4	39.3	26.9	40.9	44.7	40.3	35.9	19.8	37.8
Ridge Tillage	47.2	38.7	26.7	49.2	48.7	41.3	35.3	31.5	38.5
Conv.	47.9	38.8	32.7	48.8	51.8	48.0	37.3	38.9	40.8
Reduced	46.7	39.5	26.3	45.8	51.6	46.2	37.7	34.5	38.5
Spr. till	48.9	37.0	26.2	47.1	45.4	44.4	36.5	33.1	38.2
$LSD_{0.05}$	1.5	1.4	1.5	2.6	2.6	3.5	2.0	2.9	1.4

Table 4. Corn yields 1986 - 1993.

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	Average
					(bu/ac)				
Notill	142.0	132.4	73.7	122.2	114.5	133.4	134.2	71.9	116.1
Ridge Tillage	145.4	125.4	82.2	132.6	118.4	128.9	145.3	72.0	119.6
Conv.	141.5	136.4	76.7	139.0	137.2	132.2	153.6	76.6	125.2
Reduced	139.8	124.8	70.1	128.1	120.5	133.6	130.7	75.1	115.9
Spr. till	132.4	119.8	65.4	131.8	122.8	132.6	136.6	73.4	114.1
$LSD_{0.05}$	11.7	6.7	6.7	6.9	6.0	6.2	10.2	4.3	5.4

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1993

		Precipitation			Air Temperature			Soil Temperature (10 cm depth)	
Month/ Period	Dates/ Period	1993	100-yr. average	Dev. from av.	1993	100-yr. average	Dev. from av.	1993	10-yr. average
January	1-31	0.89	0.68	+0.21	7.4	8.0	- 0.6	27.2	20.7
February	1-28	0.36	0.67	- 0.31	10.7	12.8	- 2.1	29.5	23.9
March	1-31	1.68	1.13	+0.55	23.9	26.7	- 2.8	31.2	29.2
April	1-10	0.41	0.57	- 0.16	38.0	38.0	0	38.9	
	11-20	0.98	0.64	+0.34	43.4	44.4	- 1.0	41.9	
	21-30	0.46	1.05	- 0.59	42.4	48.3	- 5.9	47.6	
Total/ av.		1.85	2.26	- 0.41	43.0	43.6	- 0.6	42.8	41.4
May	1-10	2.60	0.77	+1.83	57.6	52.0	+ 5.6	55.8	
	11-20	0.12	0.95	- 0.83	56.2	55.8	+ 0.4	61.2	
	21-31	3.46	1.25	+2.21	55.6	60.0	- 4.4	58.2	
Total/av.		6.18	2.97	+3.21	56.4	56.1	+ 0.3	58.4	57.1
June	1-10	0.33	1.29	- 0.96	58.3	63.0	- 4.7	61.7	
	11-20	3.06	1.30	+1.76	64.8	66.3	- 1.8	66.8	
	21-30	2.08	1.37	+0.71	64.8	68.1	- 3.3	69.6	
Total/av.		5.47	3.96	+1.51	62.6	65.8	- 3.2	66.0	69.3
July	1-10	5.13	1.44	+3.69	66.4	70.1	- 3.7	67.7	
	11-20	1.10	1.06	+0.04	67.2	71.4	- 4.2	70.7	
	21-31	1.68	1.01	+0.67	70.4	71.4	- 1.0	73.5	
Total/av.		7.91	3.51	+4.40	68.1	70.9	- 2.8	71.0	76.7
August	1-10	0.23	1.04	- 0.81	65.8	70.4	- 4.6	74.8	
	11-20	2.08	0.93	+1.15	71.0	69.0	+ 2.0	76.2	
	21-31	0.53	1.04	- 0.51	68.3	66.9	- 1.4	73.9	
Total/av.		2.84	3.01	- 0.17	68.4	68.7	- 0.3	74.9	73.9
September	1-30	2.14	2.20	- 0.06	53.2	59.0	- 5.8	60.6	61.5
October	1-31	1.06	1.74	- 0.68	43.9	47.2	- 3.3	48.9	47.8
November	1-30	1.66	0.97	+0.69	26.3	29.7	- 3.4	35.1	33.6
December	1-31	0.77	0.68	+0.09	14.8	15.2	- 0.4	34.6	23.4
Growing Season	4/1-8/31	24.25	15.71	+8.54	59.8	61.0	- 1.2	62.7	63.8
Annual	1/1-12/31	32.81	23.78	+9.03	40.0	42.0	- 2.0	48.5	46.7

LONG-TERM CORN-SOYBEAN TILLAGE[1]

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

Abstract

This study covers the results of the eleventh year of a continuous tillage study at Morris, MN to evaluate the interaction of tillage with various other factors in a corn-soybean rotation. In 1993 the study was seeded to soybean following various K placement and hybrid treatments in 1992. There were no significant effects of K placement or hybrid from the previous year's treatment, but soybean yields were significantly lower with ridge till and no till than with moldboard plow and chisel plow. Yields on chisel plow were significantly higher than on moldboard plow.

Materials and Methods

This is eleventh year of a continuous tillage experiment carried out on a Tara silt loam (Pachic Udic Haploboroll, fine-silty, mixed) 2 miles east of Morris, MN. A randomized, split-block design with four replicates was established in the fall of 1983. At initiation, blocks were randomly subdivided between four tillage treatments; no-till (NT), fall chisel plowing (CP), fall moldboard plowing (MP), and ridge tillage (RT). For RT, the ridging operation was performed each year in mid- to late-June except when the plots were in soybeans when ridging was performed in July. A Hiniker Econ-0-Till cultivator was used to move the soil to the inter-row area to effect a height difference of about 6 to 9 in. After tillage initiation, each plot continued to receive the same tillage treatment. Tillage blocks measured 110 ft by 40 ft. Tillage blocks were randomly divided into five sub-blocks. Because of record rainfall in 1984 and 1992, the usual fall moldboard and fall chisel operations were carried out the following spring prior to planting.

From 1983-1989 the plots were in continuous corn with sub-blocks in N fertilizer x hybrid combinations. In 1990 the study was in a soybean inoculation study. In 1991 and 1992 the study was again in corn with sub-blocks in K placement x hybrid combinations. The treatments in 1991 and 1992 were as follows:

Treatment	Description
1	Control (no K_2O) + 124 lb/ac 10-34-0 starter
2	200 lb/ac 7-21-7 starter
3	40 lb/ac K_2O in row-band (fall) + 124 lb/ac 10-34-0 starter
4	80 lb/ac K_2O broadcast (fall) + 124 lb/ac 10-34-0 starter
5	40 lb/ac K_2O in row-band (fall) + 200 lb/ac 7-21-7 starter

Each fertilizer sub-block was further subdivided into two hybrid plots; Pioneer 3732 and Pioneer 3737. In 1993 the study was seeded to soybeans with no further treatment to the sub-blocks. In 1993 corn stalks were chopped on May 4. The MP and CP treatments were applied on May 19. These two treatments were field cultivated twice in preparation for seeding. All tillage treatments were seeded with a Hiniker planter on May 20 to Evans soybeans at 15-20 seeds/foot in 30-inch rows. The planter was set for ridge till planting for all plots to eliminate turning for each plot (enabled us to straighten rows between tillage blocks). The study was sprayed with Lasso at 3 lb/ac a.i. preemerge on May 20. Poast at 0.42 lb/ac a.i.+ COC at 1 qt/ac were applied postemergence on June 12. The MP and ACP plots were cultivated on July 20 and July 29. The RT plots were cultivated on July 20 and ridged on July 30. The first killing frost was on September 15. All plots were harvested on October 6 with a plot combine. Plot yields and seed moisture were recorded.

Results and Discussion

There were no significant effects of the previous K placement or hybrid treatments. There were significant effects of tillage (Table 1). RT and NT were significantly lower yielding than MP and CP, and CP was significantly higher yielding than MP.

Table 1. Effect of tillage treatments on soybean yield in 1993.

Tillage	Grain Yield
	- - bu/ac - -
Chisel plow	35.3 a
Moldboard plow	32.8 b
Ridge till	26.7 c
No till	26.0 c
C.V. (%)	13.6
Pr>F	0.001

[1] Support for this project provided by the West Cent. Exp. Sta., Univ. of Minnesota.

[2] Professor and Asst. Scientist, West Cent. Exp. Sta., Univ. of Minnesota.

MATCHING PRECISION PLACEMENT OF POTASH FERTILIZER TO ROOT GROWTH IN A RIDGE-TILL PLANTING SYSTEM

D. Allan, S. Evans, G. Rehm, L. Oldham, G. Nelson, A. Scobbie, and T. Sellie[1/]

ABSTRACT: Early growth, K concentration and uptake, and grain moisture and yield were compared for two tillage systems (fall chisel, ridge-till), two hybrids (Pioneer 3732, Pioneer 3737), and three potash fertilizer treatments (control, 40 lb. K_2O per acre banded, 40 lb. K_2O per acre broadcast). Early growth, K uptake, and total dry matter yields were greater in the fall chisel system and for the Pioneer 3737 hybrid. Banded application of K_2O also improved early growth and dry matter yield especially in the ridge-till planting system. Potassium uptake was always highest from the banded K_2O application, with little difference between the broadcast and control treatments. The Pioneer 3737 hybrid has higher root activity and root density in the surface, especially at interrow positions more than 3 inches from the row. The Pioneer 3732 hybrid had a higher root activity and root density was deeper in the profile early in the growing season.

Introduction:

Potassium (K) deficiency is a common problem and/or concern for corn planted in either ridge-till or no-till planting systems in Minnesota, Iowa, and South Dakota, and can cause substantial reductions in corn yields. This deficiency occurs even though soils may have a high or very high level of soil test K. The severity of the deficiency also varies with hybrid. Past research has shown that an annual banded application of 40-50 lb. K_2O per acre per year will correct the problem. This early research was summarized in the Proceedings of the 1992 North Central Extension-Industry Soil Fertility Conference.

The findings summarized in that report were the catalyst for the present research. Since response to potash varied with hybrid, it seemed that the explanation for the need for potash fertilization in these conservation tillage systems was related to differences in root growth and development as affected by tillage. The purpose of the research summarized in this report was to identify the physiological basis for early season K deficiency in ridge-till planting systems by comparing the development and morphology for a sensitive and a tolerant hybrid in ridge-till and fall chisel planting systems.

Objectives:

The research described in the study that is summarized in this report is designed to:

1. Determine more precisely the effect of potash placement on root growth and subsequent corn yield in a ridge-till planting system as contrasted to a fall chisel planting system.

2. To quantify root growth in both ridge-till and fall chisel planting systems as affected by corn hybrid.

Materials and Methods: This study is being conducted at the West-Central Experiment Station of the University of Minnesota at Morris. Three factors (tillage system, hybrid, K_2O treatment) are combined in a randomized complete block design with four replications. A split-plot arrangement is used. Tillage systems (fall chisel, ridge-till) are used as the main plots. The sub-plots are hybrids (Pioneer 3732, Pioneer 3737) and potash fertilizer treatment. The three potash fertilizer treatments are: 1) control, 2) 40 lb. K_2O per acre in a fall applied band, and 3) 40 lb. K_2O per acre broadcast in the fall.

When applied in a band, the K_2O supplied as 0-0-60 was placed at a depth of 3-4 inches below the soil surface directly below the existing row. The banded and broadcast applications were made before the fall chisel operation. All treatments received 10-34-0 as a starter at planting and ample N as anhydrous ammonia in the fall. A recommended herbicide program was used for weed control after planting.

One major objective of this study is to quantify root activity. To do this, strontium (Sr), rubidium (Rb), and lithium (Li), all non-essential cations, are injected by hand to various depths at a distance of 4 inches perpendicular to the row. These tracers are injected shortly after corn emergence. Plant and soil samples are collected at approximately 30 (V4), 40 (V6-V8), and 60 (tasseling) days after planting. The plant samples are dried, weighed, ground, and analyzed for K, Sr, Rb, and Li. Total uptake of the tracers is computed on a per plant basis and is used as an estimate of root activity. Amounts of these non-essential cations taken up by plants in a non-treated area are subtracted from uptake of plants in the treated area to determine the net uptake of the tracer. The uptake of Sr, Rb, and Li by corn differs because of differences in the chemistry of the ions and the physiology of each ion in the plant. Therefore, uptake of the tracer cations is converted to a common measure (net Rb uptake per plant). To do this, plots are established in a border area where the same amounts of Sr, Rb, and Li are injected at the same depth to determine ratios of uptake of Rb/Sr, and Rb/Li.

Soil samples are collected at 0 and 2 inches from the row at 30 and 45 days after emergence. Soil is separated into 0-3 and 3-6 inch depths. Roots are separated from the soil by washing and root length is then calculated. Root density is calculated from the root length and soil volume measurements. Soil samples for measurement of root length are also taken from the control treatments.

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Root Density As Measured By The Root Core Technique:

In addition to the use of the tracer injection technique to measure root activity, root density was measured from soil cores taken at the V4 and V8 growth stages. The results of the sampling at the V4 stage are summarized in Table 3. Results from the sampling at the V8 growth stage are provided in Figures 1 and 2.

Table 3. Root length density at V4 as measured by the root core technique, 1993.

		Tillage System and Distance From Row			
		Ridge-Till		Fall Chisel	
		Distance from Row		Distance from Row	
Hybrid	Depth	0 in.	2 in.	0 in.	2 in.
		cm/cm³			
3732	0 - 3	0.07	0.08	0.37	0.30
	3 - 6	0.04	0.05	0.08	0.05
3737	0 - 3	0.27	0.24	0.31	0.29
	3 - 6	0.04	0.04	0.08	0.07

In 1993, there were dramatic differences in root density between the two hybrids planted in the ridge-till system. Pioneer 3737 had three to four times greater root density in the 0-3 inch increment. There was little or no difference between hybrids for the 3-6 inch depth increment. In evaluating this data, it is important to remember that the excessively cool and wet weather conditions probably inhibited a substantial amount of root growth below three inches in the early part of the growing season.

For the second sampling, cores were taken in the row and at positions 3, 6, and 12 inches from the row. Although samples were collected to a depth of 24 inches, the results from the 0-6 and 6-12 inch depths are shown because they show the largest differences.

In 1993, there were much larger differences between tillage systems and between hybrids than measured in 1992. The roots in the fall chisel system were twice as dense as in the ridge-till planting system (maximum root density = .59 cm/cm^3 and .30 cm/cm^3 in fall chisel and ridge-till planting systems). Pioneer 3737 had a higher root density than Pioneer 3732. In the ridge-till planting system, there was little difference in root density between hybrids at the in row and 3 inches from the row positions. But, the root system of Pioneer 3737 was much more dense at 6 and 12 inches from the row in the ridge-till planting system (Figure 2). In the fall chisel system, Pioneer 3737 had a root system that was twice as dense as the root system from Pioneer 3732 at the 0-6 inch depth (Figure 2).

Potash Effects on Root Distribution:

The effect of potash fertilization on root activity is summarized in Table 4. The data show that there was increased root activity at the 6 and 12-inch depths from banded application.

Table 4. Effect of placement of potash fertilizer on root activity at three depths as estimated by net rubidium uptake.

	Time of Sampling and Depth								
K_2O	3 inches			6 inches			12 inches		
Treatment	30	40	60	30	40	60	30	40	60
	mg net Rb uptake/plant								
control	0.26	2.47	7.70	0.11	0.83	4.29	0.001	0.02	0.70
40 lb. K_2O/acre (band)	0.36	2.48	4.72	0.07	1.17	3.90	0.002	0.02	0.89
40 lb. K_2O/acre (bdcst)	0.16	2.42	4.85	0.05	0.58	4.58	0.002	0.01	0.68

Summary of Root Data: Both types of root measurements indicate that Pioneer 3737 has higher root activity and higher root density in the surface, especially at interrow positions more than 3 inches from the row. Pioneer 3732 had a higher root activity and root density was deeper in the soil profile early in the growing season. By tasseling, the root development of Pioneer 3737 catches up. In the ridge-till planting system, Pioneer 3737 extends more roots laterally and fewer vertically in the early growth stages. By contrast, Pioneer 3732 develops most of the root system near the row and then extends vertically. Since potassium accumulation occurs very near the soil surface in the ridge-till planting system, the root morphology of Pioneer 3737 should stimulate the uptake of potassium at the early growth stages of corn.

RIDGE TILL, 1993

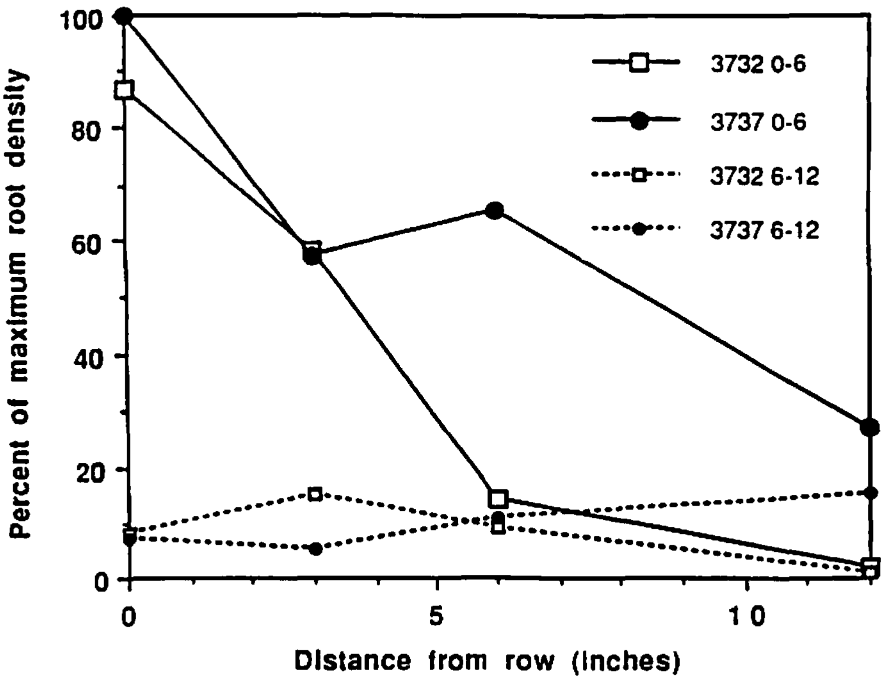

Fig. 1. Percent of maximum root density ($0.30\ cm/cm^3$) at V8 as measured by the root core technique.

FALL CHISEL, 1993

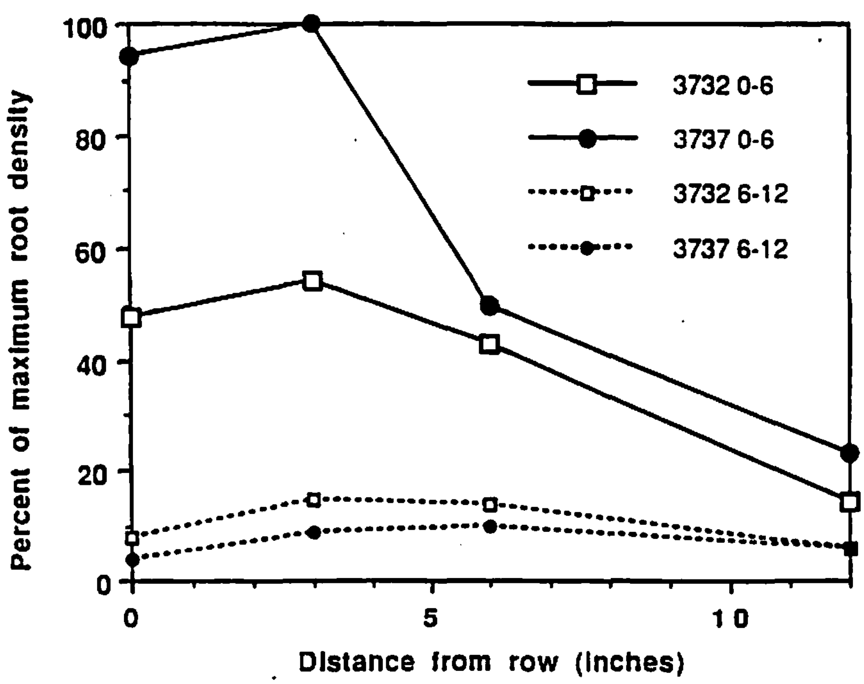

Fig. 2. Percent of maximum root density ($0.59\ cm/cm^3$) at V8 as measured by the root core technique.

Total dry matter production was measured at physiological maturity in 1993. There were no grain yields because of the excessively cool and wet growing season.

Results and Discussion:

The excessively cool and wet growing conditions limited corn growth and caused substantial delays in maturity in 1993. Consequently, there was no harvest for grain. Instead, total dry matter yields were measured. These yields are reported in Table 1. Dry matter production was significantly affected by tillage system, hybrid, and management of the potash fertilizer. When averaged over other factors, yields were higher with the fall chisel planting system. The yield from Pioneer 3737 was higher than the yield from Pioneer 3732. There was a highly significant response to potash with the banded application being superior to the broadcast application. The largest response to potash use was measured when Pioneer 3732 was planted in the ridge-till planting system. The effect of the three factors on total dry matter yield in 1993 parallels the effects on grain yields measured in 1992.

Table 1. The effect of tillage system, hybrid, and management of potash fertilizer on dry matter yield of corn. 1993.

Tillage System	K_2O Management	Corn Hybrid 3732	3737
		- lb. dry matter per acre -	
fall chisel	none	7213	8055
	40 lb. K_2O (band)	8675	9546
	40 lb. K_2O (broadcast)	7944	8293
ridge-till	none	5665	7343
	40 lb. K_2O (band)	8860	7484
	40 lb. K_2O (broadcast)	7151	8274

soil test K = 161 ppm

The measure of the uptake of the non-essential cations (Sr, Rb, Li) injected at depths of 3, 6, and 12 inches was used as an evaluation of root activity. Root activity data for 1993 are summarized in Table 2. The uptake of Sr and Li was normalized to Rb uptake and all uptake data are reported as mg net Rb uptake per plant.

Table 2. Root activity at three depths as estimated by net rubidium uptake during the 1993 growing season

	Time of Sampling and Depth								
	3 inches			6 inches			12 inches		
Treatment	30	40	60	30	40	60	30	40	60
	mg net Rb uptake/plant								
Tillage Main Effects:									
Fall Chisel	0.32	2.91	5.83	0.10	1.13	4.66	0.001	0.02	0.65
Ridge-Till	0.23	1.99	5.68	0.05	0.58	3.85	0.002	0.02	0.87
Hybrid Main Effects:									
3732	0.21	2.28	4.97	0.09	0.97	4.35	0.001	0.02	0.65
3737	0.34	2.63	6.55	0.06	0.74	4.16	0.002	0.01	0.85
Tillage X Hybrid Interaction:									
Chisel Plow:									
3732	0.19	2.97	5.37	0.13	1.22	4.70	0.001	0.017	0.61
3737	0.46	2.86	6.29	0.08	1.05	4.62	0.001	0.015	0.69
Ridge-Till:									
3732	0.23	1.58	4.57	0.06	0.71	4.00	0.001	0.024	0.73
3737	0.22	2.41	6.80	0.04	0.44	3.70	0.003	0.013	1.00

In 1993, root activity was greater at all sampling times when the fall chisel planting system was used. This activity was approximately 40% higher at the 3-inch depth and 100% higher at the 6-inch depth. When averaged over tillage treatments, Pioneer 3737 had higher root activity than Pioneer 3732 at the 3-inch depth. The reverse was true at the 6-inch depth. In general, effects of tillage system and hybrid on root activity were consistent for both 1992 and 1993.

ESTIMATION OF DIRECT AND RESIDUAL N AVAILABILITY FROM APPLIED LIQUID SWINE AND DAIRY MANURE[1]

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Abstract

The effects of application of liquid swine and liquid dairy manure applications on soil NO_3-N content and various crop parameters were evaluated for one season following fall injection. All manure treatments increased soil NO_3-N at corn emergence and at stage V5. Chlorophyll meter readings at stage V5 varied only slightly from the inorganic check, but just prior to tasseling the differences were much greater. Corn silage yield, grain yield, grain moisture, and grain N content were significantly affected by both urea and manure applications. There was a positive relationship between soil NO_3-N to a 2-ft depth at corn stage V5 and corn grain yield.

Introduction

Animal agriculture is an important part of the farm economy in west central Minnesota. Most manure is used as a nutrient source on cropland, but most farmers tend to give less credit to manure than suggested because 1) N fertilizer is cheap and 2) a little extra N gives them a cushion in case of unexpected N losses or reduced N availability from manure. It would be helpful if farmers had some technique to determine the N status and predicted N need before the period of maximum N uptake and early enough so that supplemental N could be applied. This is particularly important for slow release N sources such as manure. Early season soil and plant tests will be used to evaluate the apparent N mineralization rate and N status of the corn crop. Climatic variables will also be measured on a limited number of plots in another phase of the overall nutrient recycling effort so that apparent N mineralization can be modeled. Corn grain yields and N uptake will be used as the final measure of N availability over a growing season.

Materials and Methods

The experimental site was established in the fall of 1992 on a predominately Aastad clay loam (Pachic Udic Haploboroll, fine loamy, mixed) located on the West Central Experiment Station, Morris, MN. The 1992 crop was corn and was harvested as corn silage on October 1-2, 1992. Two trial sites were established; one to commence with manure and fertilizer applications in the fall of 1992 and the other to commence with manure and fertilizer applications in the fall of 1993.

Treatment areas were staked out in the first site on October 5, 1992. The design was a randomized, compete block with 4 replications. Plot size was 15 ft wide (6 rows) by 47.5 ft long. Thirteen treatments included a check, 4 rates of urea, 4 rates of liquid swine manure, and 4 rates of liquid dairy manure (Table 2). On October 6 the site was grid sampled on the corners of every second plot to determine depth of topsoil, soil drainage characteristics, soil pH, soil organic matter content, and depth to carbonates. Samples were air dried and saved for analysis. Each replication was sampled for N content on October 6 by compositing 10 random probes to a depth of 5 feet in 1-ft increments. The samples for N analysis were air dried. The initial NO_3-N values averaged over replicates were as follows: 0-1 ft = 4.0 ppm, 1-2 ft = 2.0 ppm, 2-3 ft = 6.7 ppm, 3-4 ft = 8.6 ppm, and 4-5 = 13.1 ppm. Fertilizer was applied broadcast to the entire study on October 13 to provide 75 lb/ac P_2O_5 and 75 lb/ac K_2O. The entire study was chisel plowed on October 14. The study was field cultivated on October 15 to level the soil to insure uniform manure application.

Manure rates were based on estimates of N content of the manures from previous samplings (Table 1). On October 19 the first 3 swine manure treatments were applied to provide 80, 160, and 240 lb/ac N and on October 20 the highest swine manure treatment was applied to provide 320 lb/ac N. All dairy manure treatments were applied on October 20 to provide 80, 160, 240, and 320 lb/ac N. All manure treatments were applied with an experimental Agricultural Engineering Department manure applicator. Samples of each manure were taken directly from the applicator in the field for subsequent analysis. The N contents of the manures taken at this time are given in Table 1. The applicator was weighed using portable load cells before and after each application treatment to calculate actual application rates. The applied manure rates were calculated from these weights (Table 2). The manure was metered through 4 hydraulically driven pumps, one for each injector, to provide very accurate, uniform application. The applicator was outfitted with 4 18-inch sweeps, 24 inches on center, for a total applicator width of 7.5 ft. Two passes were required for each plot. Application of all manure rates, except for the 320-lb dairy rate, were at a 4-5-inch depth with a single pass. For the 320-lb dairy rate one -half the manure was

[1] Support for this project was provided by the Legislative Commission on Minnesota Resources, the West Cent. Exp. Sta., the Soil Science Dept., and the Agricultural Eng. Dept., Univ. of Minnesota..

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applied at a 5-6 inch depth on an initial pass and the other half at a 3-4-inch depth with a second pass. Inorganic fertilizer as urea was applied to provide 40, 80, 120, and 160 lb/ac N. The entire study was field cultivated on October 22 to incorporate the inorganic fertilizer and remove wheel tracks from the manure applicator.

In the spring of 1993 the study was field cultivated (April 28) parallel to the manure applicator bands and future row direction. The study was planted on April 28 to Ciba-Geigy 4172 at 30,100 seeds/ac. Counter 15G was applied at 8.7 lb/ac at seeding with the planter. Lasso (3 lb/ac a.i.) + Bladex (2.2 lb/ac a.i.) was broadcast preemergence on April 29.

All plots were soil sampled in 0-1 and 1-2 ft increments on May 17 at the emergence stage of corn for soil N content. Each soil sample was a composite of 6 subsample probes (two in the corn row, two 7.5 inches from the row to the north, and two 15 inches from the row to the north). The study was sprayed with a postemergence application of Atrazine (2 lb/ac a.i.) + 1 qt/ac COC on June 18 for additional grass control. At the V5 stage of corn growth all plots were soil sampled using the same procedures as at the emergence stage. Reps 1 and 3 were sampled on June 22, and reps 2 and 4 were sampled on June 28. The delay in sampling was due to a 0.34-inch rainfall on the afternoon of June 22. Total rainfall between ceasing sampling on June 22 and beginning on June 28 was 2.29 inches. All soil samples at emergence and V5 were dried at 100°F.

Chlorophyll meter readings were taken at V5 stage on June 25 and again on July 26, just prior to tasseling. Meter readings were taken halfway between the midrib and the leaf edge, halfway between the stalk and the end of the leaf, on the most recently fully extended leaf. The study was cultivated on June 28 with a 6-row cultivator.

Silage yields were taken from 45 ft of row on September 16. Ears and stover were weighed separately and 5 stalks and the center 3/4 inch of 10 ears was saved for moisture and N analysis. Basal stalk samples from 10 plants (an 8-inch section from 6 to 14 inches from the soil surface) were collected on October 1 and saved for NO_3-N analysis. Grain yields were taken from 45 ft of two center rows on October 11 with a plot combine and a grain sample was saved for test weight and N analysis.

Post harvest soil samples were taken to a depth of 5 ft in 1-ft increments. Reps 1 and 2 and plots 302-305 (rep 3) were sampled on October 14, plots 301, 306-313, and 401-404 were sampled on October 15, and plots 405-413 were sampled on October 18. The plots were sampled using the same procedures as at the emergence stage. These samples were dried at 100°F. Urea was applied on October 18 to the same plots and rates as in the fall of 1992. The study was chisel plowed on October 18.

Results and Discussion

<u>Manure Application</u>
The target N rates were not achieved because of differences in manure N content measured at application (Table 2). Swine manure N rates were about 58% of the target and dairy manure N rates were about 115% of the target values.

<u>Soil N Content</u>
There were significant effects of treatment on soil NO_3-N content at all sample dates and depth combinations shown (Table 3). The NO_3-N values with both manures in the 0-1 and 0-2 ft depths at emergence were very similar to that with urea, except for D4 where the values were about 90% above those of F4.

At corn stage V5 the NO_3-N values were much lower than at emergence (Table 3), but there were still significant treatment effects. Precipitation at the site between the May 17 sampling date and June 22 was 7.78 in (long-term average = 4.35 in). The total precipitation between May 17 and the completion of V5 sampling on June 28 was 10.07 in (long-term average = 5.06 in). The amounts of NO_3-N in the second foot were about the same as that in the first foot indicated by the similarity between the 0-1 and 0-2 ft values. In general, the NO_3-N values increased as applied N increased.

In October after harvest the NO_3-N values of the 0-1 and 0-2 ft zones were much lower than at the earlier two sampling dates. There were significant treatment effects of all depth increments (Table 3). There was considerable NO_3-N below the 0-1 ft zone as indicated by the higher values in the 0-5 ft profile averages.

There were no significant effects of treatment on soil NH_4-N values at emergence, V5, and post harvest.

Plant Measurements

Relative chlorophyll meter readings were significantly affected by treatment on both measuring dates (Table 4), even though the range was very small on June 25. The F4 treatment was used as the corn with adequate N, but ratios at high manure rates were slightly higher than those on F4. The relative chlorophyll readings of S1 through S4 and D1 through D4 were similar to F1 through F4, respectively.

Silage dry matter yield increased with the first two increments of all N sources (Table 4). There were very small if any increases with the third and fourth increments of all N sources.

The maximum grain yield was 106.4 bu/ac with D4. Both grain and silage yields were limited by the excessive rainfall, cool temperatures, and low solar radiation during the 1993 growing season. Grain yield, grain moisture, bushel weight, and grain N were all significantly affected by treatment (Table 4). Grain yields appeared to respond to the actual N applied and the resulting soil NO_3-N levels. It appeared that 160 lb/ac N as urea was not sufficient for maximum yields in 1993 due to losses by leaching and denitrification. With the manure sources, N release during the growing season continued to supply the plant with N, resulting in higher yields with S4 and D4. However, the differences were not significant due to the high coefficient of variation. Grain moisture appeared to decline slightly as N rates increased. Grain test weight was lower than normal, but there were no apparent trends due to treatment. Grain N content increased with applied N. Significant differences were observed in the comparison of CK, F1, S1, and D1 with F3, S4, D3, and D4.

The relationship between grain yield and soil NO_3-N values (0-2 ft) at corn stage V5 is shown in Fig. 1. The best relationship (r^2 = 0.81) was with inorganic N sources. With the organic sources the r^2 = 0.49. The plot of all the data (the top graph in Fig. 1) indicates that yield reached a plateau at about 15 ppm NO_3-N in the 0-2 ft zone at corn stage V5.

Table 1. Nitrogen content of manure used.

Manure Source	Time of Sample	Total N	Organic N	NH_4-N	Available N†
		lb/1000 gal			
Swine	Pre-application‡	44.6	22.7	21.9	28.7
Swine	During application§	31.5	18.2	13.4	18.9
Dairy	Pre-application‡	28.0	14.0	14.0	18.2
Dairy	During application§	35.6	17.4	18.3	23.5

† Available N = NH_4-N + 30% of organic N
‡ Values from previous manure analyses from these manure sources
§ Sampled from the manure applicator in the field during application

Table 2. Treatments, target N rates, manure applied, and actual N applied at Morris, MN in October, 1992.

Treatment	N Source	Target N Rates	Manure Applied	Applied N Rates†
		- lb/ac -	- gal/ac -	- lb/ac -
CK	....	0	0	0
F1	Urea	40	0	40
F2	Urea	80	0	80
F3	Urea	120	0	120
F4	Urea	160	0	160
S1	Swine manure	80	2440	46
S2	Swine manure	160	4880	92
S3	Swine manure	240	7180	136
S4	Swine manure	320	9740	184
D1	Dairy manure	80	3880	91
D2	Dairy manure	160	7860	185
D3	Dairy manure	240	11320	266
D4	Dairy manure	320	15730	370

† Based on actual weight of manure applied and available N values during application from Table 1.

Table 3. Effect of N source and rate on nitrate-N in the soil profile at emergence, V5, and post harvest stages of corn growth.

Treatment	N Rate	Emergence NO_3-N 0-1 ft	Emergence NO_3-N 0-2 ft	V5 NO_3-N 0-1 ft	V5 NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-1 ft	Post Fall Harvest NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-5 ft
	lb/ac	--------	--------	--------	--ppm--	--------	--------	--------
CK	0	6.5	5.4	4.8	4.9	3.4	2.2	2.4
F1	40	9.3	9.0	5.5	5.8	3.5	2.3	3.4
F2	80	15.8	12.7	7.4	8.3	4.5	3.2	5.6
F3	120	19.8	16.0	10.5	11.2	4.6	2.9	5.1
F4	160	22.1	15.7	11.7	11.0	4.4	3.3	7.9
S1	46	6.9	7.4	4.6	5.2	3.5	3.6	6.5
S2	92	16.6	16.6	8.2	9.7	3.4	2.7	7.6
S3	136	24.2	23.3	15.3	16.1	6.9	5.4	9.5
S4	184	22.3	25.1	11.9	15.2	7.8	7.4	10.4
D1	91	7.7	6.2	9.1	7.3	3.8	2.4	4.3
D2	185	15.7	15.6	11.0	12.2	6.6	4.2	5.6
D3	266	17.5	16.0	11.0	10.9	6.9	4.9	6.9
D4	370	41.2	29.8	18.9	21.2	8.1	10.6	11.5
Pr > F		.0001	.0001	.0385	.0006	.0140	.0067	.0078
BLSD(.05)		9.2	5.4	9.7	6.6	3.6	4.4	5.0
C.V. (%)		32.7	22.6	46.9	35.6	35.3	55.1	39.2

Table 4. Influence of nitrogen source and rate on plant measurements: chlorophyll meter readings, grain yield, grain moisture, grain bushel weight, grainl N, and silage yield.

Treatment	N Rate	Chlorophyll† June 25	Chlorophyll† July 26	Grain Yield -bu/ac-	Grain Moisture --%--	Grain test wt -lbs/bu-	Grain Tot. N --%--	Silage DM Yield -lbs/ac-
CK	0	0.98	0.72	51.7	25.7	50.7	1.17	8142
F1	40	0.97	0.81	66.0	24.3	51.1	1.19	9165
F2	80	0.99	0.89	71.8	24.4	49.3	1.26	10688
F3	120	1.04	0.93	94.7	21.0	51.8	1.38	10994
F4	160	1.00	1.00	91.5	21.1	52.0	1.32	11829
S1	46	0.97	0.83	59.1	25.6	49.7	1.22	9651
S2	92	0.99	0.89	74.0	23.2	50.5	1.31	11917
S3	136	1.00	1.01	99.3	21.2	52.2	1.33	13087
S4	184	1.03	1.02	102.8	21.5	51.2	1.48	13690
D1	91	0.95	0.79	63.8	25.7	49.5	1.19	9637
D2	185	0.97	0.97	97.6	23.5	50.8	1.39	12919
D3	266	1.00	0.97	95.9	22.6	52.2	1.46	12630
D4	370	1.03	1.01	106.4	21.3	51.3	1.43	12653
Pr > F		.0354	.0044	.0001	.0002	.0570	.0062	.0001
BLSD(.05)		0.06	0.17	22.2	2.4	2.5	0.19	1896
C.V. (%)		2.9	10.3	16.0	6.0	2.3	7.7	10.2

† Actual chlorophyll meter readings for each replicate were divided by the reading on treatment F4 for that replicate.

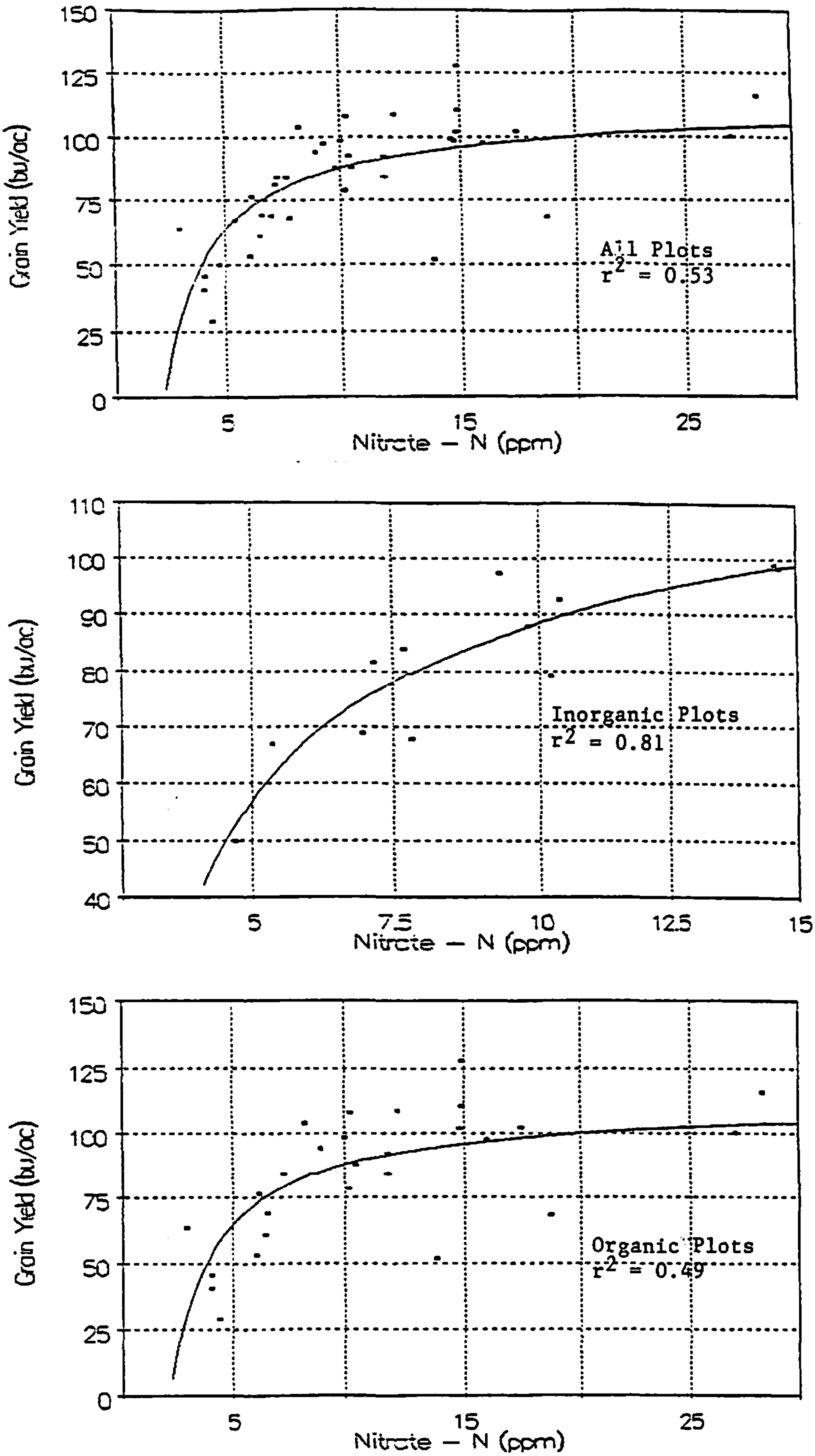

Fig. 1. Relationship between soil nitrate-N (0-2 ft. at corn stage V-5) and grain yield.

ASSESSMENT OF THE EFFECTS OF TILLAGE AND MANURE APPLICATION ON SEDIMENT AND P LOSS DUE TO RUNOFF[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, S.D. Evans, G.A. Nelson, B.J. Johnson and A. Ranaivoson[2]

Abstract

Due to low surface depressional storage, ridge till resulted in greater runoff from snow melt. During the growing season, residue between plant rows greatly reduced runoff and sediment load with the ridge tillage system. With high rainfall, ridge till system resulted in 7 and 300 times less runoff and sediment respectively compared to moldboard plowing system. The ridge till system resulted in greater runoff, higher concentration of total-P and bioavailable-P in snow melt. Application of manure improves soil properties that results in less runoff, sediment and total-P loss.

Grain yield with the moldboard system was 1.2 Mg/ha higher compared to ridge tillage system. The grain yield difference was associated with greater number of ears with the moldboard systems. Difference in tillage systems did not result in different plant stands, broken plants due to corn borer and stover yield. The absence of interaction and similar results of with and without manure application in grain yield indicates that there is not any significant residual effect of beef manure applied in May 1992.

The incubation study indicated that Olson-P decreased exponentially both in the control and the manured soil. The greater the manure rate, the greater the decrease of Olson-P with time. This suggests that the calcareous soil is a sink for mineralized phosphorus from manure through precipitation of phosphate and calcium. The mineralization of manure-P in soil with time after application needs to be considered in estimating runoff since the amount of phosphorus in runoff is dependent on the extractable initial-P in the manured soil.

Introduction

There is considerable concern regarding the contamination of surface and ground waters from land applied agricultural chemicals. Among the contaminants are nutrients (nitrate, phosphorus), herbicides and suspended sediments. Sediment is the most visible of agriculturally derived pollutants. Sediments not only contribute to costly dredging requirements of lakes, ports, and marinas but also carry sediment-bound pollutants, such as particulate P, to surface waters such as lakes. Research indicates that for water quality management, adoption of conservation tillage reduces sediment and P loading to surface water.

The concern over phosphorus with respect to water quality is focused with stimulation of algae and other aquatic plant growth. For most water bodies, phosphorus is the key limiting nutrient for aquatic plant growth. However, focusing only on total phosphorus for eutrophication control could result in no improvement in water quality. It is recommended that eutrophication control measures be directed toward controlling algal available P. Long term studies show that reducing sediments will not necessarily lead to a reduction in eutrophication. The importance of agriculture as a non-point source of pollutants lies in the significant association between total phosphorus increases in natural water bodies and various measures of agricultural land use, including fertilized acreage and cattle population density.

In Minnesota while pollution from point sources is decreasing, storm water from non-point sources continues to be an important pollution source of sediment, fertilizers, pesticides and other wastes. Confounding the problem of non-point source pollution in the Minnesota River Basin is the extensive hog, dairy and poultry farming in the area. Manure application to land is a regular management practice for crop production in the Minnesota River Basin. However to get the nutrient benefits from manure, it needs to be incorporated in the soil. The dilemma is: what degree of soil cultivation is necessary to incorporate manure while maintaining enough residue to prevent excessive erosive losses of sediment and phosphorus. The focus of this study will be to quantify and model the effect of tillage and manure interaction on phosphorus loading in surface runoff in soils of West Central Minnesota.

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[1] Support for this project was provided by the Legislature Commission on Minnesota Resources.

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Objectives

1. To evaluate the effects of moldboard vs. ridge tillage in combination with and without manure application on phosphorus and sediment loss in surface runoff both during frozen and unfrozen periods.

2. To evaluate the effects of manure residue on the yield.

3. To characterize the mineralization of manure-P mixed with calcareous Udic Haploborolls.

Materials and Methods

Objective 1

Tillage and manure interactions on sediment and phosphorus transport in surface runoff are being evaluated in the field at Morris, MN. The soil at the experimental site is a Barnes loam (fine-loamy mixed Udic Haploborolls, 12 % slope with south-eastern aspect). The soil surface layer is a black loam about 20-cm thick. The initial soil test in 1992 for pH (in water), Olson-P, Bray-P and ammonium acetate extractable K were 8, 17 ppm, 23 ppm and 155 ppm respectively.

The experimental design is a randomized complete block with split plots and three replications (tillage main plots and manure subplots). Twelve erosion plots, 22 m by 10 m (to accommodate four rows of corn) were marked and isolated using corrugated steel plates. At the end of each plot the runoff was routed with a polyvinyl chloride (PVC) sheet (3 m by .3 m) and then channeled through a PVC pipe to a collecting system. The collecting system consists of three barrels of 210 L each. The first barrel collects very coarse sediments. The overflow from the first barrel is channelled to the second barrel. At the second barrel, 9 adjacent holes of 3.8 cm diameter were drilled near the rim of the barrel. One of the holes was connected to a PVC pipe of 3.8 cm diameter which channelled the excess runoff to the third barrel. This setup allowed 1/9 of the overflow from the second barrel to be collected in the third barrel. The collector was designed for a runoff depth of 3.5 cm (10 year 24-hour rainfall of 9.7 cm considering the curve number of 71). Corrugated roofing was placed over the PVC sheet at the end of the plots to avoid direct precipitation getting into the collecting system. The plot layout is presented in Fig 1.

Tillage treatments include ridge tillage and moldboard plowing systems. Moldboard plowing allows complete soil incorporation of manure. In the moldboard system, primary tillage in fall was achieved with moldboard plowing and followed in the spring by a field cultivation prior to planting. Ridge tillage represents an intermediate level of soil incorporation. Plant residue was concentrated between plant rows during winter and spring. Ridging was done in early July. The time line of cultural practices for 1992 and 1993 is shown Fig. 2. Detailed cultural practices are presented in Table 1.

Manure treatments are with and without. Solid beef manure was applied at the rate of 56 Mg/ha. The manure contained approximately 161 kg total-P/ha.

The runoff volume in each barrel was measured using a calibrated dip stick. After volume measurement, the runoff suspension was thoroughly stirred and samples were taken for sediment and phosphorus (total-P, bioavailable-P) measurements. Sediments were measured by evaporating 200 mL of suspension followed by drying at 105 C. For each treatment sediment measurements were done in duplicate.

Total phosphorus was measured using perchloric acid digestion as described in EPA standard procedure (US EPA, 1981). For total P analysis 20 mL of suspension was pipetted while magnetically stirred to obtain a well mixed sample.

Bioavailable phosphorus was measured using extraction of the 20 mL of suspension with 180 mL of NaOH to make a final concentration of 0.1 N NaOH. This procedure has been correlated with algal available-P using an algal assay. Extraction with NaOH was done by shaking for 18 hours on a reciprocating shaker. The bioavailable-P was measured after filtration of suspension through 0.45 µm membrane filter, preceded by centrifugation. The phosphorus was then determined by measuring the intensity of blue molybdate as a coloring agent at wave length of 882 nm.

Objective 2

Corn was planted on the twelve erosion plots (objective 1) at the seeding rate of 79,319 seeds/ha. Seeding was done up and down the slope. Chemicals used for weed control are listed in Table 1. Grain and stover yield was measured. Corn ears, grain yield (after drying at 60 °C) and corn stand at harvest were estimated from rows of 60 feet long. Stover yield was estimated by harvesting randomly 10 corn plants. The plants were chopped above the ground, shredded and sample was taken for moisture determination.

Objective 3

Decomposing organic material such as manure and crop residues will release phosphorus and increase soil-P. Evaluations on the release of P from plant material in an incubation study has been reported. However incubation studies on solely plant material will not explain how phosphorus is released to runoff from cultivated soils since the P released will interact with soil. There is also a lack of data on the release of P from manure and its subsequent fate in a calcareous soil. Therefore an incubation study was undertaken to evaluate the change over time of the released inorganic-P in manured-soil. This study basically characterized the mineralization of P from manure mixed with soil.

The procedure for the incubation study involved air drying of soils and oven drying of manure at 60 °C. The dried soil and manure were ground to pass a 2-mm diameter sieve. Soil was taken from 0-15 cm from the experimental field mentioned in objective 1. Fresh beef manure was taken from the Morris Experimental Station. Moisture contents of air-dried soil and oven-dried manure were determined by oven drying the samples at 105 °C. Manure and soil were then mixed at the rate of 0 g of manure/kg soil (control), 8.7 g of manure/kg soil (equivalent to the manure-soil mixing ratio of moldboard plow treatment) and 26.1 g of manure/kg soil (equivalent to manure-soil mixing ratio of the ridge till treatment). This equivalence of soil and manure was based on assumption that manure will be mixed to 15 cm depth in moldboard system and 5 cm depth with ridge till system. Soil-manure mixing was done using a rolling drum mixer.

Incubation was done in polypropylene bottles. The procedure involved weighing a 5.1 g of soil-manure mixture in each 250 mL polypropylene bottle, adding 1.34 g of water with a syringe and incubating the mixture for 0, 1, 3, 5, 10, 30 days. The amount of water corresponded to the water content at -33 kPa matric potential (field capacity). Incubation was done at a field capacity water content and temperature of 30 °C. The experiment was arranged in a completely randomized design with three replications.

At the end of each incubation time, dissolved inorganic-P was extracted with sodium bicarbonate as Olson-P. Spectroscopy determination of P was done by measuring the intensity of blue molybdate as a coloring agent at wave length of 882 nm.

Table 1. Cultural practices at the West Central Agricultural Experimental Station, Morris, MN.

Tillage		Cropping History
1992	No-till	
	Ridge till (July 21, 1992)	1991-Alfalfa
	Spring moldboard (May 6, 1992)	1992-Corn Pioneer-3751
1993	Fall Moldboard (Oct 27, 1992)	-Corn Pioneer-3617
	Spring Moldboard(Apr. 28, 1993)	-Corn Pioneer-3921
	Ridge till (July 6, 1993)	1993-Corn Pioneer-3751

Planting and Harvest Dates

Corn - was planted with a Hiniker 4 row planter with 76 cm row spacing.
Corn was replanted due to plant damage from gophers, using an Almaco Planter

	Planting/Replanting		
Crop	Date	Rate	Harvested
Corn	May 7,1992	79,072 seeds/ha	Oct. 23, 1992 Corn was chopped, and left on field
	May 29, 1992	98,840 seeds/ha	
	June 15, 1992	148,260 seeds/ha	
	April 29, 1993	79,319 seeds/ha	Oct. 13, 1993 Two rows of 30 feet long.

Table 1. Continued

1992 Applied-Manure Analysis

Manure source	Rate	Date Applied	NH4	NO3	Mineral	Organic	Total N	Total P	Total K	Solids Total	Solids Volatile	Solids fixed
			----	----	----	----	%	----	----	----	----	----
Beef Manure	56Mg/ha	May 6/92	.215	.005	.220	.64	.860	.289	.668	29.12	84	16

Rate of applied and available N, P_2O_5 and K_2O

Manure source	Rate	Date Applied	NH4	NO3	Mineral	Organic	available N	Total N	Total P2O5	Total K2O
			----	----	----	kg/ha	----	----	----	----
Beef Manure	56 Mg/ha	May 6/92	120.4	2.8	123.2	358.4	212.8	481.6	370.7	374.1

It is assumed that 25 % of organic N and all of mineral N is available in the year of application.

1993

No manure is applied to all plots.
Non-manure plots received a topdress application of 50.4 kg/ha (NH_4NO_3) in 7/6/93.

Soil

Barnes loam (fine-loamy mixed Udic Haploborolls, 12 % slope with southern aspect. Soil is high in organic matter, and pH is 8.0. Initial soil test on Olson-P, Bray-P and K are 17, 23 and 155 mg/kg respectively.

Weed Control

1992
Lorsban 15G , 11.1 kg/ha (May 7, 1992)
Ranger 1.1 kg/ha+2,4-D ester 0.6 kg/ha+Banvel 0.3 lb/A+Lasso EC 4.5 kg/ha+Bladex DF (90%) 2.5 kg/ha (5/8/92)
Ranger 1.1 kg/ha only on no till plot to kill grasses and alfalfa (5/22/92)

1993
Round-up, 2.5 L/ha on ridge till for controlling volunteer alfalfa (4/21/93)
Counter 15 G 11.1 kg/ha over the furrow at seeding (4/29/93)
Lasso 4.5 kg/ha + Bladex 2.5 kg/ha to control volunteer alfalfa + Separate application of Round-up 2.47 L/ha (4/30/93)
Atrazine 0.84 lb/A for post emergence quack grass control (5/20/93)

Results and Discussion

Objective 1.

Ridge Till vs. Moldboard Plow

At spring thaw, due to lack of depressional storage, ridge till resulted in higher runoff compared to moldboard plow. However, after secondary tillage, moldboard plowed soil resulted in rapid increase of cumulative runoff due to the lack of residue cover. The lack of residue and susceptibility to crust formation in the moldboard plow system resulted in excessive runoff from a heavy rain in early July (Fig. 3).

At spring thaw, runoff contained a trace amount of sediment in both moldboard and ridge tilled plot. During the growing season, after secondary tillage, sediment loads from the moldboard plowing system increased rapidly. Initially due to higher runoff and total-P concentration in the snow melt, the ridge till system resulted in greater cumulative total-P losses (Fig. 3).

Due to a heavy rain in early July the moldboard plowing system had greater runoff and sediment load resulting in greater seasonal total-P loss. Similar to total-P, bioavailable-P under the ridge till system was initially higher. This was due to higher runoff and higher bioavailable-P in the snow melt (Fig.3).

The comparison between ridge till and moldboard plowing system on the cumulative loss of measured variables at the end of the season is presented (Table 2). Moldboard plowing resulted in higher cumulative runoff, sediment, total-P and bioavailable-P. Higher total-P and bioavailable-P were solely due to a heavy rainfall at the end of measurement.

Table 2. The effects of tillage and manure application on the cumulative losses, 3/29/93 (spring thaw) to 7/4/93.

	RIDGE TILL			MOLDBOARD		
	No Man	Man	Avg	No Man	Man	Avg
Runoff (cm)	3.0	1.5	2.3	5.6	4.6	5.1
Sediment (Mg/ha)	0.7	0.4	0.6	22.4	14.3	14.4
Total-P (kg/ha)	2.4	0.7	1.6	7.5	2.4	5.0
Algal-P (kg/ha)	0.2	0.3	0.3	0.7	0.4	0.6

MANURE VS. NO MANURE.

Manure application reduced runoff during winter and the growing season. This was likely due to improvement of soil structure. Manure application also reduced sediment load in runoff water (Fig. 4).

The snow melt caused greater cumulative total-P in the non-manured plots initially. Greater total-P in the snow melt was simply due to more runoff from non-manured plots; both manure and non-manured plots had similar total-P concentration. Under non-manure system, a heavy rainfall at early July which caused greater runoff and sediment load resulted in a very significant load of total-P (Fig.4).
On the contrary to total-P, despite of less runoff, bioavailable-p from the manured plots is greater initially. This was mainly due to higher concentration of bioavailable P in the snow melt from manured plots.

A heavy rainfall which resulted in an excessive runoff and sediment load in early July eliminated the difference in bioavailable-P between manured and non-manured plots (Fig. 4).

The comparison between the manure and non-manure system on the cumulative loss of measured variable at the end of measurement is presented. The non-manured system resulted in higher cumulative runoff, sediment and total-P. Bioavailable-P was similar which was due to rainfall at the end of the measurement period (Fig. 4).

Objective 2.

Grain yield differs significantly with tillage system. Average yield with the moldboard system resulted in 1.2 Mg/ha higher compared to the ridge tillage system. This significantly higher yield is partly associated with significantly greater number of corn ears with moldboard systems compared to ridge tillage systems. Differences in tillage systems did not result in different plant stands, broken plants due to corn borer or stover yield.

With and without manure application resulted in similar grain yield, numbers of corn ears, number of plants, number of corn borer damage, and stover yield. There is no significant interaction between tillage systems and manure application in any variables measured (Table 3). This indicated that there is not any significant residual effect of beef manure applied in July 1992.

Table 3. The effects of tillage and manure application on the grain yield, number of corn ears, number of plants and broken plants, and stover yield, at West central Experimental Station, Morris, MN, 1993.

	RIDGE TILL			MOLDBOARD		
	No Man	Man	Avg	No Man	Man	Avg
Grain (Mg/ha)	6.1(.4)	6.3(0.3)	6.2(0.3)	7.1(0.6)b	7.7(0.7)	7.4(0.7)a†
Ears (1000/ha)	70.1(5.5)	63.9(5.0)	67.0(5.8)b	73.7(2.2)	72.7(4.0)	73.2(2.9)a
Plants (1000/ha)	74.9(6.7)	63.1(6.5)	69.0(8.7)a	73.9(1.2)	75.3(6.4)	74.6(4.1)a
Broken Plants (1000/ha)	21.0(6.3)	13.4(2.3)	17.2(6.0)a	31.8(18.2)	27.3(9.7)	29.5(13.3)a
Stover (Mg/ha)	4.9(1.0)	5.1(0.4)	5.0(0.7)a	5.4(0.1)	5.6(0.6)	5.5(0.4)a

† different letters following the average value in the same line indicates significant difference by tillage at significant level of 0.1.

The main effects of the manure and without manure application do not differ significantly in any variables measured. Also, there is no significant interaction between tillage and manure in any variables measured (Table 4).

Table 4. Probability (P > F) value of main and interaction effects of tillage and manure on the grain yield, number of corn ears, number of plants and broken plants, and stover yield, at West central Experimental Station, Morris, MN, 1993.

	Grain yield	Number of ears	Plants	Broken Plant	Stover
Tillage	0.060	0.096	0.162	0.245	0.237
Manure	0.277	0.281	0.269	0.352	0.655
Tillage*Manure	0.496	0.413	0.177	0.802	0.959

Objective 3

INCUBATION STUDY

Olson-P decreased exponentially both in the control and the manured soil. The greater the manure rate, the greater the decrease of the slope of the regression line. The regression lines from manured treated soil converge after incubation of 30 days (Fig. 5). This suggests that the calcareous soil is a sink for mineralized phosphorus from manure.

Since desorption of P to runoff depends on the initial soil-P level, the mineralization of manure-P in the with time after application needs to be considered.

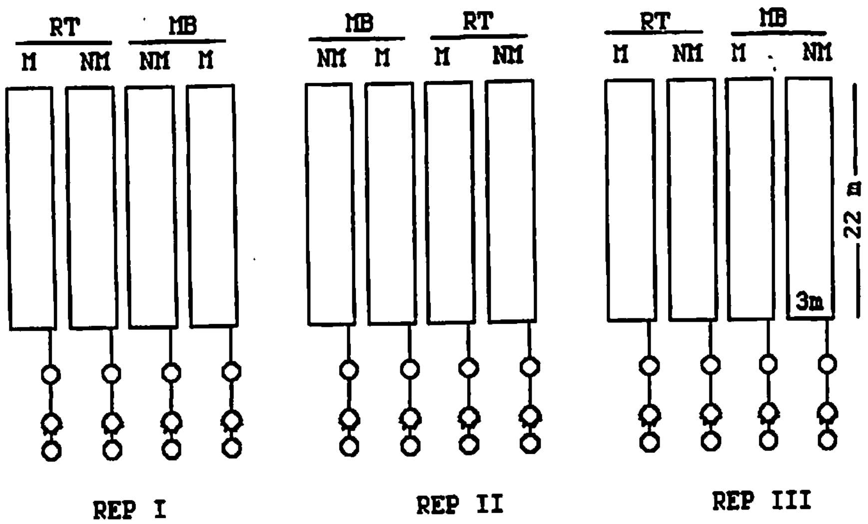


Fig. 1. Plot diagramm of erosion study at West Central Experiment Station, Morris, MN.

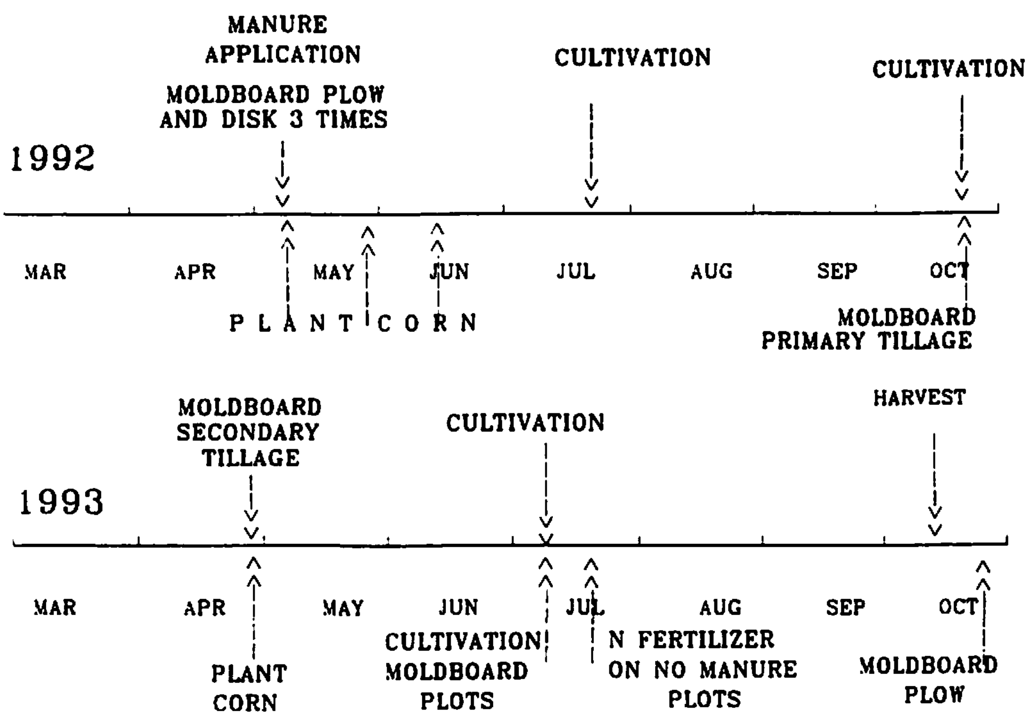


Fig. 2. Time line of cultural practices on runoff plots, Morris, MN.

Fig. 3. Tillage influence on cumulative runoff, sediment, total Phosphorus and Bioavailable Phosphorus at The West Central Experiment Station, Morris, MN

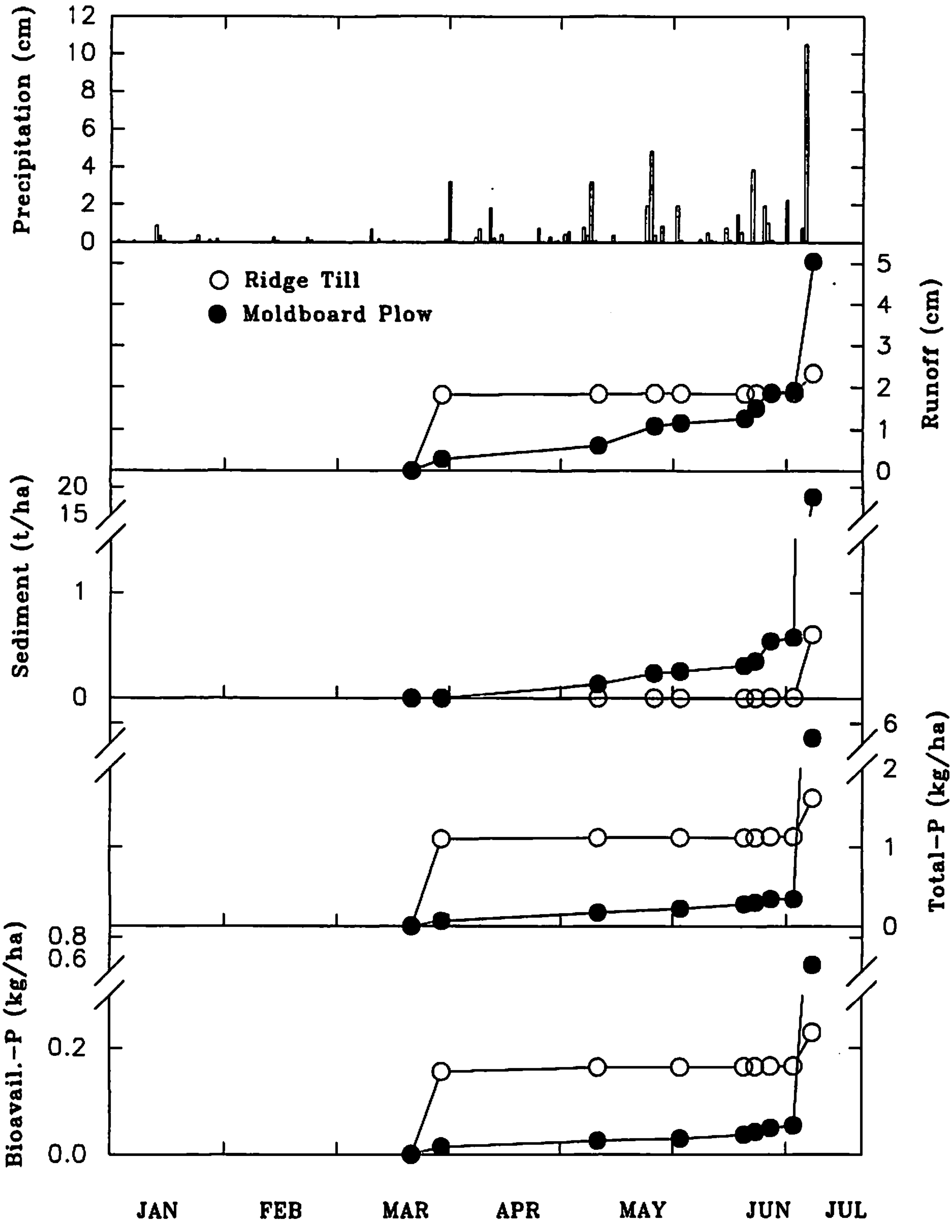
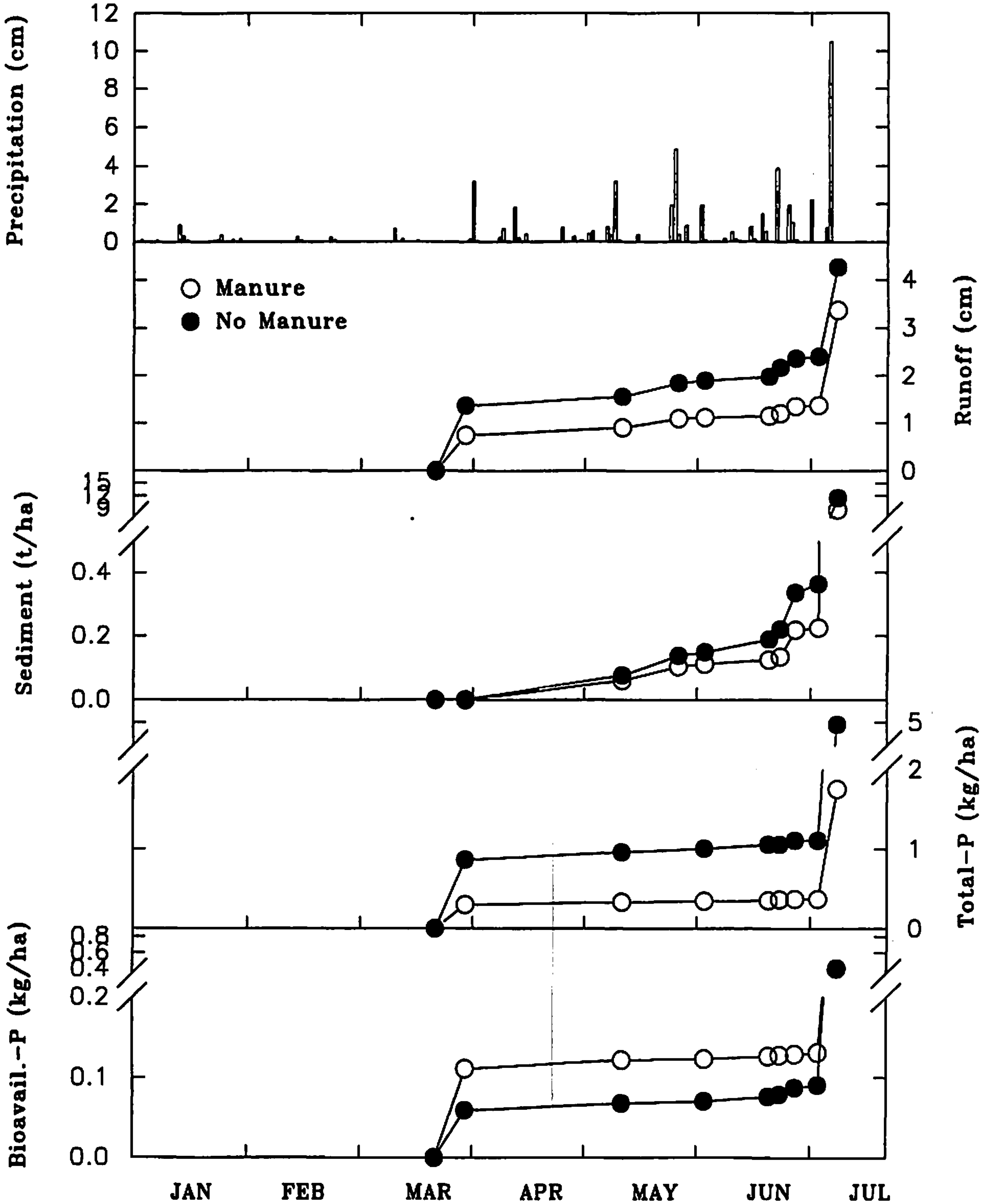


Fig.4. Manure influence on cumulative runoff, sediment, total Phosphorus and bioavailable Phoshphorus at The West Central Experiment Station, Morris, MN, 1993.



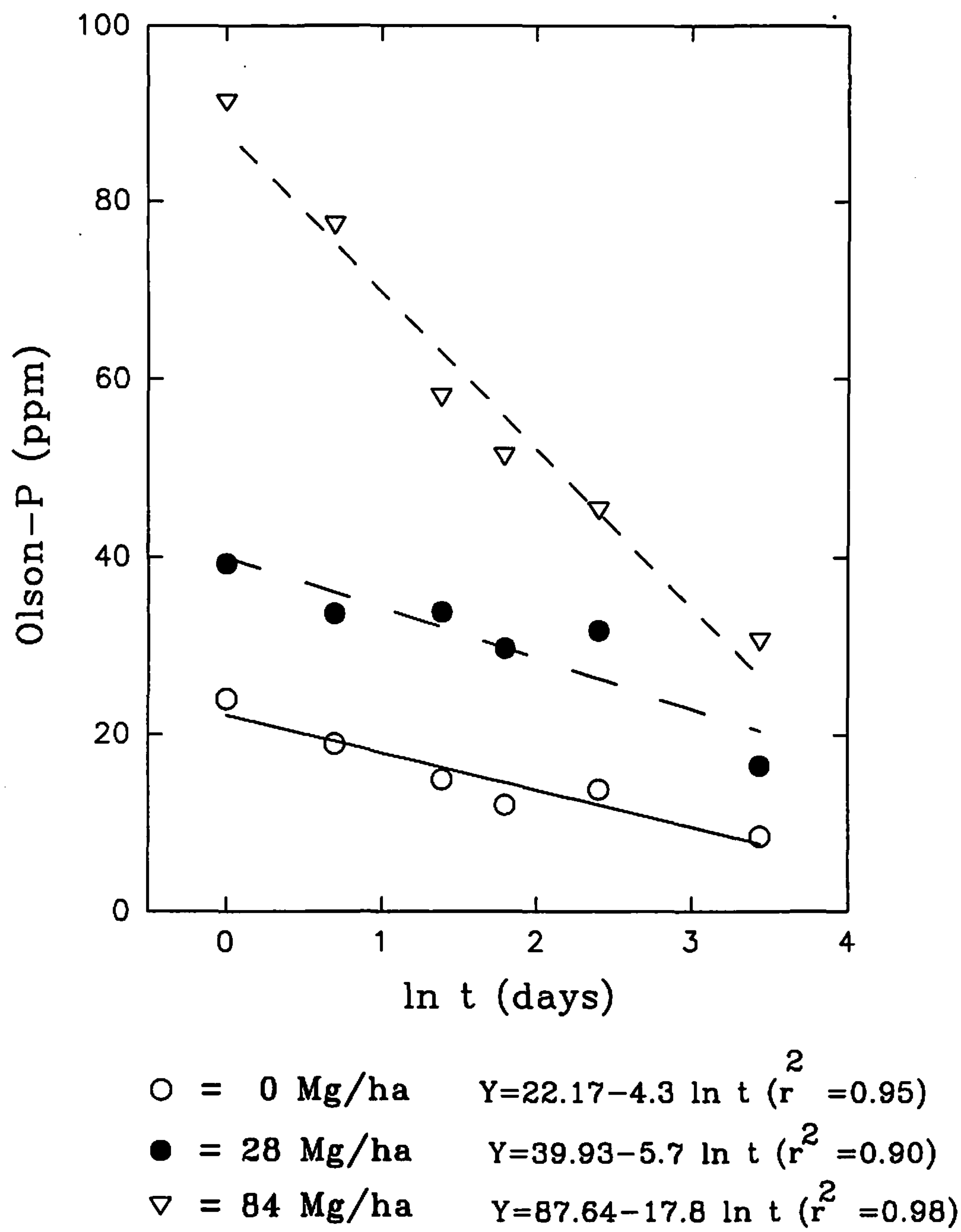


Fig. 5. Sodium bicarbonate extractable−P (Olson−P) and duration of incubation relationships of manured and non−manured soil (Barnes loam: fine−loamy mixed Udic Haploborolls).

POTASSIUM FERTILIZATION OF ALFALFA GROWN ON AN IRRIGATED SANDY SOIL

G. Rehm, T. Sellie, and A. Scobbie[1/]

ABSTRACT: There was a need to evaluate potassium requirements for alfalfa grown on an irrigated sandy soil. Five rates of plowdown K_2O (0, 80, 160, 240, 320 lb./acre) were combined with five rates of annual K_2O (0, 60, 120, 180, 240 lb./acre) in a complete factorial design with four replications. Three cuttings were harvested in 1993. Yields were not affected by the rate of potash plowed down before planting. The application of K_2O in early spring produced small but significant increases in yield.

Introduction:

In recent years, some have questioned the potash recommendations for alfalfa currently used by the University of Minnesota. Alfalfa is a heavy user of K and removal or uptake is high. High yielding alfalfa can remove over 300 lb. K per acre. Stand longevity is also important for alfalfa production in north-central Minnesota. So, adequate potash fertilization is necessary for optimum production as well as stand longevity.

Objective:

This study was established to evaluate the effect of both plowdown and annual application of potash applied at several rates on alfalfa yield and stand longevity.

Experimental Procedure:

This study was initiated at the Irrigation Center at Staples in late spring of 1990. Soil samples (0-6 in.) were collected prior to seeding and the results are summarized in Table 1.

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

pH	6.5
P (Bray & Kurtz #1), ppm	43
K (ammonium acetate), ppm	63

Plowdown rates of K_2O (0, 80, 160, 240, 320 lb./acre) were combined with annual rates (0, 60, 120, 180, 240 lb./acre) in a complete factorial design with four replications. A split-plot arrangement of treatments was used. The plowdown rates of K_2O were the main plots. The annual rates of K_2O were the split plots. The K_2O was always supplied as 0-0-60.

The research site was planted to oats in the spring of 1990. The oats stubble was disced following grain harvest and lime as well as the plowdown rates of K_2O were applied at this time. Sulfur applied at a rate of 50 lb. S per acre as granular gypsum was also incorporated for each treatment at this time.

Alfalfa (Profit variety) was seeded at a rate of 16 lb. per acre on August 9, 1990. Irrigation water was applied as needed to insure a good stand and adequate growth before winter. The established stand was excellent.

The annual rates of K_2O were topdressed to the established stand in early spring of 1991, 1992, and 1993. Each year, the alfalfa in all plots was topdressed with 50 lb. S per acre supplied as granular gypsum. These cuttings were harvested each year. Whole plant samples were collected from each plot at each harvest and analyzed for K. Soil samples (0-6 in.) were taken from each plot in the fall of 1991, 1992, and 1993. These samples will also be analyzed for K.

Results and Discussion:

The total dry matter yields for the 1993 growing season are summarized in Table 2. The analysis of soil and plant samples for K is not complete at the time of preparation of this report.

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

Table 2. The effect of plowdown and annual rates of K_2O on yield of alfalfa grown on an irrigated sandy soil. 1993.

Plowdown K_2O	Cutting	0	60	120	180	240
lb./acre		ton dry matter/acre				
0	1	.89	1.02	.96	.97	.98
	2	.82	.90	1.03	1.10	1.10
	3	1.19	1.19	1.35	1.30	1.37
	Total	2.68	3.11	3.34	3.37	3.45
80	1	.80	.87	.90	.87	.82
	2	.89	.90	1.04	1.01	1.04
	3	1.11	1.26	1.22	1.33	1.24
	Total	2.79	3.03	3.16	3.21	3.10
160	1	.90	.99	.90	.92	.97
	2	1.13	1.12	1.46	1.02	1.17
	3	1.24	1.30	1.25	1.36	1.38
	Total	3.27	3.41	3.60	3.30	3.52
240	1	.61	.94	.94	.98	.84
	2	.84	.97	1.07	1.00	1.04
	3	1.18	1.24	1.36	1.21	1.40
	Total	2.63	3.14	3.37	3.19	3.27
320	1	.93	.77	.91	.94	.91
	2	.90	.92	1.08	1.10	1.10
	3	1.20	1.09	1.35	1.30	1.32
	Total	3.03	2.79	3.34	3.34	3.33

The rate of K_2O plowed down before planting had no significant effect on alfalfa yield. Yields were significantly increased by the rate of K_2O applied on an annual basis. Although total yields were relatively low for alfalfa production, the annual rate of 60 lb. K_2O per acre appeared to be optimum in 1993. The alfalfa at this site had not responded to K_2O fertilization prior to 1993. Apparently, the K supplied by the soil decreased in 1993 and there was a response to potash fertilization.

ESTABLISHMENT OF FORAGE LEGUMES ON SANDY SOILS IN NORTH-CENTRAL MINNESOTA

George Rehm, Thor Sellie, Andy Scobbie, Craig Sheaffer, and Neal Martin[1/]

ABSTRACT: This study was conducted from 1991 through 1993 to evaluate the effect of various methods of establishment on yield of legumes in the year of establishment and subsequent production years. The 1992 yield of legumes established in 1991 was affected by both the legume and the method of establishment that was used. The same was true for the legumes seeded in 1992. The method of establishment also had a significant effect on the density of stand measured in early September of 1992.

There are legumes other than alfalfa that are adapted to the climate and soils of North-Central Minnesota. These legumes may be used for pastures or for hay production. As with alfalfa, establishment of an acceptable stand is a major problem in the region. Therefore, this study is being conducted to evaluate the effect of various methods of establishment. Four forage legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, red clover) are involved.

Experimental Procedure:

This study was initiated at the Irrigation Center at Staples in 1991, and repeated at an adjacent location at the Center in 1992. Prior to seeding, adequate rates of lime, phosphate, potash, and sulfur were broadcast and incorporated with a disk. The experimental area was disked and packed prior to seeding.

Five establishment methods were evaluated. These are described below:

A. Clean Seedbed: With this method, Balan Herbicide was applied at a rate of 3 qts. per acre at two weeks before seeding and incorporated with a rototiller. The Balan restricts the growth of grassy weeds as well as volunteer small grain. The legumes were seeded into the prepared seedbed.

B. Conventional: Oats is used as a companion or nurse crop. Oats was seeded into a prepared seedbed approximately two weeks before seeding of the legumes. The legumes were then seeded into the emerging oats crop. The oats crop was harvested as oatlage when it reached the milk to soft dough stage of development.

C. Companion Oats Plus Herbicide: The sequence of seeding oats and legumes was identical to that used for method B described above. The oats crop was killed when 10-15 inches tall by spraying with Poast (1.5 pints per acre) plus Dash (1 qt. per acre).

D. Late Summer Companion Crop: For this method, oats was planted in early spring and allowed to mature and the grain was harvested. A new seedbed was prepared by rototilling the stubble. A second oats crop was planted in mid-July. The legumes were seeded into the emerging oats in early August. Freezing temperatures in the fall killed the established oats.

E. No-Till Establishment: The legumes were seeded into existing oats stubble in early August. The initial oats crop was planted in early spring, allowed to mature, and was harvested for grain.

In the year of establishment, legumes were harvested when growth appeared to be adequate. Late harvest was avoided so that the potential of winter-kill would be reduced. Adequate rates of phosphate, potash, and sulfur were broadcast to the established stands in the spring of 1992 and 1993. Both sites were irrigated as needed in 1991, 1992, and 1993.

The legumes established in 1991 were harvested in 1992 and 1993. Three cuttings of alfalfa were taken each year. All other legumes were harvested twice each year. The legumes seeded in 1992 were harvested in 1993 following the harvest schedule for the legumes seeded in 1991.

The stand density for each legume in all establishment methods at both sites was measured in early September 1992. For this measurement, plants were dug from a 3 ft^2 area and the number of plants in that area was counted.

Results and Discussion:

The 1993 forage yields for the legumes seeded in 1991 are summarized in Table 1. The establishment method used had a significant effect on the yield of the first and second cutting of alfalfa and the first cutting of red clover. Otherwise, yields were not affected by method of establishment. In general, there was a substantial amount of variability in yield which was due, in part, to the consistent and sometimes heavy rainfall throughout the summer.

[1/] Extension Soil Scientist, Junior Scientist, Assistant Scientist, Professor and Extension Specialist – forage crops, respectively.

Table 1. The effect of method of establishment used in 1991 on yield of four legumes in 1993.

Legume	Cutting	Method of Establishment A	B	C	D	E
		-------- ton dry matter/acre --------				
alfalfa	1	1.33	1.18	1.22	1.08	1.22
	2	1.76	1.73	1.58	1.62	1.81
	3	1.28	1.27	1.08	1.27	1.16
	Total	4.37	4.17	3.88	3.97	4.20
birdsfoot trefoil	1	1.94	1.55	1.60	1.66	1.88
	2	1.79	1.75	1.20	1.64	1.23
	Total	3.73	3.20	2.80	3.30	3.11
cicer milkvetch	1	1.73	1.47	1.33	1.46	1.53
	2	1.46	1.29	1.32	1.11	1.19
	Total	3.19	2.77	2.65	2.56	2.72
red clover	1	1.41	1.41	1.44	1.75	1.73
	2	1.93	1.75	1.90	1.94	1.87
	Total	3.34	3.16	3.34	3.69	3.60

For alfalfa, the lowest yield of the first cutting was associated with establishment method D. The highest yield was associated with method A (clean seedbed). Other establishment methods produced intermediate yields. For red clover, the highest first cutting yields were associated with methods D and E. The effects of the differences in first cutting yields were reflected in total yield.

The total yields for the 1992 and 1993 growing seasons for the legumes seeded in 1991 are summarized in Table 2.

Table 2. Effect of establishment method used in 1991 on total dry matter production for 1992 and 1993.

Legume	Establishment Method A	B	C	D	E
	---------- ton dry matter/acre ----------				
alfalfa	10.50	9.75	9.50	7.62	8.65
birdsfoot trefoil	8.16	7.15	7.89	6.35	6.89
cicer milkvetch	7.05	4.40	5.03	3.62	4.16
red clover	8.56	8.26	8.75	8.17	8.79

In evaluating these yields, it's important to recognize that 1st year yields (1991) were not measured for methods D and E which were seeded in August of that year. For red clover, yields resulting from these establishment methods were higher in 1992 and 1993. This was not the case for the other three legumes.

Yields from the study established in 1992 are summarized in Table 3. Except for the first cutting of alfalfa and cicer milkvetch, method of establishment that was used in 1992 had no significant effect on forage yield measured in 1993. For the alfalfa, the lowest yields resulted from the use of methods A and E. For cicer milkvetch, the lowest yield of the first cutting resulted from the use of method D. For this legume, all other establishment methods had an equal effect on yield.

Stand counts were taken from a 3 ft^2 area in September of 1992 by digging and counting whole plants. These stand counts are summarized in Table 4.

As would be expected, stand counts were lower if the legumes were seeded in 1991 instead of 1992. This reflects a natural decrease in legume stands with age.

Measured stand varied with legume and method of establishment. For example, no-till produced the lowest stand for alfalfa seeded in 1991. Yet, this method of seeding produced the highest stand for birdsfoot trefoil that was seeded in 1992. The method of establishment had no consistent effect on measured stand throughout the study.

Table 3. The effect of method of establishment used in 1992 on yield of four legumes in 1993.

Legume	Cutting	A	B	C	D	E
		Method of Establishment				
		-------- ton dry matter/acre --------				
alfalfa	1	.71	.64	.82	.82	.65
	2	1.70	1.82	1.70	1.80	1.63
	3	1.28	1.36	1.31	1.31	1.39
	Total	3.69	3.83	3.83	3.93	3.67
birdsfoot trefoil	1	2.64	2.94	2.57	2.61	2.52
	2	1.67	1.33	1.64	1.48	1.85
	Total	4.31	3.27	4.21	4.09	4.37
cicer milkvetch	1	2.13	2.33	2.41	1.68	2.15
	2	1.41	1.25	1.50	1.26	1.45
	Total	3.54	3.58	3.91	2.94	3.60
red clover	1	2.32	2.26	2.10	2.53	2.48
	2	1.92	1.86	1.99	1.53	1.73
	Total	4.24	4.12	4.09	4.06	4.21

Table 4. The effect of method of establishment on the number of plants counted in a 3 ft^2 area in September of 1992.

Legume	Year of Establishment	A	B	C	D	E
		Method of Establishment				
		---------- plants/3 ft^2 ----------				
alfalfa	1991	41	41	43	57	36
	1992	56	55	37	70	89
birdsfoot trefoil	1991	28	27	30	49	37
	1992	30	27	37	28	39
cicer milkvetch	1991	18	15	25	49	46
	1992	35	54	33	63	66
red clover	1991	28	27	30	39	36
	1992	55	55	67	87	82

Evaluation of Best-Management of N on Irrigated Potatoes: Yield and Nitrate Losses[1]

B.M. Carlson, C.F. Reece, and C.J. Rosen

Abstract
Positionally-dependent nitrate leaching from potatoes grown using conventional nitrogen management (banding at planting, emergence, and hilling) were compared to nitrogen management using petiole-nitrate sap-test based fertigation at the Staples Irrigation Center. Time-averaged soil water nitrate concentrations increased with the amount of solid fertilizer applied to the soil. On the other hand, concentrations were insensitive to N applications through irrigation (fertigation) as evidenced by a value of 17 ppm for the Fertigated - Reduced plots, and 25 ppm for the Nonfertigated - Conventional plots which had similar amounts of total applied N. Analysis of yield from the plots showed no significant differences between any Reduced or Conventional treatments. By using fertigation and further lowering N rates there is great potential to maximize yield while lowering costs and reducing groundwater contamination.

Introduction
Various potato management systems which may reduce groundwater contamination have been proposed. One of these is a system which applies N in a liquid form through an irrigation system (called "fertigation"). This system has the potential of reducing contamination by applying fertilizer only when the plants show deficiency and has the advantage of placing the N directly in contact with the roots. This combined with soil bulk density differences and root uptake can lead to differences in water flux and nitrate concentration between rows and furrows. These effects can be taken advantage of to reduce leaching in a fertigated system.

Objectives
Compare nitrate losses under a N-management system involving Conventional fertilization, and one using fertigation. Evaluate relative contribution of row and furrow N-fluxes to total N-loss.

Materials and Methods
As the first year of a two year project plots were established at the Staples Irrigation Center on Verndale sandy loam, growing Russet Burbank potatoes . The plots had 36" row spacing, and 10" seed spacing. Plots consisted of three treatments of solid fertilizer (Control, Reduced and Conventional) duplicated with and without fertigation. Starter fertilizer (urea) was applied at planting at a rate of 9.1Kg for Reduced, and 18.2Kg for Conventional. Urea banded at emergence (24 May) and hilling (17 June) consisted of 31.8Kg for Reduced, and 45.5Kg for Conventional. Three fertigation treatments of 9.1Kg N as a solution of 28% ammonium nitrate were applied in July. Fertigation was scheduled by using petiole sap nitrate tests. Nonfertigated - Reduced and fertigated - Conventional plots were designated for intensive study. Suction cup samplers were installed at 30 and 60 cm depths in the rows and between the rows. Non -intensive study plots received samplers at 60 cm between the rows. Tensiometers were placed at 30 and 60 cm following the same configuration for intensive or non-intensive plots. Tipping bucket rain gages were used to measure irrigation. Water flux was calculated using Darcy's equation. Soil water samples were analyzed for nitrate content on a Wescan analyzer.

Results
Nitrate concentrations were higher in the row at the beginning of the growing season. Concentrations in the furrow became larger as the growing season progressed. Reduced treatment plots had lower concentrations than Conventional regardless of fertigation. Water flux was greater in the furrow (ex. 12.6 cm fert.-Reduced, 26.9 cm nonfert.-Conv.) than the row (ex. 8.6 cm fert.-Reduced, 11.2 cm nonfert.-Conv.).

Nitrate movement was associated with water flux (Fig. 1). Time-averaged soil water nitrate concentrations increased with the amount of solid fertilizer applied to the soil, while N applications through irrigation (fertigation) had little effect on nitrate concentrations (Fig. 1 &3 and Table 1). This was especially evident comparing the fertigated-Reduced treatment (17 ppm) to the nonfertigated-Conventional (25 ppm) since both treatments had similar totals of N applied (100 to 109 Kg-N/A) (Fig 4). Analysis of yield from the plots showed no significant differences between any Reduced or Conventional treatments (Fig. 5 and Table 2).

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[1]Funding for this project was provided by the Legislative Committee for Minnesota Resources.

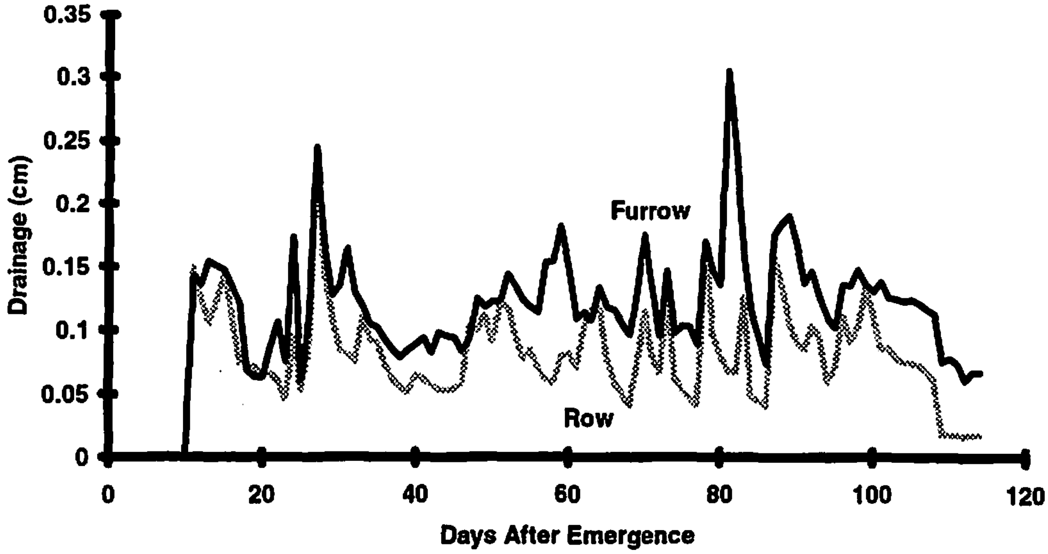

Figure 1. Drainage from a furrow and a row position at 60 cm in fertigated - Reduced plots. Other plots followed a similar pattern.

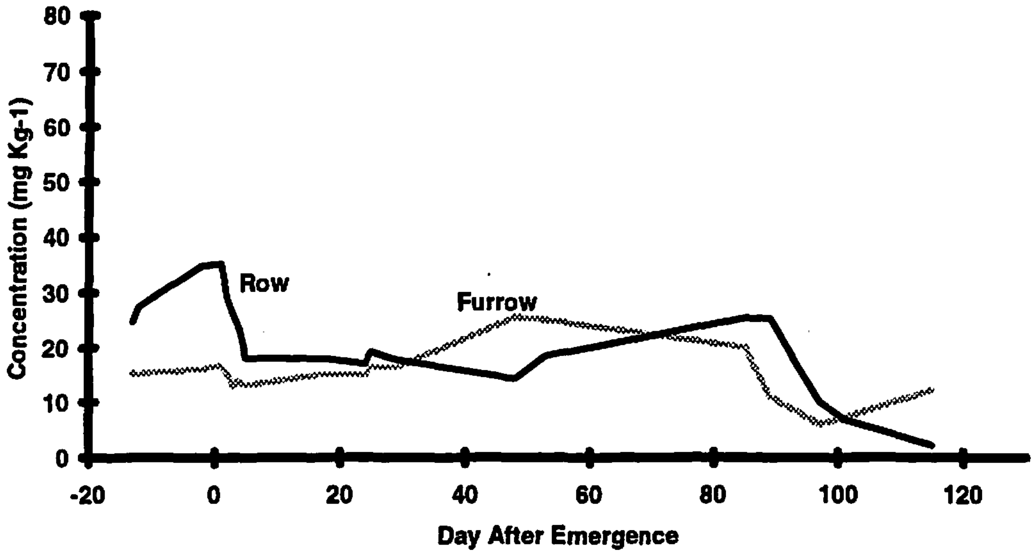

Figure 2. Soil water nitrate concentrations over the growing season for a fertigated plot. 100 Kg/A N applied. Other fertigated plots followed a similar pattern.

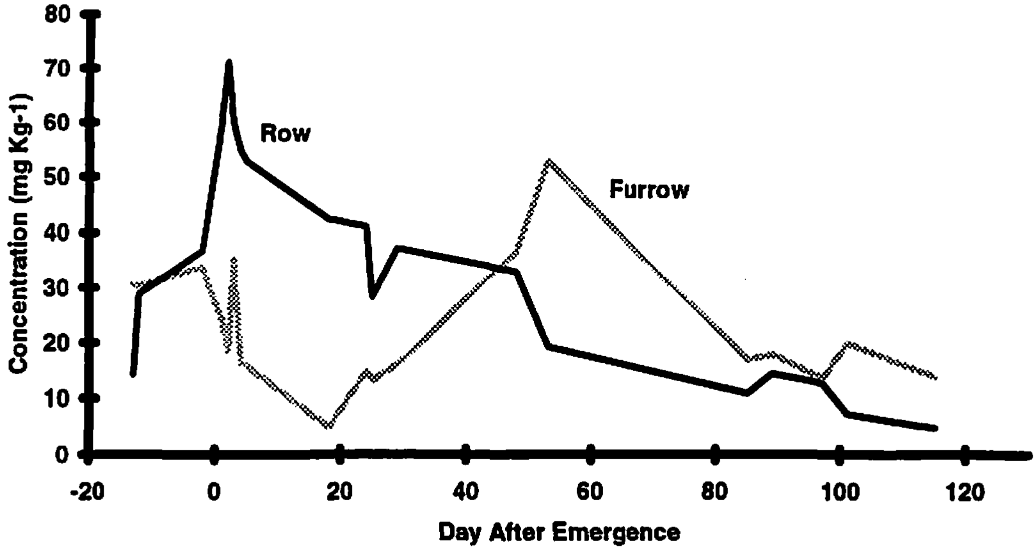

Figure 3. Soil water nitrate concentrations over the growing season for a nonfertigated plot. 109 Kg/A N applied. Other nonfertigated plots followed a similar pattern.

Table 1. Nitrate concentrations in soil water at 60 cm depth, between rows.

date	fertigated			nonfertigatd		
	Control	Reduced	Conventional	Control	Reduced	Conventional
10-May-93	16.3	15.4	30.2	15.4	16.5	30.6
11-May-93	19.4	15.3	23.8	16.8	21.1	30.3
21-May-93	21.6	16.0	39.3	19.2	25.4	33.7
24-May-93	26.8	16.8	24.8		28.3	24.2
25-May-93	17.3	15.3	25.2	17.9	20.5	18.3
26-May-93	13.9	13.1	21.4	15.5	19.0	35.2
27-May-93	12.5	13.9	20.4	14.1	15.2	16.4
28-May-93	13.4	13.2	18.9	11.9	15.7	15.7
10-Jun-93	10.2	15.2	19.8	9.5	12.4	4.9
16-Jun-93	12.2	15.1	16.8	11.5	14.0	14.7
17-Jun-93	11.6	16.5	12.2	11.2	13.8	13.2
21-Jun-93	12.6	16.4	17.0	12.9	15.2	16.1
10-Jul-93	14.7	25.6	19.8	17.4	23.9	36.6
15-Jul-93	14.6	25.1	41.2	26.4	33.8	52.7
16-Aug-93	8.0	20.2	35.8	8.5	20.9	16.9
20-Aug-93	7.7	11.2	42.2	13.2	1.8	17.9
28-Aug-93	3.3	6.0	20.0	9.0	6.2	13.6
1-Sep-93	4.5	7.2	31.4	11.0	2.3	20.0
15-Sep-93	3.0	12.3	12.9	7.9	0.5	13.9

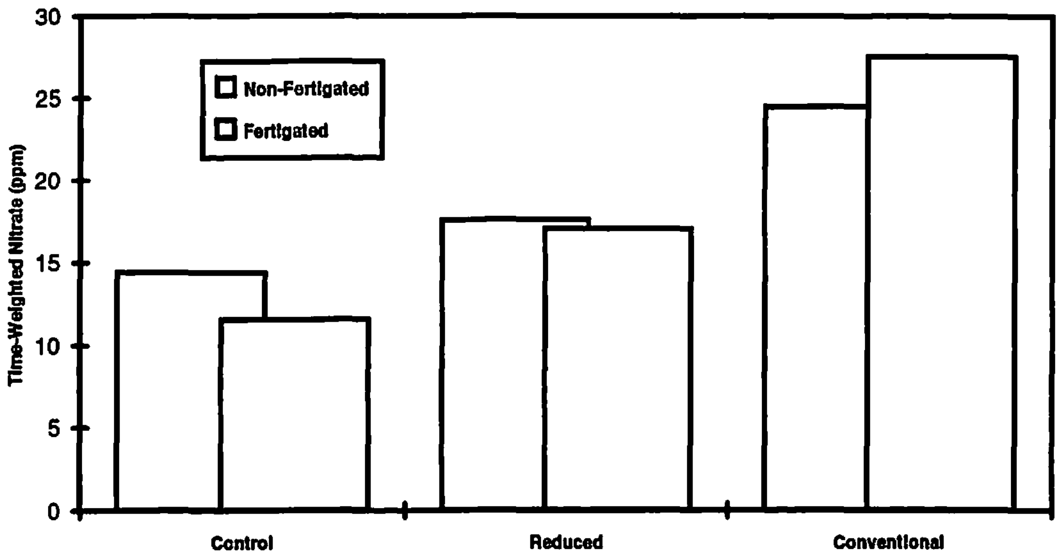

Figure 4. Time-weighted nitrate concentration averages for 1993.

Table 2. Graded yields for 1993.

Treatment		Grade					
water	soil	culls	2's	1's	jumbo	misshapen	total (sd)
		cwt/A					
nonfertigated	Control	20.7	125.1	22.0	15.9	3.1	186.8 (46.4)
nonfertigated	Reduced	38.0	182.2	136.9	16.3	36.1	409.5 (15.3)
nonfertigated	Conventional	32.0	169.4	145.4	34.8	31.6	413.1 (17.1)
fertigated	Control	21.8	140.5	83.7	4.6	7.8	258.4 (21.7)
fertigated	Reduced	36.5	183.7	139.1	21.1	27.7	408.0 (16.4)
fertigated	Conventional	34.0	169.9	175.0	24.6	35.6	439.1 (22.5)

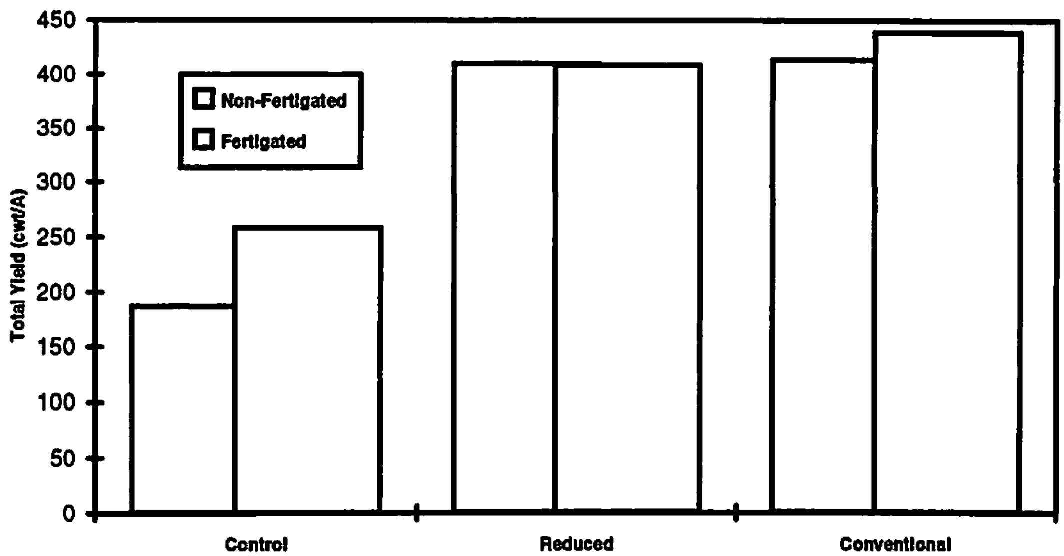

Figure 5. 1993 yield.

Discussion

Due to consistently low nitrate concentrations between plots initially starter N probably did not significantly add to nitrate leaching. On the other hand, the banded applications at emergence and hilling did raise soil solution nitrate concentrations significantly in the row. Higher nitrate concentrations under the Conventional treatments did not translate into higher yields. This tends to indicate that less N could have been applied at emergence and hilling.

Analysis of the water flux data shows a marked increase in water flux in furrow positions compared to rows. This can probably be attributed to lower root density and water uptake in the furrows. It is important to note that nitrate flux followed a pattern very similar to drainage. We conclude that if N can be kept out of the areas of highest water flux - the furrow - groundwater contamination can be Reduced.

Conclusions

Yields were not significantly Reduced when solid fertilizer was substituted with fertigation. Evidence so far indicates that by using fertigation and lowering solid N applied to the soil, there is great potential to maximize yield while lowering costs and lessening groundwater contamination.

Significant differences in soil water nitrate concentration exist between row and furrow positions at both 30 and 60 cm. Water quality studies should account for these differences to obtain an accurate measure of nitrate leaching. Potato management systems utilizing fertigation can reduce N losses to groundwater markedly.

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CARROT RESPONSE TO FERTILIZER ON AN IRRIGATED SANDY SOIL[1]

Carl Rosen, Mel Weins, and Shelly Johnson[2]

Abstract: Fertilizer trials were conducted at the Staples Irrigation Center to refine fertilizer recommendations for carrot production on sandy soils. The previous crop was soybeans. The soil tested high in P, medium in K, and low in B. Carrots responded up to 60 lb N/A. Excessive N application tended to reduce yield and dry matter. A significant yield response to K fertilizer was obtained. Phosphate and B fertilizer did not significantly affect yields. Nutrient concentrations in leaves during the growing season and tops and roots at harvest are presented.

In recent years there has been an increased interest in producing carrots in Minnesota for dehydration. Little is known about the nutrient requirements of carrots under Minnesota conditions, particularly on irrigated sandy soils where an early harvest is desired. The objective of this study was to obtain baseline information related to carrot response to nitrogen, phosphorus, potassium and boron fertilizer amendments.

Materials and Methods: A carrot fertility experiment was conducted at the Irrigation Center at Staples during the 1993 growing season. The soil is a Verndale sandy loam with an organic matter content of 2.3%. The previous crop was soybeans and selected soil chemical properties (0-6") were as follows: pH, 5.9; Bray P, 42 ppm; K, 64 ppm; Mg, 163 ppm; Ca, 1190 ppm; S, 4 ppm; B, 0.2 ppm; and Zn, 1.2 ppm. Eight fertilizer treatments were evaluated:

Fertilizer Treatment				
#	N	P_2O_5	K_2O	B
	-------- lb N/A -------			
1.	0	0	0	0
2.	120	50	0	2
3.	120	0	150	2
4.	0	50	150	2
5.	60	50	150	2
6.	120	50	150	2
7.	220	50	150	2
8.	120	50	150	0

All phosphorus (0-46-0), potassium (0-0-60), and boron (solubor) applications were broadcast and incorporated on April 21, 1993. Half the nitrogen (urea) was applied on April 21 and the remainder was sidedressed on June 28. Carrots were planted on April 22, 1993. Each main row was 22" on center and consisted of 2 rows 2" apart. The population was originally set to be at 13 plants per foot; however, final plant population was measured at 4 to 5 plants per foot. The planting depth was 0.75". The variety used was 'Legend'. Each treatment was replicated four times. Recently matured leaf samples were collected on July 26 for nutrient analyses. On August 20, 10 feet of row was harvested from each plot. Top and root weight were recorded and subsamples were taken for dry matter determination and nutrient analyses.

Results: Lowest carrot yields were obtained in the control plots where no fertilizer was applied (Table 1). Carrots responded up to 60 lb N/A in this study. Excessive rates of N tended to lower yields and reduce dry matter percentage of the carrot. The previous crop of soybean may have provided some N and lowered the N response. Additionally, the low final stand count may have also reduced the overall yield and N demand. Potassium fertilizer significantly increased yield by 46 cwt/A where as the response to phosphate was not significant. The greater response to K fertilizer compared to P fertilizer is in line with the relatively low soil test level for K and high test for P. Boron fertilizer had no effect on carrot yield or quality.

In the diagnostic leaf sampled July 26, nitrogen fertilizer increased tissue concentrations of nitrate, total N, and Mn, but decreased concentrations of Ca, Cu, and B (Table 2). Potassium fertilizer increased tissue K. Phosphate fertilizer did not significantly affect leaf tissue nutrient concentrations. Boron fertilizer decreased tissue P concentrations.

Nitrogen fertilizer increased concentrations of nitrate, total N, Mg, Mn, and Cu and decreased K and Fe in carrot tops at harvest (Table 3). Phosphate fertilizer decreased concentrations of total N and Zn. Boron and potassium fertilizer did not significantly affect nutrient concentrations in carrot tops at harvest.

[1]Partial funding for this study was provided by AURI.

[2]Extension Soil Scientist, Dept. Soil Science; Research Plot Coordinator and Research Plot Technician, Staples Irrigation Center.

Nitrogen fertilizer increased concentrations of nitrate, total N, Mg, Mn, Zn, and B in carrot roots at harvest (Table 4). Nitrate concentrations were not at a level that would be of concern for human consumption. Phosphate fertilizer increased concentrations of nitrate and Fe. Potassium fertilizer increased concentrations of K and Fe. Boron fertilizer did not significantly affect nutrient concentrations in carrot tissue.

Additional studies on sandy soils need to be conducted to refine N and K fertilizer recommendations at higher plant populations.

Table 1. Effect of various fertility treatments on carrot yield and quality.

Fertilizer Treatment					Carrot	Root	Root	Dry
#	N	P_2O_5	K_2O	B	Yield	Length	Diameter	Matter
	-------- lb N/A --------				cwt/A	inches	inches	%
1.	0	0	0	0	214	8.6	1.37	11.7
2.	120	50	0	2	236	9.3	1.43	11.8
3.	120	0	150	2	269	9.6	1.50	11.2
4.	0	50	150	2	242	8.7	1.43	11.4
5.	60	50	150	2	281	9.6	1.58	11.4
6.	120	50	150	2	282	10.0	1.55	11.7
7.	220	50	150	2	250	9.6	1.60	10.5
8.	120	50	150	0	293	9.8	1.50	11.9
Significance					*	*	*	NS
BLSD (5%)					49	0.9	0.18	--
Contrasts								
Lin Rate N (4, 5, 6, 7)					NS	*	*	++
Quad Rate N (4, 5, 6, 7)					*	*	NS	NS
Boron (6 vs 8)					NS	NS	NS	NS
K (2 vs 6)					*	++	++	NS
P (3 vs 6)					NS	NS	NS	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

Table 2. Effect of various fertility treatments on nitrate - N and the elemental composition of carrot leaves sampled July 26, 1993.

Fertilizer Treatment					Nutrient										
#	N	P_2O_5	K_2O	B	NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	-------- lb N/A --------				ppm	---------- %			---------	---------	ppm			------------	
1.	0	0	0	0	361	2.50	0.41	4.59	1.38	0.23	169	72	7	34	45
2.	120	50	0	2	2407	2.85	0.36	4.12	1.33	0.24	163	80	6	32	36
3.	120	0	150	2	2520	3.00	0.36	4.69	1.20	0.23	159	87	7	34	37
4.	0	50	150	2	374	2.31	0.39	4.83	1.52	0.22	175	67	6	32	40
5.	60	50	150	2	1577	2.74	0.38	4.69	1.16	0.23	166	75	6	32	37
6.	120	50	150	2	2318	2.88	0.37	4.55	1.24	0.23	165	86	6	33	37
7.	220	50	150	2	3382	3.09	0.34	4.59	1.24	0.22	149	100	5	32	34
8.	120	50	150	0	2346	2.86	0.40	4.95	1.19	0.23	192	81	6	31	39
Significance .					**	**	**	++	*	NS	NS	++	NS	NS	**
BLSD (5%)					843	0.24	0.04	0.61	0.25	--	--	26	--	--	2
Contrasts															
Lin Rate N (4, 5, 6, 7)					**	**	**	NS	++	NS	NS	**	++	NS	**
Quad Rate N (4, 5, 6, 7)					NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS
Boron (6 vs 8)					NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
K (2 vs 6)					NS	NS	NS	++	NS	NS	NS	NS	NS	NS	NS
P (3 vs 6)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

Table 3. Effect of various fertility treatments on nutrient composition of carrot tops at harvest.

Fertilizer Treatment					Nutrient										
#	N	P_2O_5	K_2O	B	NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	-------- lb N/A --------				ppm	---------- % ---------				--------- ppm ------------					
1.	0	0	0	0	42	1.71	0.32	3.37	1.99	0.26	176	83	6	28	47
2.	120	50	0	2	132	1.60	0.32	2.96	1.48	0.26	108	64	6	28	42
3.	120	0	150	2	198	2.08	0.32	3.45	1.47	0.25	159	84	7	32	40
4.	0	50	150	2	17	1.42	0.32	3.76	1.80	0.23	197	78	5	27	41
5.	60	50	150	2	51	1.65	0.31	3.69	1.50	0.23	186	79	6	29	40
6.	120	50	150	2	60	1.72	0.31	3.33	1.55	0.25	141	75	6	27	40
7.	220	50	150	2	497	2.16	0.32	3.38	1.51	0.26	134	97	7	31	40
8.	120	50	150	0	151	1.81	0.33	3.56	1.50	0.23	129	68	6	26	41
Significance					**	**	NS	++	*	NS	NS	*	*	NS	**
BLSD (5%)					191	0.26	--	0.55	0.36	--	--	20	1	--	2
Contrasts															
Lin Rate N (4, 5, 6, 7)					**	**	NS	++	NS	++	*	*	**	NS	NS
Quad Rate N (4, 5, 6, 7)					*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boron (6 vs 8)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K (2 vs 6)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P (3 vs 6)					NS	*	NS	NS	NS	NS	NS	NS	NS	++	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

Table 4. Effect of various fertility treatments on nutrient composition of carrot roots at harvest.

Fertilizer Treatment					Nutrient										
#	N	P_2O_5	K_2O	B	NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	-------- lb N/A --------				ppm	---------- % ---------				--------- ppm ------------					
1.	0	0	0	0	10	0.77	0.33	2.97	0.36	0.12	57	20	5	22	25
2.	120	50	0	2	39	1.05	0.32	2.50	0.34	0.12	48	18	5	23	23
3.	120	0	150	2	56	1.20	0.34	3.03	0.37	0.12	49	23	5	26	23
4.	0	50	150	2	10	0.70	0.33	3.10	0.36	0.12	58	22	4	22	21
5.	60	50	150	2	24	1.15	0.35	3.20	0.34	0.11	53	22	4	23	22
6.	120	50	150	2	25	1.05	0.35	2.89	0.37	0.13	67	21	5	24	24
7.	220	50	150	2	95	1.45	0.36	3.12	0.39	0.14	54	28	4	28	24
8.	120	50	150	0	37	1.13	0.34	2.78	0.35	0.13	58	22	5	22	23
Significance					**	**	NS	*	NS	NS	NS	++	NS	NS	NS
BLSD (5%)					36	0.20	--	0.51	--	--	--	7	--	--	--
Contrasts															
Lin Rate N (4, 5, 6, 7)					**	**	NS	NS	NS	*	NS	*	NS	*	*
Quad Rate N (4, 5, 6, 7)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boron (6 vs 8)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K (2 vs 6)					NS	NS	NS	++	NS	NS	*	NS	NS	NS	NS
P (3 vs 6)					++	NS	NS	NS	NS	NS	++	NS	NS	NS	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

TILLAGE, N RATE, ROW CULTIVATION, AND INOCULATION EFFECTS ON STAND ESTABLISHMENT, NODULATION, INCIDENCE OF WHITE MOLD, AND YIELD OF RED KIDNEY BEAN[1]

J.F. Moncrief, C.J. Rosen, B.J. Johnson, M.J. Wiens, B. Sheets and P.H. Graham, [2]

This study evaluated the effects of tillage, N rate, row cultivation, and inoculation on the response by Red Kidney Beans. Reduced tillage options reduced yields 200 to 350 pounds per acre. Grain yield responded to 123 pounds per acre of urea applied in two equal applications. The main effects of row cultivation and inoculation were not statistically significant although they interacted with tillage. Row cultivation reduced yields with the moldboard and disc treatments but increased them when grown with no tillage. Inoculation increased yields with the disc system but reduced them with the no till and moldboard systems.

This study was undertaken to evaluate the effect of tillage, N rate, row cultivation, and inoculation on the growth of Red Kidney Beans. The preceding three years corn was grown. Preceding that there was three years of alfalfa. Kidney beans have not been grown on this site.

The experimental design is a randomized complete block with split plots. Main plots are tillage. Subplots are nitrogen rate, row cultivation, and inoculation. Main plots are 16 rows (30") wide and 100 feet long. Nitrogen subplots were four rows wide and 100 feet long. Cultivation subplots are 16 rows wide and 50 feet long. Inoculation subplots are 2 rows wide and 100 feet long. Tillage, N rate, and cultivation history is three years. Two of the four planter hoppers received red kidney beans inoculated with Rhizobium. Kidney beans were treated with Lindane, Captan, and Streptomyicin. Two 10 foot rows in the center of each subplot were monitored for growth and yield. Five plants were removed from each subplots, roots gently washed and nodules counted. Shoot weight was also measured.

The percent soil cover with weeds by species on July 1, 1993 is shown in table 2. There was more foxtail with the no till system. Although foxtail was reduced by one half with cultivation in the no till system, there was still 19 percent cover by this weed. The other two systems evaluated did not have appreciable amounts of grass. An application of Poast was applied one week after these observations and resulted in good grass control the rest of the season. Ragweed was also higher with no tillage at this point in time, although basagran was applied two days after these observations.

The planter used in this study was equipped with row clearing discs. Their effectiveness in clearing the row area of corn residue was influenced by cultivation in previous years. Previous cultivation reduced in row cover with corn residue with the no till system (table 3). Although soil cover in the row was high, it did not affect stands. Less plants showed insect damage with the no till system.

Tillage reduced bean yields with the residue systems. More plants were infected with white mold when grown with moldboard plowing. Nodule numbers were increased with no tillage. The nitrogen rate affected bean yields, number of diseased plants, and shoot weights. Nodule numbers were not affected by N rate. The optimum N rate appeared to be close to 120 pounds per acre and did not interact with tillage. Cultivation reduced plant stands by 5,000 plants per acre. Inoculation reduced nodule numbers but did not affect yield.

Although cultivation and inoculation did not affect average bean yields there were offsetting interactions for both of these treatments with tillage (table 4).

Inoculation did not interact with N rate (table 5). There was an interaction between tillage, N rate, and inoculation (table 7). Kidney beans responded to inoculation consistently over the range of applied N for the disc tillage system. Beans grown with moldboard tillage responded to inoculant but not consistently over N rates. When grown with no tillage there was a consistent decrease due to inoculation.

There was also a four way interaction between tillage, N rate, cultivation, and inoculation (table 8). There was a positive response to inoculation when no till plots were cultivated and a negative response when not cultivated. The opposite trend occurred with the disc system and moldboard plowing resulted in a mixed response.

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[1] Support for this project was provided by the Legislative Commission on Minnesota Resources. Their support is greatly appreciated.

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Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1993.

Tillage

No Till
Spring disc
Moldboard plowed with plow packer May 20
Cultivated with a Hiniker 5000 on July 27

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 row cleaners.

	Planting		Harvested
Crop	Date	Rate	Grain
Bean	May 28	122,000seeds/A	September 28 & 29

Soil

The soil is a Verndale sandy loam (coarse-loamy mixed, Udic Argiboroll) with a slope of 0 to 2 percent. The soil is well drained.

Previous Crop

1987-89 Alfalfa
1991-92 Corn - Pioneer
1993 Red Kidney Beans - Montcalm

Weed Control

2 pt/A of Ranger on 5/11/93
2 qt/A of Lasso on 6/2/93
1.5 qt/A of Basagran on 7/2/93
2 pt/A Poast + 2 pt/A crop oil on 7/8/93

Irrigation schedule

Month	inches
July	.50
Aug.	1.80

Disease Control

2 lb/a Benlate 50 DF on 7/20/93

Rainfall

Month	inches
June	3.37
July	4.89
Aug.	6.04
Sept.	1.69

Fertilizer 1991

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Zn	Date Applied
	------ lb/A ------						
8-12-28-4-1[1]	150	12	18	11	6	2	5/8/91
46-0-0[2]	0	0	0	0	0	0	5/29/91
46-0-0[2]	65	30	0	0	0	0	5/29/91
46-0-0[2]	152	70	0	0	0	0	5/29/91
46-0-0[2]	239	110	0	0	0	0	5/29/91
46-0-0[2]	0	0	0	0	0	0	6/13/91
46-0-0[2]	65	30	0	0	0	0	6/13/91
46-0-0[2]	152	70	0	0	0	0	6/13/91
46-0-0[2]	239	110	0	0	0	0	6/13/91

1. Planter applied 2" below and 2" beside row.
2. Broadcast as split urea and irrigated in.
3. The resulting N rates are: 12, 72, 152, and 244 lbs/A

Fertilizer 1992

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Date applied
	------ lb/A --------					
15-5-30-10[1]	115	17	6	34	12	5/5/92
46-0-0[2]	0	0	0	0	0	6/8/92
46-0-0[2]	65	30	0	0	0	6/8/92
46-0-0[2]	152	70	0	0	0	6/8/92
46-0-0[2]	239	110	0	0	0	6/8/92
46-0-0[2]	0	0	0	0	0	6/30/92
46-0-0[2]	65	30	0	0	0	6/30/92
46-0-0[2]	152	70	0	0	0	6/30/92
46-0-0[2]	239	110	0	0	0	6/30/92

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in with .24" and .60" for the 6/8 and 6/30 application dates
3. The resulting N rates are: 53, 113, 193 and 273 lbs/A 36 lbs. NO3-N/A from irrigation was added to N rates (refer to table 5.1992).

Fertilizer 1993

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Date applied
	------ lb/A --------					
15-5-20-10[1]	154	23	8	31	15	6/1/93
46-0-0[2]	0	0	0	0	0	6/25/93
46-0-0[2]	54	25	0	0	0	6/25/93
46-0-0[2]	109	50	0	0	0	6/25/93
46-0-0[2]	163	75	0	0	0	6/25/93
46-0-0[2]	0	0	0	0	0	7/22/93
46-0-0[2]	54	25	0	0	0	7/22/93
46-0-0[2]	109	50	0	0	0	7/22/93
46-0-0[2]	163	75	0	0	0	7/22/93

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea by split application.
3. The resulting N rates are: 23, 73, 123 and 176 lbs/A.

Table 2. Effect of tillage and cultivation on weed cover.

7/1/93	No till		Disc		Mldbrd		(Pr>F)		
	--- % weed cover ------								
	C[1]	NC	C	NC	C	NC	Till	Cult	TxC
Alfalfa	.5	3.1	.1	.1	.0	.0	.084	.123	.122
Lambs	3.8	5.5	6.2	7.3	1.4	1.5	.322	.200	.806
Bindweed	3.4	4.0	10.9	15.4	3.1	3.1	.055	.056	.130
Foxtail	19.4	38.5	.6	5.2	.2	.3	.004	.008	.040
Thistle	.7	.8	.2	.0	.1	.0	.003	.872	.798
Ragweed	1.3	4.7	1.1	1.6	.2	.2	.042	.035	.077

1. C=cultivated NC=not cultivated.

Table 3. Effect of tillage on soil cover by corn residue, emergence and plant injury from insects[1].

	Residue[2] (%)				Stand		Injury[3]	
	Date 6/9/93				6/25/93	9/22/93	6/25/93	
Tillage	In Row		Bet Row		Emergence	Final	Cult	No Cult
	C	NC	C	NC	---------------- plants/acre x 10^{-3}			----------------
No Till	51.8a	91.6a	73.3a	96.2a	59.2	54.4	36.5a	28.3a
Disc	19.7b	23.8b	30.3b	34.3b	60.8	52.7	53.4b	45.7b
Moldboard	11.1c	10.6c	12.5c	11.2c	61.0	56.6	49.0b	40.3b
Signif. (Pr > F)					.372	.149	.004	.003

1. Means within the same column when followed by the same letter are not significantly different(α=.10).
2. The p values for residue, row position, cultivation, tillage, tillage by row position, and the cultivation by row position interactions are .076, .005, .001, .720, .446, respectively. C=cultivated. NC=no cultivation.
3. Number of plants per acre with "bald head" (the plants are clipped above the cotyledon by insects).

Table 4. Effect of tillage, nitrogen rate, cultivation and inoculation on kidney bean response., 1993[1].

	9/28/93		9/22/93		7/26/93	
Treatment	Bean Moisture	Bean Yield	Stand 1000's	Disease 1000's	Nodule number	Shoot Weight
	--%--	-lbs/A-	-plt/A-	-plt/A-	- /plt-	-gms/plt-
Tillage (n=64)						
No Till	2.34a	2052a	54.7ab	11.1ab	184a	79.0a
Disc	2.24ab	2187a	52.7b	9.6b	112b	89.5ab
Moldboard	2.16b	2409b	56.6a	15.1a	120b	92.9b
Sig. (Pr > F)	.084	.043	.149	.087	<.001	.124
N Rate lb N/A (n=48)						
23	2.21	2045a	54.6	9.1a	142	72.6a
73	2.22	2138a	55.4	12.8b	---	90.4b
123	2.28	2370b	53.6	11.6ab	135	80.6ab
173	2.27	22312b	54.6	14.2b	---	107.7c
Sig. (Pr > F)	.722	<.001	.851	.037	.408	<.001
Cultivation (n=96)						
Cultivation	2.23	2212	52.1a	12.8	---	---
No Cultivation	2.26	2220	57.1b	11.0	---	---
Sig. (Pr > F)	.550	.845	<.001	.176	---	---
Inoculation (n=96)						
Inoculation	2.22	2207	---	---	121a	88.5
No Inoculation	2.27	2225	---	---	156b	85.6
Sig. (Pr > F)	.154	.315	---	---	.039	.766
Interactions						
Tillage X Cultivation (n=32)						
No Till W/	2.27	2127	52.2	12.7	---	---
No Till W/O	2.40	1977	56.5	9.5	---	---
Disc W/	2.22	2163	48.6	9.8	---	---
Disc W/O	2.25	2212	56.8	9.3	---	---
Mldbd W/	2.18	2346	55.4	16.0	---	---
Mldbd W/O	2.14	2471	57.8	14.2	---	---
Sig. (Pr > F)	.554	.018	.220	.707	---	---
Tillage X Inoculation (n=32)						
No Till W/	2.33	1977	---	---	170	74.7
No Till W/O	2.35	2128	---	---	198	83.3
Disc W/	2.17	2249	---	---	98	91.2
Disc W/O	2.31	2126	---	---	126	87.7
Mldbd W/	2.17	2395	---	---	94	99.5
Mldbd W/O	2.15	2422	---	---	145	85.7
Sig. (Pr > F)	.060	<.001	---	---	.799	.254

Table 5. Effect of tillage, nitrogen rate, cultivation, inoculation and their interactions on kidney bean response., 1993[1].

Tillage X N Rate lb N/A (n=16)[1]

Treatment		Bean Moisture	Bean Yield	Stand 1000's	Disease 1000's	Nodule number	Shoot Weight
		--%--	-lbs/A-	-plt/A-	-plt/A	- Avg.-	- gms -
Notill	23	2.31	1984	56.1	7.2	191	56.2
Notill	73	2.16	1869	55.2	14.3	---	80.9
Notill	123	2.51	2309	53.6	10.0	171	79.1
Notill	173	2.37	2047	52.6	12.8	---	100.5
MEAN		2.34	2052	54.4	11.1	184	79.0
Disc	23	2.24	1965	51.2	6.4	120	81.8
Disc	73	2.44	2139	56.0	8.6	---	96.4
Disc	123	2.10	2307	51.3	9.4	104	77.6
Disc	173	2.17	2335	52.5	13.8	---	105.0
MEAN		2.24	2187	52.7	9.6	112	89.0
Mldbd	23	2.08	2185	56.6	13.7	115	81.4
Mldbd	73	2.07	2404	54.9	15.5	---	90.8
Mldbd	123	2.22	2491	56.1	15.5	125	85.1
Mldbd	173	2.27	2553	58.8	15.8	---	122.0
MEAN		2.16	2408	56.6	15.1	120	93.0
Sig. (Pr > F)		.011	.219	.594	.581	.364	.632

1. Means within the same column with the same mean are not significantly different.

N Rate X Cultivation (n=24)

23	W/	2.24	1948	50.4	10.2	---	---
23	W/O	2.18	2142	58.9	8.0	---	---
73	W/	2.26	2194	53.6	14.9	---	---
73	W/O	2.19	2080	57.1	10.7	---	---
123	W/	2.24	2394	51.6	12.6	---	---
123	W/O	2.31	2344	55.7	10.6	---	---
173	W/	2.17	2311	52.7	13.6	---	---
173	W/O	2.37	2312	56.6	14.7	---	---
Sig. (Pr > F)		.436	.047	.529	.558	---	---

N Rate X Inoculation (n=24)

23	W/	2.16	2053	---	---	129	70.0
23	W/O	2.26	2037	---	---	155	75.6
73	W/	2.18	2116	---	---	---	89.6
73	W/O	2.27	2159	---	---	---	91.2
123	W/	2.31	2332	---	---	113	85.6
123	W/O	2.25	2407	---	---	157	75.6
173	W/	2.25	2326	---	---	---	112
173	W/O	2.29	2298	---	---	---	103
Sig. (Pr > F)		.231	.146	---	---	.580	.821

1. Means within the same column with the same mean are not significantly different.

Table 6. Interaction of tillage, nitrogen rate, and cultivation on kidney bean response., 1993[1].

Treatment		Bean Moisture		Bean Yield		Stand 1000's		Disease 1000's		Nodule number		Shoot Weight	
		---%---		-lbs/A-		-plts/A-		-plts/A-		-Avg.-		- gms -	
Till x N Rate(lb/A)x Cult. (n=8)													
		C[2]	NC[2]	C	NC	C	NC	C	NC	C	NC	C	NC
NT	23	2.43	2.19	1988	1980	51.2	61.0	9.1	5.2	---	---	--	--
NT	73	2.16	2.17	1990	1748	50.1	60.3	17.4	11.1	---	---	--	--
NT	123	2.36	2.67	2412	2207	53.8	53.4	9.2	10.9	---	---	--	--
NT	173	2.15	2.59	2121	1973	53.8	51.4	15.0	10.7	---	---	--	--
MEAN		2.27	2.40	2127	1977	52.2	56.5	12.7	9.5	---	---	--	--
DISC	23	2.16	2.32	1805	2126	45.3	57.1	7.6	5.2	---	---	--	--
DISC	73	2.52	2.37	2187	2091	54.0	57.9	10.7	6.5	---	---	--	--
DISC	123	2.15	2.05	2269	2347	45.7	56.8	9.4	9.4	---	---	--	--
DISC	173	2.06	2.28	2390	2282	49.4	55.5	11.5	16.1	---	---	--	--
MEAN		2.22	2.25	2162	2211	48.6	56.8	9.8	9.3	---	---	--	--
MB	23	2.13	2.04	2051	2319	54.7	58.6	13.9	13.5	---	---	--	--
MB	73	2.09	2.04	2407	2401	56.6	53.1	16.6	14.4	---	---	--	--
MB	123	2.21	2.22	2502	2480	55.3	56.8	19.4	11.5	---	---	--	--
MB	173	2.29	2.25	2424	2682	54.9	62.7	14.2	17.4	---	---	--	--
MEAN		2.18	2.14	2346	2470	55.4	57.8	16.0	14.2	---	---	--	--
SIG. (Pr> F)		.568		.690		.214		.595		.---		.---	

1. Means within the same column with the same mean are not significantly different.
2. C = cultivated. NC= not cultivated.

Table 7. Interaction of tillage, nitrogen rate, and inoculation on bean response at Wadena Co.,1993[1].

Treatment		Bean Moisture		Bean Yield		Stand 1000's		Disease 1000's		Nodule number		Shoot Weight	
		---%---		-lbs/A-		-plts/A-		-plts/A-		-Avg.-		- gms -	
Till x N Rate(lb/A)x Inoc. (n=8)													
		W[2]	W/O[2]	W	W/O	W	W/O	W	W/O	W	W/O	W	W/O
NT	23	2.21	2.41	1924	2044	---	---	---	---	188	194	52	60
NT	73	2.21	2.12	1719	2019	---	---	---	---	---	---	72	90
NT	123	2.52	2.50	2237	2382	---	---	---	---	152	201	76	82
NT	173	2.38	2.36	2029	2065	---	---	---	---	---	---	98	103
MEAN		2.33	2.35	1977	2128	---	---	---	---	170	198	75	83
DISC	23	2.29	2.19	2020	1911	---	---	---	---	96	143	73	91
DISC	73	2.22	2.67	2230	2048	---	---	---	---	---	---	105	88
DISC	123	2.12	2.08	2330	2285	---	---	---	---	99	108	84	71
DISC	173	2.05	2.30	2414	2257	---	---	---	---	---	---	103	108
MEAN		2.17	2.31	2249	2126	---	---	---	---	98	126	91	88
MB	23	1.99	2.18	2215	2156	---	---	---	---	101	127	86	75
MB	73	2.12	2.02	2399	2409	---	---	---	---	---	---	86	96
MB	123	2.27	2.16	2428	2554	---	---	---	---	87	161	97	74
MB	173	2.32	2.22	2536	2570	---	---	---	---	---	---	145	99
MEAN		2.17	2.15	2395	2422	---	---	---	---	94	145	103	86
SIG. (Pr> F)		.003		.103		.---		.---		.466		.600	

1. Means within the same column with the same mean are not significantly different.
2. W = with inoculation. W/O= with out inoculation.

Table 8. Interaction of tillage, nitrogen rate, cultivation and inoculation on kidney bean response at Wadena Co.,1993[1].

Treatment		KIDNEY BEAN							
		Moisture				Yield			
		---%---				---lb/A---			
		Cult.[2]		No Cult.		Cult.		No Cult.	
Till x N Rate(lb/A)x Cult x Inoc.(n=4)		W[3]	W/O	W	W/O	W	W/O	W	W/O
NT	23	2.19	2.66	2.23	2.15	2026	1950	1822	2139
NT	73	2.18	2.13	2.24	2.10	1848	2132	1590	1906
NT	123	2.24	2.48	2.81	2.52	2338	2486	2135	2279
NT	173	2.19	2.11	2.57	2.60	2163	2080	1895	2051
MEAN		2.22	2.34	2.46	2.34	2094	2162	1860	2094
DISC	23	2.09	2.23	2.49	2.15	1846	1765	2195	2058
DISC	73	2.19	2.84	2.24	2.50	2315	2059	2145	2037
DISC	123	2.21	2.09	2.03	2.06	2244	2293	2417	2278
DISC	173	2.09	2.04	2.00	2.55	2317	2463	2512	2052
MEAN		2.14	2.30	2.19	2.32	2180	2145	2317	2106
MB	23	1.98	2.27	1.99	2.10	2107	1996	2324	2315
MB	73	2.18	2.01	2.06	2.02	2409	2405	2389	2414
MB	123	2.20	2.23	2.35	2.10	2376	2629	2480	2480
MB	173	2.34	2.24	2.29	2.21	2437	2412	2635	2730
MEAN		2.18	2.13	2.17	2.11	2332	2360	2457	2485
SIG. (Pr> F)		.050				.003			

1. Means within the same column with the same mean are not significantly different.
2. C = cultivated. NC= not cultivated.
3. W = inoculated. W/O = with out inoculation.

Nitrogen Source Effects on Corn/Potato Yields and Nitrate Leaching[1]

J.T. Waddell, J.F. Moncrief, C.J. Rosen, S.C. Gupta and M.J. Weins[2]

Abstract

Plots were established at Staples, MN with the following treatments: Anhydrous ammonia with and without nitrification inhibitor, turkey manure, urea-ammonium nitrate, granular urea and a control. Each treatment (except the control) had fertilizer applied at approximately 200 pounds N per acre. No differences in yield or moisture content occurred in the corn grain supplied with different N sources, however a significant increase in grain yield was observed versus treatment effects on the control. Stover yields were found to be non-significant. Potato tubers and vines did respond to the different N sources. Anhydrous ammonia and turkey manure applied preplant and subject to 10 inches of rainfall in May still resulted in similar marketable and total potato yields to other N sources that were applied in split applications in June and July. There was also a significant potato response to nitrification inhibition. A comparison of vine dry matter yield shows that using urea as an N source enhances vine growth. Nitrogen collected in suction cups was lower for corn than potato. Crude estimations using excess soil moisture coupled with N concentrations sampled at 2 feet indicate that as much as 100 pounds per acre may have been lost.

Introduction

Crop production on the sandy soils in Minnesota has been advanced by the introduction of irrigation systems (Wright and Bergsrud, 1991). Wright and Bergsrud (1991) developed an irrigation schedule termed 'the Checkbook Method' which predicts daily water use for several different crops. It has been shown by Dylla et. al. (1980) that these tables to predict water use are comparable to estimates obtained by more precise methods. While the checkbook method may be a valuable tool for predicting irrigation scheduling, the variability of climate from year to year plays a major role in assessing the risks of loosing nitrogen to sub-surface water reservoirs. It has been shown that varying the source of nitrogen (either Urea or Turkey manure) in corn cropping systems may have an effect on yields and contribute to contamination of groundwater (Nathan et. al., 1992 and Sexton 1993). Nitrogen source studies on potato yield in Minnesota are infrequent.

It was the purpose of this study to discern the effects of nitrogen source on corn/potato yields and to qualitatively describe N movement below the root zone.

Materials and Methods

The test plots were located on a Verndale sandy loam. The site had a maximum slope of 2% with little or no runoff. Soils of the area are unique. An illuvial soil horizon of limiting hydraulic conductivity (0.54 in h^{-1}) exists with a clear upper boundary at approximately 10 inches and a gradual lower boundary at 16 inches below the surface (Sexton, 1993). Visual observations of the soil showed a limited number of preferential flow paths (macropores) due primarily to ant burrows. Earthworms are less common on soils of such a sandy nature.

Individual plots were 20 x 40 square feet. Corn (Pioneer 3921) was planted on 5 May in 30 inch rows at a rate of approximately 32,000 seeds per acre. On 6 May, the herbicides Bladex (cyanozine) and Dual (metalachlor) were applied at rates of 2.5 pounds and 2 pints per acre, respectively. No insect or fungus control procedures were needed in the corn. Weed control was good with a few weeds (quackgrass, lambsquarter and nightshade). Some eyespot was observed in the corn plots.

Potato (Russet Burbank) was planted on 27 April in 36 inch rows with a density of 43560 seed pieces per acre along with 30 pounds N per acre. Pre-plant and post-harvest knock down herbicide Diaquat was applied at rates of 1.5 pints per acre, otherwise weeds were controlled during the growing season by cultivation on 1 and 25 June. Furadan was applied on 27 July after noticing Colorado Potato Beetle infestation. Fungicide (Bravo) was applied on 23 June, 2 and 9 July, and 13 August (with Ridomil) at rates of 1.5 pints per acre. Some Early Blight was detected during the growing season.

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[1] *Support for this project was provided by the Legislative Commission on Minnesota Resources. Their support is greatly appreciated.*

[2] *J.T. Waddell, Graduate Research Assistant, J.F. Moncrief and C.J. Rosen, Extension Specialists, S.C. Gupta, Professors of Soil Sci., Dept. Soil Sci., Univ. Minn, St. Paul, MN. M.J. Wiens is the Univ. Minn. Senior Plot Coordinator, Staples Irrigation Center, Staples, MN.*

The design for both corn and potato studies was a completely randomized complete block with four replications. This conservative rate for high yields was used in order to discern differences if any in the uptake and loss of nitrogen. Table 1 shows the application rates and schedules of the various treatments. Anhydrous ammonia was placed below the row for potato pre-plant and between the row for corn sidedress on 30 June.

Irrigation scheduling was based on the Checkbook Method (Wright and Bergsrud, 1991), with attempts to apply 0.75 inches (Figure 1). During the corn stages from planting to 12 leaf, irrigation was applied at a deficit of 60% of the available water (1.42 inches); from 12 leaf to first dent, the irrigation trigger was 0.95 inches (40%); and from first dent to maturity, irrigation was initiated at 66% (1.6

Table 1. Nitrogen sources, application rates and dates.

Treatment	Potato			Corn		
	Rate	Date	Total‡	Rate	Date	Total
Anhydrous Ammonia with N-serve	239 (197)† lbs/ac	22 April	227 lbs/ac	347 (286) lbs/ac	30 June	303 lbs/ac
Anhydrous Ammonia	239 (197) lbs/ac	22 April	227 lbs/ac	347 (286) lbs/ac	30 June	303 lbs/ac
Urea	182 (85) lbs/ac	1 & 25 June	200 lbs/ac	182 (85) lbs/ac	1 & 25 June	187 lbs/ac
Urea Ammonium Nitrate (28%)	28 (85) gal/ac	1 & 25 June	187 lbs/ac	28 (85) gal/ac	1 & 25 June	187 lbs/ax
Turkey Manure§	6.8 (211) ton/ac	21 April	211 lbs/ac	6.8 (211) ton/ac	21 April	211 lbs/ac

† Values in parenthesis represent the calculated applied N (pounds per acre) for each source. Note that an additional 30 pounds N per acre was applied to potato and 17 pounds N per acre of corn in starter application.

‡ Represents total nitrogen applied to individual plots including starter fertilizer.

§ Applied value calculated by 100 % of mineral N (24.7 lbs N/ton dry weight) and 30% of organic N (59.1 lbs N/ton). Moisture content was 26.9%.

inches) depletion. For potatoes, an irrigation deficit of 50% was used from planting to tuberization and from tuberization to maturity a 40% deficit was used. Rainfall events which exceeded half of field capacity were followed by two days of cumulative soil water deficits at zero. Whenever the water deficit by the Checkbook Method was less then 10 centibars of tension, suction was applied to suction cup samplers. Also, suction was applied to samplers before irrigation events or when the chance of precipitation was 50% or greater.

Suction samplers were made from high flow (1 bar) porous ceramic cups (2 inch diameter) were glued to poly vinyl chloride (PVC) pipe. Access tubes were inserted through a rubber stopper from which suction was used for collection of soil water percolate. Suction samplers were installed in plots amended with Urea and turkey manure along with the control plot. Suction samplers were installed at the 24 inch depth. Samples collected were quickly frozen and taken to the analytical lab where nitrate and ammonia concentrations were measured.

Corn was harvested by hand on 21 October. Stover and grain moisture content, yield and N uptake were determined. Potatoes were harvested on 16 September with biomass, N accumulation and quality parameters determined.

Results and Discussion

From figure 1, it is evident that rainfall was not limiting during the growing period except for a few instances when irrigation was used. Ample or excess rainfall occurred in all months except June and July which were close to average values determined at the Irrigation Center. Mean temperatures were below normal for the growing season. For this reason, corn yields may have been depressed.

Corn

Table 2 shows the parameters measured for corn. No differences were seen in stover accumulation, likewise for grain yield (except in the case of grain, the control yielded significantly less). The lack of significant differences may be attributed to large variabilities between replications. Average grain yield over all treatments (except control) was 110 bushels per acre and for stover 1330 pounds per acre. Because of the wet and cold growing season, drying time was reduced as seen by moisture content in the grain (> 30%) and stover (50 to 70% water). Again, no differences were observed in grain moisture content and only slight differences in stover water content, due to high variability between replications.

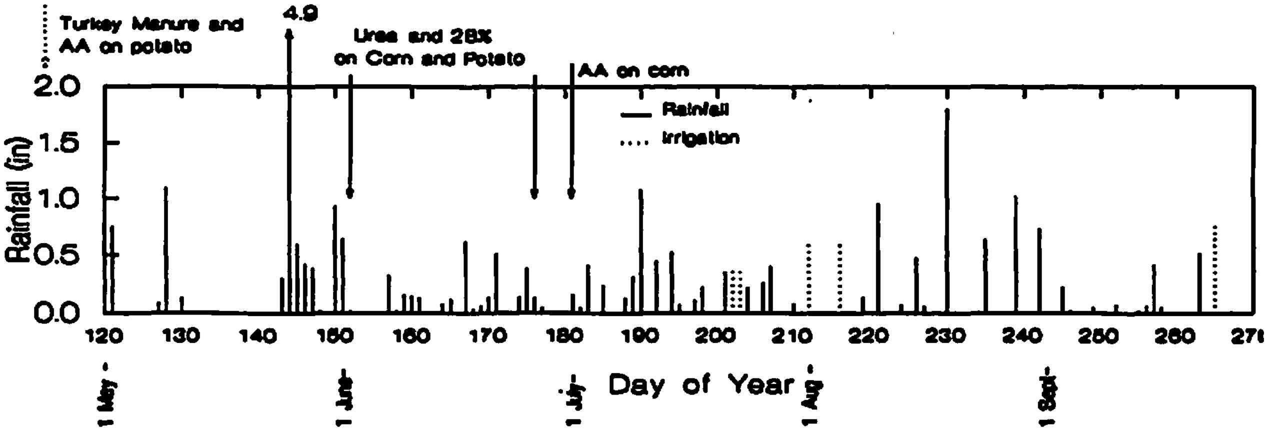

Figure 1. Rainfall and irrigation events for 1993 corn/potato growing season. Also shown is schedule of fertilizer applications.

Table 2. Response of corn to different nitrogen sources.

Nitrogen Source	Grain Yield	Grain Moisture	Stover Yield	Stover Moisture	Nitrogen Uptake		
					Grain	Stover	Total
	bu/ac	%	lbs/ac	%	-------------lbs/ac-------------		
Anhydrous Ammonia with N serve	106.6a	32.1a	1241a	64.6ab	75.7ab	11.1abc	86.8 b
Anhydrous Ammonia without N serve	107.0a	32.3a	2045a	50.4 b	75.0ab	17.4a	92.4ab
Urea	113.0a	32.6a	1073a	58.0ab	84.7a	17.1ab	101.8a
28%	107.7a	32.3a	1094a	77.7a	74.2ab	9.2abc	83.4 b
Turkey Manure	116.9a	31.7a	1314a	73.9a	73.4 b	8.8 bc	82.2 b
Control	70.1 b	33.4a	1220a	64.4ab	39.6 c	6.6 c	46.2 c

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test ($\alpha=0.1$).

Nitrogen uptake in corn grain and stover is also shown in table 2. Plots with urea as the nitrogen source had the highest N uptake, although not significantly different then the anhydrous ammonia (with and without N-serve) or the urea ammonium nitrate (28%) sources. Nitrogen uptake in the urea plot was significantly greater than the turkey manure treatment. Figure 2 shows total nitrogen concentrations in soil water collected with suction samplers. From the figure, it can be seen that the N content moving out of the root zone increased steadily over time until mid August after which it dropped off. Increased uptake of nitrogen during the middle of the growing season is evident from the drop in the curve in the check plots, after which the concentration of N in the water increased probably due to mineralization of organic matter.

The first week in July shows the greatest moisture excess of approximately 1.5 inches in a week. Nitrogen lost in the turkey manure treatment increased sharply probably as a result of high mineralization rates which increased the potential for leaching.

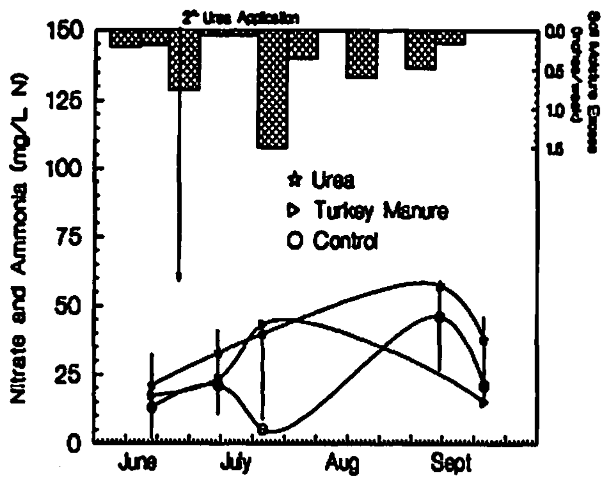

Figure 2. Soil water nitrate concentrations under corn along with soil moisture excess (calculated by checkbook method) and standard errors.

Table 3. Response of potato tubers to different nitrogen sources totalling to 210 (± 5) lbs/ac applied N.

Nitrogen Source	Culls	Ones	Twos	Jumbo	Knobs	Market	Total	Vine Yield
		--------------------------------	--------cwt/ac	--------	--------	--------------------------------		lbs/ac
Anhydrous Ammonia with N serve	23.0ab	139.9a	198.7a	9.1ab	11.6b	338a	382ab	1093b
Anhydrous Ammonia without N serve	21.6ab	120.2a	176.1a	15.4a	11.5b	296b	344ab	1070b
Urea	19.0b	161.4a	172.9a	10.0ab	23.9a	334a	387a	1999a
28%	18.6b	129.9a	160.8a	17.9a	14.5ab	290b	341b	1218b
Turkey Manure	24.5ab	122.8a	191.3a	6.7ab	24.3a	314ab	369ab	965b
Control	28.8a	32.9b	162.7a	0.6b	5.4b	195c	230c	318c

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

Potato

Table 3 shows the response of potato tubers to the different nitrogen sources. Marketable tuber yield was highest with the anhydrous application with N-serve, however this yield (338 cwt/ac) was not significantly different than the urea or turkey manure sources. The urea and AA (with N-serve) did yield significantly higher than the AA (without) and the 28% treatments. Besides marketable tubers, total tubers harvested followed a similar trend. Vine yield, which may not be economically important to the farmer, is important in accumulating nitrogen and perhaps reducing nitrate concentrations in subsurface water reservoirs. Table 3 shows that N accumulation in the vine was highest for the urea treatment. However, vine yields and N concentrations play only a minor role in the N budget. Nitrogen uptake in tubers was highest for AA with and without N-serve and urea treatments. Turkey manure amended to plots was not as efficient a source in that N uptake was less. As a result of tuber yield in turkey manure amended treatments not being significantly less than other treatments, luxury consumption of nitrogen was not a factor. Instead, as the growing season progressed the organic fraction of N in the turkey manure may have been made more available. Figure 3 shows nitrogen concentrations in soil water peaked for the manure treatments during the final stage of the growing season. A possible explanation would be that as mineralization increased (as can also be seen by the upward trend in the control treatment) plant requirements also increased. As the plants matured, the manure was still mineralized and as a result became susceptible to leaching. Figure 3 also shows the N content in soil water under plots amended with urea. The very high peak in late June after the second urea application may not actually be potentially leached. The samples collected from this treatment at this time contained as much as half the total in the form of ammonium. The lower leaching potential of NH_4^+ leads to questions of its arrival at the 2 foot depth. One explanation is that as a result of significant precipitation after urea application, the urea was solubilized and moved to the lower depth where it hydrolyzed and transformed into nitrate (by nitrification bacteria) and ammonium (hydrolysis product).

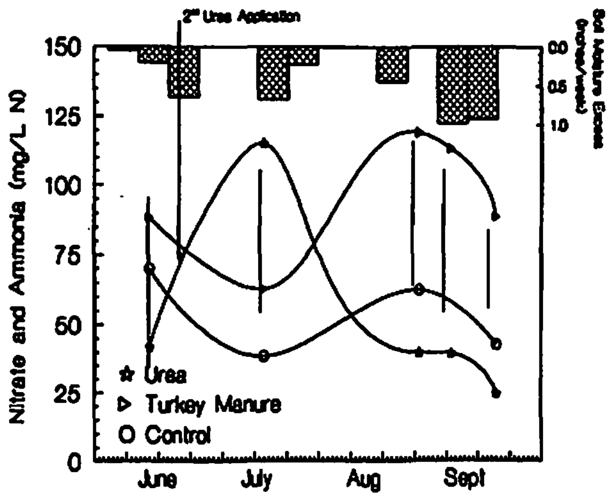

Figure 3. Soil water nitrate concentrations under potato along with soil moisture excess (calculated by checkbook method) standard errors.

Summary

Rainfall during the month of May totalled just under 7 inches (25 year mean rainfall = 3.2 inches), resulting in above average leaching conditions. Grain and stover yields did not differ significantly compared to different N sources at approximately equivalent rates. The response of greatest marketable tuber yield with application of Turkey manure, urea and anhydrous ammonia occurred. However, these results only apply in the case of above average rainfall. In order to determine whether different sources of N plays a role in yields and N losses, further study must occur. This study will be continued next year.

Table 4. Some quality parameters and Nitrogen uptake values along with moisture content of tuber data.

Nitrogen Source	Specific Gravity	Hollow Heart	Tuber N uptake	Tuber Water Content	Vine N Uptake	Vine Water Content
	g cm^{-3}	%	lbs / ac	%	lbs / ac	%
Anhydrous Ammonia with N Serve	1.096a	8.0 b	121a	75.8abc	18.6 bc	86.7a
Anhydrous Ammonia without N serve	1.095a	12.0ab	116ab	75.3 c	20.0 b	85.5a
Urea	1.094a	9.0 b	118ab	76.6a	32.9a	86.6a
28%	1.095a	10.0 b	106 bc	75.6 bc	20.2 b	87.5a
Turkey Manure	1.096a	9.0 b	99 c	76.3a	9.44 cd	87.8a
Control	1.095a	18.0a	52 d	75.6 bc	2.76 d	67.5 b

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

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SOUTHERN EXPERIMENT STATION
35838 120th STREET
WASECA, MINNESOTA 56093-4521

WEATHER DATA - 1993

Month	Period	Precipitation 1993	Precipitation Normal[1]	Avg. Air Temp. 1993	Avg. Air Temp. Normal[1]	Growing Degree Units 1993	Growing Degree Units Normal[1]
		---- inches ----		----- °F -----			
January	1 - 31	1.65	0.98	10.5	10.2		
February	1 - 28	1.21	0.97	13.8	16.1		
March	1 - 31	1.92	2.28	26.1	19.1		
April	1 - 30	5.12	2.97	42.4	43.1		
May	1 - 10	2.64		58.1		93.5	
	11 - 20	1.01		55.0		83.5	
	21 - 31	2.54		56.7		96.5	
	Total	6.19	3.65	56.6	57.7	273.5	327
June	1 - 10	.63		59.9		114.0	
	11 - 20	4.55		66.6		169.5	
	21 - 30	1.64		68.6		181.0	
	Total	6.82	4.11	64.9	67.1	464.5	515
July	1 - 10	2.37		70.2		199.0	
	11 - 20	3.21		69.3		187.0	
	21 - 31	1.58		70.7		226.5	
	Total	7.16	4.21	70.0	71.3	612.5	646
August	1 - 10	0.86		65.9		162.0	
	11 - 20	5.69		73.9		234.0	
	21 - 31	1.76		70.5		223.0	
	Total	8.31	4.20	70.1	68.4	619.0	567
September	1 - 30	3.29	3.56	55.2	59.9	230.0	316
October	1 - 31	0.75	2.45	46.5	47.9	0	31
November	1 - 30	1.73	1.72	29.9	32.3		
December	1 - 31	1.22	1.35	19.9	16.2		
Year	Jan-Dec	45.37	32.45	42.2	43.4	2200.0[2]	2402
Growing Season	May-Sep	31.77	19.73	63.5	64.9	2200.0	2371

[1] 30-year normal from 1961 - 1990.
[2] 50 to 86° F base, May 1 until first fall frost.

Notes:
1) Highest April-September precipitation in 79-yr record.
2) Second highest annual precipitation in 79-yr record.
3) Highest 24-hour precipitation on August 15 - - - 4.52"
4) Growing degree units 8% below normal for season, 5th lowest since 1950.
5) Highest temperature on August 11 and 13 - - - 90°F.
6) Last spring frost - - - April 30.
7) First fall frost - - - September 27.
8) Third coldest September on record.
9) First time on record where May - Sept. precipitation exceeded pan evaporation.
10) Solar radiation for May - Sept. was 9% below normal and lowest in 21 yrs of record keeping.

1993 Soil Moisture

0-5' Profile, Webster Clay Loam

Continuous Corn

Southern Experiment Station, Waseca, MN 56093

Depth	4/30	5/14	6/1	6/15	7/3	7/16	8/3	8/20	9/1	9/16	10/1	10/15	11/1
inches	inches available water in zone												
0 - 6[1/]	1.08	1.16	0.99	1.17	1.13	0.91	0.87	1.19	1.22	0.90	1.10	0.87	0.94
6 - 12	0.84	0.89	0.71	0.81	0.70	0.35	0.48	1.02	0.89	0.56	0.78	0.64	0.71
12 - 18	0.88	0.89	0.98	0.80	0.86	0.72	0.54	0.94	0.92	0.70	0.74	0.65	0.74
18 - 24	0.76	0.72	0.84	0.61	0.74	0.68	0.51	0.75	0.62	0.56	0.55	0.55	0.64
24 - 36	2.10	2.03	1.81	1.74	1.97	1.64	1.22	1.89	1.50	1.78	1.45	1.79	1.68
36 - 48	2.93	2.88	2.36	2.71	3.09	2.06	2.08	2.43	2.41	2.49	2.16	2.59	2.76
48 - 60	2.60	2.24	1.66	2.11	1.87	1.70	1.61	1.74	2.07	1.99	1.80	1.91	2.05
Total available water in 0-5' profile (inches)	11.19	10.82	9.36	9.95	10.36	8.06	7.30	9.96	9.64	8.98	8.58	9.01	9.51
% of Capacity[2/]	101	98	85	90	94	73	66	90	87	81	78	82	86

[1/] All values obtained by gravimetric sampling using Waseca D_b and WP constants.

[2/] Assuming 11.05" field moist capacity.

Above average rainfall resulted in plentiful soil moisture in the five-foot profile throughout the 1993 growing season. Lowest soil moisture levels occurred in late July and early August during peak use. With soil moisture conditions at 86% of maximum in November soil moisture entering the 1994 growing season will likely be at field capacity.

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

Waseca, 1993

G.W. Randall and T.K. Iragavarapu[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. An 11-year study was conducted to determine if greater amounts of NO_3-N and pesticides were being lost to tile drainage water with NT compared to moldboard plow (MP) tillage. In November 1992, all plots were moldboard plowed; thus results in 1993 are the residual effects of these two tillage systems. Rainfall during 1993 was 12.9" above normal and tile flow was plentiful. In this residual year, plots with NT history for the past eleven years had slightly higher tile flow compared to the MP tillage plots; however, the NO_3-N concentrations in the tile water were higher for the MP compared to NT. Nitrate-N losses to the tile lines were 20% higher for the MP system. Grain yield and N removal in the grain were not different between the two tillage systems. Silage yield,nitrogen uptake in the silage, and grain N concentration were higher for NT compared to the MP system. Under the stress conditions of 1993 these data indicate somewhat greater availability of N in the system following eleven years of NT; perhaps due to mineralization of higher amounts of immobilized N in the surface soil. The two tillage systems did not differ greatly in the amounts of NO_3-N in the 8-foot soil profile in November.

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 one-year study was to determine if previous long-term tillage has a residual 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. Beginning in 1990, three replications and 6 plots were used. Corn was grown on these plots from 1982 through 1992. In the fall of 1992, the stalks were chopped and all 8 plots were moldboard plowed.

On April, 23, 180 lb N/A as urea was applied with an air-flow applicator before field cultivation. Corn (Pioneer 3578) was planted on May 6 at a population of 32000 plants/A with a 6-row planter. Starter fertilizer was not used because of the high soil tests. Force was applied at 1 lb ai/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3.5 lb ai/A) and Bladex (3 lb ai/A) applied May 13. Weed and insect control were excellent.

Silage yields were taken at physiological maturity. Grain yields were taken by combine from 2-45' rows. Tile line flow began on March 29 and continued to flow each month until September 30. 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 November 16, 1993.

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[1] Funding provided by the North Central Regional Research Committee (NC-201) and the Southern Experiment Station

[2] Professor and Post-Doctoral Research Associate, Univ. of Minnesota

RESULTS

Moldboard plowing the plots that had a 11-year NT history increased silage yield, total N uptake by the whole plant, and grain N concentration over the long-term MP tillage plots (P=90% level) (Table 1). In addition, trends toward increased grain yield and higher grain N removal after plowing the NT plots suggests greater N availability probably due to the mineralization of the organic N that accumulated in the top 6" of the NT plots over the 11-year period. Grain moisture was not affected by the previous tillage systems.

Precipitation during the growing season and for the year was 12.49 and 12.92" above normal, respectively. Consequently, tile flow was higher than usual for both the tillage systems (Table 2). Highest tile flow occurred in April followed by June. Flow-weighted NO_3-N concentration for the season averaged 23% higher with MP tillage. Thus, NO_3-N losses via the drainage water were 20% higher for MP tillage. On an annual basis these NO_3-N losses were the equivalent of 28% and 33% of the fertilizer added for NT and MP, respectively, in this very wet year.

Table 1. Influence of previous tillage systems on corn production and N utilization at Waseca in the residual year.

Tillage System	Final Population	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal	Grain H_2O
	$x10^3$	T DM/A	lb N/A	bu/A	%	lb N/A	%
Moldboard Plow	26.5	4.96	75.7	104.6	1.09	54.1	29.6
No Tillage	27.0	5.47	93.5	112.0	1.20	63.5	29.2
Signif.Level (%)[1]	98	92	94	60	94	88	37
CV (%)	0.4	3.6	6.4	8.1	2.9	7.4	3.0

[1] Probability level of significance.

Table 2. Influence of previous tillage systems on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1993.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in	ppm	lb/A
		Moldboard Plow	
March	0.74	7.0	1.23
April	6.53	9.1	12.74
May	4.33	9.2	8.45
June	6.18	16.4	22.35
July	1.64	18.2	5.83
August	2.45	14.9	7.74
September	0.59	14.2	1.57
Total	22.46	Avg = 12.7	59.91
		No Tillage	
March	1.26	6.7	1.87
April	7.28	6.8	11.02
May	4.57	6.3	6.39
June	5.67	11.8	14.72
July	1.81	13.8	5.77
August	2.46	14.6	8.05
September	0.72	12.0	2.14
Total	23.77	Avg = 10.3	49.96

Residual NO_3-N in the soil profile at the end of 1993 growing season showed little difference between the two tillage systems. These results are different from the previous years where MP tillage contained consistently higher amounts of residual NO_3-N. The increased amounts of NO_3-N in the 0-8' profile of the former NT plots indicates that greater amounts of mineralized N became available after plowing in this system compared to the long-term MP tillage.

Table 3. Influence of previous tillage systems on residual NO_3-N in the soil profile in November, 1993.

Profile	Tillage System	
Depth	Mb.Plow	No Tillage
feet	------------------NO_3-N (lb/A)------------------	
0-1	13.1	18.1
1-2	4.4	5.6
2-3	5.1	6.0
3-4	13.6	18.4
4-5	12.3	15.2
5-6	10.7	10.9
6-7	10.8	12.0
7-8	10.1	9.4
Total (0-8')	80.1	95.6

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

Waseca, 1993

Gyles W. Randall, Gary L. Malzer and Jeffrey A. Vetsch[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 1993. Results from this seventh year showed significant yield improvement over the control with all N treatments. Fall application of N without N-Serve gave the lowest yields and N use efficiency of the N treatments. Yields and N use efficiency were not different among the fall + N-Serve, spring, and split N treatments. Tile lines flowed from late March through late September. Tile flow averaged 11.16" for corn and 10.55" for soybean. Highest NO_3-N concentration and losses in the corn plots occurred with the fall application of N without N-Serve while the highest concentration and losses under soybean occurred with spring and split application of N to the previous corn crop. Nitrate-N concentrations and losses from continuous fallow plots that did not receive fertilizer N or a planted crop for seven years were 60% higher than from the fertilized corn. This was due to soil mineralization and no crop uptake over this period.

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 soybean.

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 soybean was planted on the other half. Thirty two plots (16 with corn and 16 with soybean) 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 primary 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 28, 1992. Average soil temperature at the 4" depth on that date was 50°F with an average of 40°F over the following 10-day period. Spring preplant treatments were applied on May 5. The sidedress portion (60%) of the split treatments was applied at the V-8 stage on July 12.

The corn area (1992 soybean area) was field cultivated once before planting, while the soybean area (1992 corn area) was fall chiseled and field cultivated once prior to planting. Surface residue accumulation was estimated by the line-transect method in both the corn and soybean area before and after planting. Surface residues averaged 61, 64, 17, and 34% in the corn and soybean (1992) plots before and after planting, respectively. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3578) was planted at 32,200 seeds/acre on May 17 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) on May 22. Soybeans (Sturdy) were planted in 30" rows at 9 beans per foot of row on May 17. Weeds were chemically controlled with 3.0 lb/A Lasso preemergence (June 1) plus a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage (July 7).

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 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-4 stage and plots were thinned to 29,040 plants/acre. 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. 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. 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 soybean plots on May 5. Chemical analyses of whole plant stover, grain, water, and soil samples were performed by the Research Analytical Laboratory, University of Minnesota.

[1/] Partial funding provided by Dow Chemical U.S.A., Minnesota Agric. Exp. Stn., and the Southern Experiment Station.

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Plant

Stover N concentration at physiological maturity was significantly affected by fertilizer N and its time of application (Table 1). Stover N was incresed over the control by all N treatments except when applied in the fall without N-Serve. Split application of N resulted in higher stover N concentration (0.82%) than the fall treatment without N-Serve (0.63%). Stover N for the fall with N-Serve and spring treatments (0.72%) was not different (P = 95% level) than the fall without N-Serve and split treatments.

Stover yield was increased over the control by all of the fertilizer N treatments (Table 1). However, statistical differences among the four primary treatments were not significant (P = 90% level). When all seven treatments were analyzed as a completely randomized design, it is clear that highest stover yields (average of 1.84 tons) were obtained with the spring preplant N treatments while the lowest yields (average of 1.55 tons) were consistently obtained with the split treatments. Fall application of N did not increase stover yield above that obtained with the split application of N.

Similar to stover yield, N uptake in the stover was incresed above the control by all fertilizer N treatments (Table 1). Differences in stover N uptake among the four primary treatments occurred only at the P = 84% level. Analyses of all seven treatments indicated significantly (P = 95% level) lower N uptake with the fall application without N-Serve compared to all spring and split N treatments.

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

N Application		Stover			Final
Time	N-Serve	N	Yield	N uptake	Population
		%	TDM/A	lb/A	ppA x 10^3
Primary trts					
Fall (Oct.)	No	0.63	1.61	20.3	28.8
Fall (Oct.)	Yes	0.72	1.68	24.3	28.8
Spring (April)	No	0.72	1.78	25.7	28.9
Split[1]	No	0.82	1.54	25.6	28.8
Additional trts					
Check	–	0.54	1.08	11.6	28.7
Spring (April)	Yes	0.80	1.90	30.2	28.8
Split[1]	Yes	0.83	1.56	26.1	28.6
		Statistical Analysis			
Latin square (Primary trts)					
Significance Level (%) :		97	80	84	8
BLSD (.05) :		0.12	–	–	–
CV (%) :		8.9	8.4	13.6	0.9
Completely randomized (7 trts)					
Significance Level (%) :		99	99	99	6
BLSD (.05) :		0.09	0.19	4.6	–
CV (%) :		8.7	8.6	14.2	1.3

[1] 40% preplant + 60% sidedress.

Grain and silage yields were increased significantly over the control (0 lb N/A) by all of the N treatments (Table 2). Fall application of N without N-Serve gave consistently lower grain and stover yields than the three other primary treatments. Yields among the fall with N-Serve, spring, and split N treatments were not different. Grain moisture at harvest was significantly higher for the 0-lb N treatment compared to the rest, but differences in moisture among the four primary treatments did not exist.

Grain N concentration was higher for all fertilizer N treatments compared to the control (Table 2). Among the four jprimary treatments, significantly higher grain N was found with the split treatment. Grain N concentrations tended to be higher with the spring N + N-Serve and split treatments compared to the fall and spring without N-Serve treatments. Nitrogen removed in the harvested grain was lowest with the fall-applied N treatment without N-Serve and highest for the split and spring N + N-Serve treatments (Table 2). Total N uptake was increased over the control by 35.9 lb/A (90%) for the fall without N-Serve, 47.5 lb/A (120%) for the fall + N-Serve, 45.3 lb/A (114%) for the spring preplant treatment, and an average of 56.1 lb/A (141%) for the spring with N-Serve and split N treatments.

The General Linear Model program in SAS was used to "contrast" the four primary treatments and determine if significant differences existed. The significance levels shown in Table 3 show an improvement in stover N concentration, grain yield, silage yield, grain N removal, and silage N uptake (P = 90% level) with N-Serve added to the fall-applied N. Spring application of N showed significant advantages over fall-applied N for stover N concentration, grain moisture, and silage N utake. Split application of N resulted in higher stover and grain N concentrations, lower stover yield, higher grain N removal, and lower silage N uptake compared to the spring preplant application.

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

N application		Grain				Silage	Total N uptake
Time	N-Serve	Yield	H_2O	N	N removal		
		bu/A	%	%	lb/A	TDM/A	lb/A
Primary trts							
Fall (Oct.)	No	103.9	41.1	1.12	55.2	4.06	75.6
Fall (Oct.)	Yes	114.2	40.7	1.16	63.0	4.35	87.2
Spring (April)	No	112.6	40.6	1.11	59.3	4.45	85.0
Split[1]	No	116.7	39.4	1.23	68.1	4.30	93.7
Additional trts							
Check	--	57.5	43.8	1.03	28.1	2.44	39.7
Spring (April)	Yes	124.0	41.8	1.24	72.4	4.83	102.8
Split[1/]	Yes	114.8	42.1	1.20	65.0	4.28	91.0
Latin square (Primary trts)		Statistical Analysis					
Significance Level (%):		90	85	98	94	88	98
BLSD (.05)	:	11.6	1.8	0.07	9.5	0.36	9.7
CV (%)	:	5.5	2.3	3.3	8.4	4.5	6.4
Completely randomized (7 trts)							
Significance Level (%):		99	99	99	99	99	99
BLSD (.05)	:	9.2	1.6	0.07	7.0	0.30	9.7
CV (%)	:	6.5	2.6	4.3	8.9	5.5	8.8

[1/] 40% preplant + 60% sidedress.

Table 3. Significance levels for differences among the four primary treatments as determined by contrast statistics.

Parameter	Contrast: Fall w/o N-Serve vs Fall w/N-Serve	Contrast: Fall vs Spring	Contrast: Spring preplant vs Split
	Significance Level (%)		
Stover N Concentration	91	98	94
Grain N Concentration	82	82	99
Grain Moisture	41	90	89
Grain Yield	94	88	62
Stover Yield	47	23	95
Silage Yield	92	87	67
Final Population	10	14	47
Grain N Removal	92	88	95
Silage N Uptake	98	97	94

Water

Weather conditions during the 1993 growing season were colder than normal and were 12.0" wetter than normal. This resulted in tile flow from March 31 through September 27. Tile drainage volumes shown in Table 4 indicate highest flows in Appril, May, and June. Drainage from the 16 corn plots averaged 11.76" with a 1.59" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 10.55" from the 16 plots and a range of 4.63" among the four time/methods. Ideally, drainage should be uniform among the time/method treatments; however, normal soil and drainage variability exists in these plots and results in these unfortunate differences.

Monthly flow-weighted NO_3-N concentrations in the corn plots showed greater temporal variation than in previous years. Very low NO_3-N concentrations were found in the very first samples collected (March) (Table 5). In April, NO_3-N concentrations were 2X to 3X higher than in March with the highest concentration found in the fall treatment without N-Serve. In May the flow-weighted NO_3-N concentratijons were 2.6, 1.6, and 0.9 mg/L higher than in April for the fall, fall + N-Serve, and spring treatments, respectively, while the split treatment showed no change in concentration. High flow rates in June apparently were responsible for the high NO_3-N concentrations being leached to the drainage water. Flow-weighted NO_3-N concentrations in June were 7.3, 5.4, 3.9, and 2.8 mg/L higher than in May for the fall, fall + N-Serve, spring, and split applications, respectively. In July, highest concentrations continued with the fall treatment; however, NO_3-N concentrations escalated more quickly (3.0, 4.9, and 1.6 mg/L) with the fall + N-Serve, spring, and split applicatijons, respectively. Nitrate-N concentrations began to decline in August with all N treatments. In September, highest NO_3-N concentrations were found with the fall + N-Serve and spring treatments. Flow-weighted NO_3-N concentrations for the year were highest for the fall treatment, intermediate for the fall + N-Serve and spring treatments, and lowest for the split treatment. These concentrations were lower than in previous years, probably due to the high rainfall over the last 3 years. These data clearly show the susceptibility of fall-applied N without N-Serve to loss of NO_3 in tile drainage water when spring rainfall is excessive.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1993.

N application		Month							Year
Time	N-Serve	March	April	May	June	July	August	Sept.	Total
		acre -inches							
		CORN							
Fall (Oct.)	No	0.00	3.10	2.59	3.58	0.46	1.26	0.07	11.06
Fall (Oct.)	Yes	0.00	3.24	2.76	3.87	0.67	1.29	0.08	11.90
Spr. (April)	No	0.12	2.76	2.37	3.93	0.67	1.40	0.12	11.36
Split	No	0.28	3.32	2.69	3.94	0.78	1.59	0.05	12.65
		SOYBEANS							
Fall (Oct.)[1/]	No	0.04	3.06	2.10	3.33	0.73	1.22	0.04	10.52
Fall (Oct.)[1/]	Yes	0.23	3.59	2.89	4.00	0.78	1.24	0.01	12.74
Spr. (April)[1/]	No	0.00	3.16	2.32	3.41	0.83	1.09	0.03	10.84
Split[1/]	No	0.00	2.16	1.33	3.42	0.27	0.92	0.01	8.11
		FALLOW							
NONE		0.00	2.35	1.16	2.87	0.62	1.10	0.17	8.28

[1/] N applied for the 1992 corn crop.

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1993.

N application		Month							Year
Time	N-Serve	March	April	May	June	July	August	Sept.	Total
		mg NO_3-N/L							
		CORN							
Fall (Oct.)	No	—	8.6	11.2	18.5	18.9	12.7	9.1	12.5
Fall (Oct.)	Yes	—	6.9	8.5	13.9	16.9	13.0	13.0	10.5
Spr. (April)	No	2.0	6.4	7.3	11.2	16.1	9.7	16.9	9.9
Split	No	3.7	6.6	6.4	9.2	10.8	8.8	8.1	7.6
		SOYBEANS							
Fall (Oct.)[1/]	No	—	10.8	10.2	8.7	9.2	8.7	—	8.3
Fall (Oct.)[1/]	Yes	2.2	6.6	6.2	6.2	6.4	6.2	5.5	5.9
Spr. (April)[1/]	No	—	10.7	10.1	8.5	7.8	6.9	—	9.1
Split[1/]	No	—	11.4	10.5	10.1	9.0	8.7	—	11.0
		FALLOW							
NONE		—	27.0	28.6	24.6	23.4	22.4	15.6	22.7

[1/] N applied for the 1992 corn crop.

Table 6. Nitrate-N loss for each month from the corn, soybean, and fallow plots in 1993.

N application		Month							Year
Time	N-Serve	March	April	May	June	July	August	Sept.	Total
		lb NO_3-N/A							
		CORN							
Fall (Oct.)	No	0.00	5.61	6.07	14.30	1.94	3.15	0.14	31.21
Fall (Oct.)	Yes	0.00	4.74	5.13	11.98	2.66	3.53	0.23	28.27
Spr. (April)	No	0.05	4.59	4.62	10.23	2.43	3.22	0.45	25.59
Split	No	0.23	4.72	3.94	7.91	1.90	2.94	0.10	21.74
		SOYBEANS							
Fall (Oct.)[1/]	No	0.05	6.54	4.04	5.83	1.19	2.14	0.04	19.83
Fall (Oct.)[1/]	Yes	0.12	5.10	3.70	5.41	1.03	1.68	0.01	17.05
Spr. (April)[1/]	No	0.00	7.57	5.22	6.46	1.48	1.68	0.03	22.44
Split[1/]	No	0.00	6.39	3.59	7.68	0.61	1.89	0.01	20.17
		FALLOW							
NONE		0.00	13.54	6.50	13.84	3.00	5.00	0.60	42.49

[1/] N applied for the 1992 corn crop.

In the soybean plots, where N had been applied either in the fall of 1991 or spring of 1992, NO_3-N concentrations were consistently lower throughout the season and seldom averaged greater than 10 mg/L (Table 5). Highest flow-weighted NO_3-N concentrations were found with the split treatment, especially early in the season. Lowest annual flow-weighted concentration occurred with the fall + N-Serve treatment. Nitrate-N concentrations under a 7-year continuous fallow system (no fertilizer N applied) were approximately 2 to 3X higher than from the fertilized corn and soybean plots. Again, the monthly flow-weighted NO_3-N concentrations appeared to decline over the season; probably a reflection of the high amounts of rainfall which flushed mineralized NO_3 from the soil profile.

Nitrate-N losses in the drainage water were slightly higher for corn than for soybeans (Table 6). Under corn greatest loss of NO_3 occurred with the fall applications, especially when N-Serve was not applied. Losses were least with the split application of N. This would be expected because most of the percolation occurred in May and June prior to application of 60% of the N in this treatment. Nitrate-N losses under soybean were highest for the spring treatment, intermediate for the split and fall treatments, and lowest for the fall + N-Serve treatment. Nitrate-N losses in the fallow system, where mineralization of the soil organic matter was the NO_3 source, was 30 to 150% higher than from the fertilized corn-soybean rotation. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

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 for corn were highest for the fall w/o N-Serve, intermediate for fall + N-Serve and spring, and lowest for the split treatment. In the year following corn and its associated treatments, normalized losses ranked in the order split > spring preplant > fall w/o N-Serve > fall w/N-Serve. Apparently, sufficient N was not utilized by the corn and remained in the soil profile following the split and spring applications; thus, higher NO_3 losses in the succeeding year. Normalized NO_3-N losses for the corn-soybean system were highest for the fall treatment, intermediate for the spring and split treatments, and lowest for the fall + N-Serve treatment. Additional years with adequate drainge 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 1993.

	Time/Method of N Application			
Crop System[1/]	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	2.82	2.38	2.25	1.72
Soybean	1.88	1.34	2.07	2.49
Corn Soybean System	2.36	1.84	2.16	2.02

[1/] Continuous fallow (7 years without fertilizer N) = 5.13.

Soil

Nitrate-N remaining in the 0-8' soil profile in late-April was considerably lower for both crop systems compared to previous years (Table 8). This was especially true for the fallow system. Slightly more NO_3 accumulted below the tile depth in the fallow system compared to the soybeans. The above-normal rainfall conditions in 1990, 1991, and 1992 undoubtedly affected residual soil NO_3 levels at the start of this year. Because of this and the fact that record amounts of growing season rainfall were received in 1993, no soil samples were taken for residual NO_3 after harvest.

Table 8. Nitrate-N in the soil profile in April, 1993 as influenced by previous crop in 1992.

	1992 Crop	
Profile depth	Fallow	Soybean
feet	lb/A	
0 - 1	9.4	19.2
1 - 2	.5	8.8
2 - 3	10.1	6.1
3 - 4	10.8	3.3
4 - 5	9.3	3.7
5 - 6	9.2	4.4
6 - 7	11.6	4.2
7 - 8	12.8	5.0
Total in		
0 - 5' profile	47.1	41.1
0 - 8' profile	80.7	54.7

CONCLUSIONS

The cold and wet conditions resulted in fair corn production and plentiful tile drainage. Corn production was greatly improved by the various N treatments over the control. Corn grain and silage production was influenced by time of application with fall application generally resulting in lowest yields and N use efficiency. Corn production and N uptake were quite similar for the fall N + N-Serve, spring, and split treatments; however, split-appiked N did result in lower stover yields and higher grain N concentrations. Tile flow data indicated only small differences among the four N treatments with respect to amount of drainage but did show elevated NO_3-N concentrations and losses with the fall application of N w/o N-Serve. Flow-weighted, monthly average NO_3-N concentrations closely reflected the time of N application. Nitrate-N concentrations from the fall treatment w/o N-Serve began to excalate in May and quickly rose in June to 18.5 mg/L. Adding N-Serve to the fall-applied N delayed the escalation of NO_3 in the drainage with the peak reaching 16.9 mg/L in July. Spring and split applications delayed NO_3 escalation until June with peak concentrations of 16.1 and 10.8 mg/L, respectively, occurring in July. Nitrate-N concentrations and losses in the drainage water in the "residual" year with soybeans were much lower but were highest with the previous spring and split application treatments. Residual soil NO_3 at the beaginning of the season was very low due to the wet conditions of the past three years.

NITROGEN FERTILIZATION OF ESTABLISHED REED CANARYGRASS

Waseca, 1993

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

ABSTRACT: Recently developed low-alkaloid varieties of reed canarygrass are being considered as an alternative forage for dairy enterprises. The objectives of this study were to determine the effect of single early-season and split applications of fertilizer N on the yield and quality of reed canarygrass. Forage yields were optimized at the 300 lb N/A rate. Total N uptake and N concentration increased with increasing N rate (both April and June) except the second harvest where they were maximized at 150-lb N rate applied in June. Single early-season applications of N were as effective as split applications for yield and forage quality. Residual soil NO_3-N in the 0-3' profile after the third cutting significantly increased when N applications exceeded 400 lb N/A. Continued research will be needed to accurately determine the environmental effects of high N rates applied to reed canarygrass.

Research conducted in Iowa in the early 70's indicated that reed canarygrass contained high concentrations of N and utilized fertilizer N very efficiently when fertilized with ample N. The objectives of this study were to determine the effect of single early-season and split applications of fertilizer N on the yield and quality of reed canarygrass.

EXPERIMENTAL PROCEDURES

Twenty plots, each measuring 20' x 40', were laid out on established reed canarygrass (var. Palaton) in April 1993 on a Webster clay loam soil. Plots were fertilized with varying rates of N as ammonium nitrate on April 23. After the first cutting the main plots were split into subplots and again were fertilized with varying rates of N as ammonium nitrate on June 14 (Table 1). A randomized complete block design with four replicates was used in the analysis of the first harvest (June 3). An unbalanced split-plot design was used for the second (July 15) and third (Sept. 1) harvests. Yields were taken by harvesting a 3' x 40' swath (first cut) and a 3' x 20' swath (second and third cuts) from each plot. Forage subsamples were taken for moisture and total Kjeldahl N analyses. The analyses were conducted by the Research Analytical Laboratory in St. Paul. Soil samples, three cores per plot to a depth of 3 feet in 1 foot increments, were taken from selected treatments on November 23. All soil samples were immediately forced-air dried at 125° F, ground, and analyzed for NO_3-N by the Research Analytical Laboratory.

RESULTS AND DISCUSSION

Yield

First harvest dry matter yields were increased significantly over the control by the early (April 23) application of N fertilizer. Yields were not increased further at rates greater than 150 lb N/A (Table 1). Second harvest yields were increased significantly over the control by both the April and June applications. A significant April x June interaction was found for the second harvest. This interaction is explained by the 1.29 TDM/A yield increase with the 150 lb N/A rate applied in June when no N was applied in April, compared to a 0.44 T/A yield increase with the same June rate applied to plots receiving 150 lb N/A in April. Moreover, the highest second cut yield (1.51 TDM/A) occurred with the 0 + 150 lb N/A (April + June) application rates, compared to 1.34 TDM/A when 150 lb N/A was applied in both April and June. Third cut yields responded significantly up to 300 lb N/A for early application and 200 lb N/A for the late application. The April x June interaction was not significant. The 200 lb (April) + 200 lb (June) treatment produced the highest yield.

Total dry matter yield was optimized at a combined total of 300 lb N/A. An April application of 300 lb N/A produced yields equal to the split application of 150 + 150 lb N/A. The significant April x June interaction for total dry matter yield is shown by the 2.10 TDM/A yield increase when 150 lb N/A was applied in June to plots that received no N in April, compared to only a 0.98 TDM/A increase when the same June rate was applied to plots receiving 150 lb N/A in April. In addition, no yield increase was found when 300 lb N/A was added in June to plots receiving 300 lb N/A in April. More N (300 compared to 250 lb N/A) was required to obtain optimum yield of reed canarygrass in 1993 as compared to 1992. Higher rainfall in 1993 could explain the differences in N required between the two years.

N Concentration

Total N concentration in the forage increased significantly with N application for all three harvests (Table 2). However, N concentration in the second harvest did not increase with June N rates above 150 lb N/A. Nitrogen concentration was very high for the 0 (April) + 150 lb N/A (June) application indicating rapid uptake of N in the 30-day period between application and harvest. Generally, June N affected N concentration more than April N for the second harvest. The treatment effects on N concentration are consistent with the observed significant yield interaction between April and June applications. No N concentration interaction was found for the third harvest; thus N concentration increased with increasing N rate for both April and June application.

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Table 1. Dry matter yield of Reed Canarygrass as influenced by N fertilization at Waseca in 1993.

Rate/Time of N Applc'n		Cutting Number & Date			
April 23	June 14	1st 6/3	2nd 7/15	3rd 9/1	Total
------------- lb N/A -------------		------------------- TDM/A -------------------			
0	0	1.26	0.22	0.39	1.87
0	50		1.05	0.59	2.90
0	100		1.45	0.76	3.47
0	150		1.51	1.19	3.97
50	0	1.88	0.38	0.45	2.70
50	50		1.02	0.57	3.47
50	100		1.31	0.81	4.00
50	150		1.43	1.23	4.53
100	0	2.21	0.70	0.57	3.49
100	50		1.12	0.78	4.11
100	100		1.37	0.95	4.52
100	150		1.39	1.27	4.87
150	0	2.49	0.90	0.74	4.12
150	50		1.26	0.95	4.70
150	100		1.26	1.14	4.89
150	150		1.34	1.28	5.10
200	0	2.37	1.20	0.96	4.53
200	200		1.38	1.41	5.16
300	0	2.53	1.34	1.29	5.16
300	300		1.32	1.35	5.20
Individual Factors					
April N Rate					
0		1.26	1.06	0.73	3.05
50		1.88	1.03	0.76	3.67
100		2.21	1.14	0.89	4.25
150		2.49	1.19	1.03	4.70
200		2.37	1.29	1.18	4.85
300		2.53	1.33	1.32	5.18
Signif. Level (%):		99	99	99	99
BLSD (.05):		0.28	0.10	0.13	0.36
June N Rate					
0			0.79	0.73	3.65
50			1.11	0.72	3.96
100			1.35	0.91	4.38
150			1.42	1.24	4.78
200			1.38	1.41	4.92
300			1.32	1.35	4.79
Signif. Level (%):			99	99	99
BLSD (.05):			0.10	0.14	0.21
Interaction April x June Application					
Signif. Level (%):			99	34	99
CV (%):		9.5	9.7	9.8	5.7

N Uptake

Total N uptake for the first harvest was significantly increased above the control by each April N rate (Table 2). Highest uptake values with the early application were obtained at 300 lb N/A for all harvests. A significant interaction between April and June application was observed for the second harvest. The highest uptake values for the second harvest were obtained with the late 150 lb N/A rate following zero early N. No significant interaction occurred in the third harvest as uptake rates increased at each rate for both application times. Total N uptake, sum of all three harvests, increased with increasing N supply (Table 3). Apparent N recovery was high (80% or more) for all application rates except 400 and 600 lb N/A. Highest percent recovery was generally obtained with a single April application of $\geq$100 lb N/A, unlike 1992, where split applications were better.

Table 2. Nitrogen concentration in and N uptake by Reed Canarygrass as influenced by N fertilization in 1993.

Rate/time of N application		N Concentration			N Uptake		
April 23	June 14	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
---------- lb N/A ----------		-------------- % --------------			------------ lb N/A ------------		
0	0	2.35	2.68	2.45	59.6	11.7	19.4
0	50		2.86	2.51		59.8	30.0
0	100		2.62	2.47		105.0	37.3
0	150		4.25	2.66		128.7	63.4
50	0	2.26	2.70	2.33	84.7	20.7	20.8
50	50		3.12	2.31		63.2	26.4
50	100		3.84	2.31		100.7	37.0
50	150		3.98	2.53		113.5	62.2
100	0	3.04	2.86	2.42	134.8	40.6	27.6
100	50		3.00	2.34		67.4	36.6
100	100		3.97	2.34		108.6	44.2
100	150		4.28	2.85		118.6	72.3
150	0	3.48	3.35	2.32	173.7	61.2	34.6
150	50		3.69	2.56		93.3	49.4
150	100		3.26	2.66		81.7	60.9
150	150		4.35	3.08		116.6	79.0
200	0	3.45	3.67	3.02	163.2	90.1	63.8
200	200		4.14	3.14		114.5	89.2
300	0	3.99	4.10	3.20	200.6	109.6	83.4
300	300		4.47	4.25		118.1	114.0
Individual Factors							
April N Rate							
0		2.35	3.35	2.52	59.6	76.3	37.5
50		2.26	3.41	2.37	84.7	74.5	36.6
100		3.04	3.53	2.49	134.8	83.8	45.2
150		3.48	3.66	2.65	163.2	88.2	56.0
200		3.45	3.90	3.08	173.7	102.3	76.5
300		3.99	4.28	3.72	200.6	113.9	98.7
Signif. Level (%):		99	99	93	99	99	99
BLSD (.05):		0.35	0.34	0.53	21.6	13.4	17.9
June N Rate							
0			3.22	2.62		55.6	41.6
50			3.17	2.43		70.9	35.6
100			3.67	2.44		99.0	44.9
150			4.21	2.78		119.4	69.2
200			4.14	3.14		114.8	89.2
300			4.47	4.25		118.1	113.9
Signif. Level (%)			99	99		99	99
BLSD (.05):			0.45	0.31		13.3	12.1
Interaction April x June Application							
Signif. Level (%):			99	20		99	1
CV (%):		8.0	13.7	12.1	11.4	17.3	25.5

Root N uptake

Immobilization of N in the roots of reed canarygrass was measured by sampling the root mass in late fall. Three inch diameter cores, 4 inches deep, were taken from selected treatments. Roots were separated from soil, dried, and analyzed for total N at the Research Analytical Laboratory in St. Paul. Because of high variability among the root mass weights, they were averaged and a mean of 5.5 TDM/A-4 inch was obtained. Total N concentration ranged from 0.77% with the 50 lb N/A rate to 0.96% with the 300 lb N/A rate. Total N uptake ranged from 85 lb N/A-4 inch with the 50 lb N/A rate to 106 lb N/A-4 inch with the 300 lb N/A rate. These data suggest that reed canarygrass has a great potential for immobilizing large amounts of N in its root system.

Table 3. Total N uptake and nitrogen use efficiency of Reed canarygrass as affected by N treatments in 1993.

Rate/Time of N Application		Total N	Apparent N[1]
April 23	June 14	Uptake	Recovery
--------- lb N/A ----------		lb N/A	%
0	0	90.7	—
0	50	149.5	118
0	100	202.0	111
0	150	251.7	107
50	0	126.2	71
50	50	174.4	84
50	100	222.5	88
50	150	260.5	85
100	0	203.0	112
100	50	238.9	99
100	100	287.6	98
100	150	325.8	94
150	0	269.4	119
150	50	316.4	113
150	100	316.3	90
150	150	369.3	93
200	0	317.1	113
200	200	366.9	69
300	0	393.7	101
300	300	432.6	57

[1] (Total N uptake - N uptake from control) ÷ Total N applied.

Soil Residual Nitrate-N

Soil samples taken in late-November showed a significant increase in soil NO_3-N remaining in the 0-3' profile when N rates for reed canarygrass exceeded 400 lb N/A (Table 4). At application rates of 300 and 400 lb N/A slightly higher soil NO_3-N levels existed at the 1-2' and 2-3' depths compared to the 250 lb N/A rate. Nitrate-N accumulation in the 0-5' profile was minimal with N rates of 0, 150, and 400 lb N/A, but high levels of residual NO_3 remained when 600 lb N/A was applied. Fertilizing reed canarygrass at N rates greater than 400 lb N/A could result in considerable build up of soil NO_3-N, which could later be lost to ground or surface waters.

Table 4. Nitrate-N remaining in the 0-3' soil profile on Nov. 23 as influenced by N rates applied to Reed canarygrass.

N rate applied on:		Soil Profile Depth						
April 23	June 14	0 - 1'	1 - 2'	2 - 3'	3 - 4'	4 - 5'	0 - 3'	0 - 5'
------- lb N/A -------		lb NO_3-N/A						
0	0	6.0	3.3	2.4	3.8	3.5	11.7	19.0
50	50	4.9	2.5	2.7			10.1	
100	100	6.8	2.3	2.4			11.5	
100	150	5.8	1.9	2.2			9.9	
150	0	8.5	3.5	2.9	2.6	4.3	14.9	21.8
200	0	7.4	2.6	2.6			12.6	
200	200	9.1	14.3	11.4	8.3	5.7	34.8	48.8
300	0	13.6	8.6	12.3			34.5	
300	300	31.2	53.3	65.9	46.0	17.6	150.4	214.0

IMPACT OF ADDING WHEAT TO A TRADITIONAL CORN-SOYBEAN STRIP SYSTEM ON CROP YIELDS, EROSION CONTROL, AND PEST INFESTATION[1/]

T. K. Iragavarapu, G. W. Randall, and W. C. Stienstra[2/]

ABSTRACT: Four single crop production components (ridge tillage; 3-crop wheat-corn-soybean rotation; narrow, alternate strips (15' wide); and legume interseeding) were integrated into a complete cropping system. Studies were started in 1991 at two locations in southern Minnesota on Webster clay loam soil. The rotations compared were: a) continuous corn; b) corn-soybean; c)corn-soybean-wheat with and without interseeded legumes (Nitro alfalfa and hairy vetch). Each corn strip following wheat and soybeans was fertilized at four N rates (0, 40, 80, and 120 lb N/A) to determine N contribution of legumes. Results from the last 3 years suggest that the narrow-alternate strips of corn, soybean, and wheat in a ridge-till system provide excellent surface residue coverage and satisfy erosion control goals. While corn yields were enhanced (3 and 12% in E-W and N-S row orientation, respectively) and soybean yields decreased slightly (5 and 3% in E-W and N-S row orientation, respectively), wheat yields were unaffected in the narrow strips compared to conventional systems. Wheat introduced into the traditional corn-soybean strip system not only reduced border effects on soybeans but also reduced soybean cyst nematode (SCN) egg populations.

Narrow, alternate strip cropping systems have been receiving much attention in the farm press the last few years. These aesthetically pleasing cropping systems are touted as sustainable systems that reduce chemical inputs and pest activity while improving net profit and erosion control.

Studies show that in traditional corn-soybean strip crop systems improved corn yields in the border rows are offset by reduced soybean yields. Adding wheat to this 2-crop strip system should reduce border effects on soybeans without sacrificing wheat yields. Wheat planted north of corn and south of soybeans on east-west rows will allow adequate sunlight for soybeans. Wheat, a cool-season crop, will not be shaded as it heads out before corn gets tall enough to shade it. Addition of wheat to the corn-soybean system will not only facilitate interseeding of legumes that provide nitrogen to the following corn, but also will break corn root worm diapause and reduce soybean cyst nematode infestation.

The objective of this study was to evaluate the potential of a 3-crop (wheat-corn-soybean) system on crop yields, erosion control, and pest infestation.

PROCEDURE

Studies were started in 1991 at the Southern Experiment Station with east-west rows and on the Lynn Sorenson farm in Freeborn Co. with north-south rows. All crops were planted in 15' wide by 120' long strips on ridges. Corn (Pioneer 3751) was planted in 30" rows at a rate of 30,200 plants/A in rows 2-5 and 36,000 ppA in the outside rows (1&6). Nitrogen as ammonium nitrate was broadcast-applied by hand at rates of 0, 40, 80, and 120 lb N/A to plots measuring 6 rows wide x 30' long in each strip. Weeds were controlled with a 15" band-application of Lasso (3 lb ai/A) and Bladex (2.5 lb ai/A) and ridge till cultivation. Hand-harvest grain yields were obtained from a 25-foot section within each row of each plot.

Soybean (Sturdy) was planted at a rate of 9 to 10 beans/foot of row in 30" rows. Weeds were controlled with a preemergence, 15" band-application of Lasso (3 lb ai/A), and postemergence, 15" band-application of Pursuit (4 oz ai/A), and by ridge cultivation. Each individual row was harvested with a plot combine.

Spring wheat (Grandin) was planted at a rate of 94 lb/A with a minimum-till drill in 8" rows. Broadleaf weeds, when present, were controlled with a broadcast-application of Bromoxynil.

RESULTS

The yield advantage of the narrow strips for corn in the 3-crop (wheat-corn-soybean) rotation was 4.6 bu/A in the E-W system and 16.9 bu/A in the N-S row orientation compared to the whole-field averages (Table 1). In the E-W rows, row 1 (next to wheat) and row 6 (next to soybeans) yielded 6 and 19% higher, respectively, compared to the average of the center two rows, which were assumed to represent the whole field situation. When the rows were oriented N-S, the yield advantage was 32 and 34% for rows 1 and 6, respectively, compared to the center two rows.

[1/] Funding provided by USDA-LISA and Minnesota Department of Agriculture.
[2/] Post-doctoral Research Associate, Professor, and Professor, respectively, Univ. of Minnesota.

Soybean yields were depressed 6.1 bu/A (16%) for row 1 (next to corn) and 2.1 bu/A (6%) for row 6 (next to wheat) compared to the center two rows in the E-W row orientation (Table 2). In N-S rows, row 6 (next to wheat) yielded only 0.2 bu/A less compared to the center two rows while the row bordering corn (row 1) suffered 6.1 bu/A (19%) yield loss compared to the center two rows. The strip yields were 1.9 and 1.0 bu/A less for the E-W and N-S systems, respectively, compared to the whole-field averages.

Soybean yields were decreased much more severely in narrow strips alternated with corn (Table 3). Outside rows (rows 1 & 6) bordering corn yielded 23% less (8.4 bu/A) than the center two rows in the E-W system and 18% less (5.8 bu/A) in the N-S system. The soybean row on the N side of corn (E-W system) and E side of corn (N-S system) yielded 33 and 26% less, respectively, than the center two rows. Seed yields for the 6-row alternate strips were decreased by 3.6 bu/A in the E-W system and 2.3 bu/A in the N-S system compared to the whole-field averages. Averaged over the three years, wheat yields were not affected greatly either by the corn or soybean borders (Table 4).

Surface residue coverage prior to planting was ideal for all crops (Table 5). After planting, residue coverage was still > 30% following corn and wheat. Residue coverage after soybean was only 24%, but this was offset by mid-May with a well-established stand of wheat capable of providing erosion control in this 3-crop system.

Nitro alfalfa and hairy vetch interseeded into wheat in 1991 reduced corn yields the following year. Neither the alfalfa nor the vetch winter-killed; thus, spring regrowth was abundant in 1992. Scalping the ridges about 1/2" before planting corn was not sufficient to kill either the alfalfa or vetch. As a result, soil water in the seed zone was lower, seed germination and emergence were somewhat slower, and the regrowth provided too much competition for the small corn. In 1993, the ridges were scalped more deeply (2-3") followed by treating the spring regrowth with a herbicide. This suppressed the spring regrowth of alfalfa and hairy vetch and provided a more favorable early plant growth environment in 1993. Therefore, the N contribution from the legumes (approximately 40 lb N/A) was seen only in 1993 (Table 6).

Soybean cyst nematode egg counts were taken in November, 1992. Considerably lower SCN population was recorded in all the cropping systems where either wheat or corn were grown in the last two years compared to those systems that included soybean in either 1991 or 1992 (Table 7).

Table 1. Corn grain yield in a C-Sb-W rotation as influenced by row position and direction†.

Row	Row/Position					Yield Adv.of
Direction	1	2	3&4	5	6	6-row strip‡
			bu/A			
E-W Rows	158.7	141.9	149.1	146.1	177.4	4.6
N-S Rows	178.9	143.6	135.7	139.5	182.3	16.9

† 3-yr (1991-1993) averages at the 120-lb N/A rate.
‡ Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent the whole-field situation.

Table 2. Soybean seed yield in a C-Sb-W rotation as influenced by row position and direction†.

Row	Row/Position					Yield Adv.of
Direction	1	2	3&4	5	6	6-row strip‡
			bu/A			
E-W Rows	31.2	33.8	37.3	37.6	35.2	-1.9
N-S Rows	25.8	31.0	31.9	33.1	31.7	-1.0

† 3-yr (1991-1993) averages
‡ Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent the whole-field situation.

Table 3. Soybean seed yield in a C-Sb rotation as influenced by row position and direction†.

Row Direction	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip‡
	bu/A					
E-W Rows	31.1	33.3	36.0	33.7	24.1	-3.6
N-S Rows	24.2	30.9	32.8	32.3	29.8	-2.3

† 3-yr (1991-1993) averages
‡ Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent the whole-field situation.

Table 4. Border effects on wheat yields as influenced by row direction†.

Row Direction	N⅓ or E⅓	Center⅓	S⅓ or W⅓	Yield Adv. of 15' strip‡
	bu/A			
East-West	42.9	42.3	40.9	-0.3
North-South	42.6	42.1	37.9	-1.2

† 3-yr (1991-1993) averages
‡ Relative yield advantage of the 15'strip compared to the center 5', which is assumed to represent the whole-field situation.

Table 5. Surface residue coverage (2-year average)† as influenced by previous crop at Freeborn Co.

Previous crop	Before planting	After planting
	%	
Corn	72	41
Soybean	59	24
Wheat	82	35
Wheat + Alf.	87	54
Wheat + Vetch	90	49

† 1992-1993 averages

Table 6. Nitrogen fertilizer response of corn following wheat in a C-Sb-W rotation at Freeborn Co. in 1993.

N rate	Previous crop: Wheat	Wheat + Alf.	Wheat + Vetch
lb/A	bu/A		
0	47	73	65
40	73	86	76
80	78	92	100
120	101	101	106

Table 7. SCN population as influenced by cropping system at Freeborn Co.

Previous crop 1991	Previous crop 1992	Eggs/100 cc of soil
Soybean	Corn	5120
Soybean	Wheat	7366
Soybean	Wheat + Alf.	3419
Corn	Soybean	6376
Corn	Corn	2317
Wheat	Corn	2117
Wheat + Alf.	Corn	1190

Soybean was the crop in 1990 in all the plots

CONCLUSIONS

1. Narrow alternate strips of corn, soybean, and wheat satisfy erosion control goals.
2. Corn yields are enhanced in both the 2- and 3-crop systems, but soybean yields are decreased significantly, especially in the 2-crop system.
3. Wheat yields were not affected either by corn or soybean borders.
4. Introducing wheat into the 2-crop system reduced border effects on soybeans and SCN egg populations.
5. Economic analyses of all inputs and outputs from these cropping systems is needed before we can compare the profitability of these narrow strip systems to conventional systems.

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

1993

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 20% at both Waseca and Morris in 1993. Soil test K decreased by 10% at Waseca and increased by about 20% at Morris. Corn yields at Waseca were increased by 36 to 50 bu/A at soil P tests from 16 to 90 lb Bray P_1/A compared to yields when the test was 7 lb/A. At Morris, corn yields were increased 13 to 14 bu/A when Bray P_1 tested >29 lb/A compared to yields from plots that tested 16 lb Bray P_1/A. Although soil test K ranged from 200 to 320 lb K/A at Waseca, corn yields were not affected by soil test K. Over the 7-yr period (1986 - 1993) soil test P declined by 1.3, 4.4 and 6.1 lb/A/yr when no fertilizer was added to soils initially testing 16, 49 and 90 lb Bray P_1/A, respectively, at Waseca. Soil test K varied considerably from year to year and did not allow consistent decline rate calculations. At Morris, soil P declined by 2.6 and 5.1 lb/A/yr when no fertilizer was added to soils initially testing 37 and 67 lb Bray P_1/A.

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

EXPERIMENTAL PROCEDURES

High rates of P and K were applied over a 12-year period (1973-84) in studies at the Southern Experiment Station at Waseca (Table 2) and the West Central Experiment Station at Morris (Table 3). These rates created a wide range of soil test values upon which we can evaluate the decline rates of soil test P and K when no additional fertilizer is added. Treatments 2, 3, and 4 have not received additional P since 1984 while treatments 6 and 7 at Waseca have not received K. The K treatments were not included at Morris because of very high native soil test K levels. Treatment 5, which had a moderately high level of fertilization prior to 1985, continues to receive P and K, and thus, serves as the high fertility control. The P and K materials (0-46-0 and 0-0-60) were broadcast on the soil surface and incorporated by chisel plowing the soybean residue in the fall of 1992. 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.

Table 1. Experimental procedures for corn on the high P and K rate study at the two branch stations in 1993.

Variable	Location: Morris	Location: Waseca
Planting date	4/26	5/6
Row spacing	30"	30"
Planting rate (plants/A)	29,600	32,000
Hybrid	Pioneer 3788	Pioneer 3578
Herbicide	3# Lasso + 2.2# Bladex (Bdct.)	3# Lasso + 3# Bladex (Bdct.)
Harvest date	10/11	11/10
Soil type	Aastad clay loam	Webster clay loam

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 1985-91 rates resulted in highly significant differences in soil test P at both locations and soil test K at Waseca. At Waseca soil test P ranged from 7 to 90 lb/A (Table 2). Soil test P declined about 20% in the fertilized plots compared to 1992, while soil test K decreased by 10%. Corn yields were increased significantly by P but plateaued at soil P levels higher than 16 lb/A. Corn yield was not influenced by soil test K in this wet and cool year, which limited yields.

[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 7 to 64 lb/A while Olsen's $NaHCO_3$ test ranged from 8 to 57 lb P/A (Table 3). Soil test P values declined about 20% at Morris, while soil K values increased about 20%. Corn yields at Bray P_1 levels of 7 and 16 lb/A were significantly lower than those from the plots testing 29 lb/A and above.

Table 2. Soil test values, seed moisture, and seed yield as influenced by 20 years' application of P and K at Waseca.

	P and K Treatments		Soil Test[2/]			Grain	
No.	Total 1973-84	1985-92[1/]	pH	P	K	Moisture	Yield
	----- lb P_2O_5 + K_2O/A ------			----- lb/A ----		%	bu/A
2	0 + 1200	0 + 100	6.5	7	320	26.9	79.3
3	600 + 1200	0 + 100	6.3	16	300	28.7	121.6
4	1200 + 1200	0 + 100	6.5	42	294	28.1	115.8
5	600 + 1200	100 + 100	6.5	90	272	29.0	129.2
6	1200 + 0	100 + 0	6.6	74	202	28.2	134.4
7	1200 + 600	100 + 0	6.5	68	200	27.4	130.7
	Signif. Level (%):		17	99	99	28	99
	BLSD (.05) :			13	51	-	18.0
	CV (%) :		4.5	15.	11.	8.3	8.6

1/ Treatments applied each fall. P was discontinued for treatments 6 & 7 in 1988.
2/ Samples were taken in October before 1993 treatments were applied.

Table 3. Soil test values, seed moisture, and seed yield as influenced by 20 years' application of P and K at Morris.

	P and K Treatments		Soil Test[2/]				Grain	
No.	Total 1973-84	1985-92[1/]	pH	P_1	P	K	Moisture	Yield
	------ lb P_2O_5 + K_2O/A -----			------- lb/A -------			%	bu/A
2	0 + 1200	0 + 100	8.0	7	8	606	30.0	74.8
3	600 + 1200	0 + 100	7.9	16	16	572	29.8	84.0
4	1200 + 1200	0 + 100	8.0	29	23	516	30.8	98.4
5	600 + 1200	100 + 100	7.9	64	57	543	31.5	96.8
	Signif. Level (%):		44	99	99	94	66	94
	BLSD (.05) :		-	18	16	-	-	-
	CV (%) :		1.0	39.	40.	7.3	5.0	13.6

1/ Treatments applied each fall.
2/ Samples were taken in October before 1993 treatments were applied.

SIX-YEAR SOIL TEST DECLINE RATES

Regression analysis was used to assess the average decline rates for Bray P_1 and exchangeable soil test K at Waseca and Bray P_1 at Morris. Soil test data from each of the plots in treatments 2, 3 and 4, which have not received fertilizer P since 1984, were included for the 7-year period (1986-1993) for both sites. Similarly, soil test data for each of the plots in treatments 6 and 7, which have not received fertilizer K since 1984, were included for the 7-year period at Waseca. Both soil test P and K were included from all plots in treatment 5, which received 100 lb P_2O_5/A + 100 lb K_2O/A annually.

Soil Bray P_1 change over the 7-year period at Waseca is shown by each of the lines in Fig.1. Average soil P test for each of the treatments in any particular year is shown by the appropriate symbol. Coefficients of determination (R^2) indicate highly significant relationships (99% level) for the treatments where fertilizer P was not applied and a significant (95% level) relationship where P was applied (Table 4). Soil test P was shown to decline by 1.3 lb/A/yr when the initial soil test was 16 lb/A. At initial soil test values of 49 and 90 lb/A, soil Bray P_1 declined by 4.4 and 6.1 lb/A/yr, respectively, in this corn-soybean rotation. Annual additions of 100 lb P_2O_5/A increased the soil test an average of 4.1 lb/A/yr when the initial test was 62 lb/A.

No relationship was found between the exchangeable soil K test and time (years after 1986) when 100 lb K_2O/A was applied annually (trt 5) or with treatments 6 and 7 (Fig. 2). Soil test K was extremely variable over this period as shown by the symbols in Fig. 2. Very high K levels were found in 1988, 1991 and 1992 while K tests were lower in 1987, 1990 and 1993.

At Morris, soil test P variability was high and decline rates could not be calculated from the regression equations which were not significant (treatment 2). However, soil P did decline by 2.6 and 5.1 lb/A/yr when P was not added to the plots that initially tested 37 and 67 lb P/A, respectively. This decline rate was slightly less than at Waseca where soil P test was also very high.

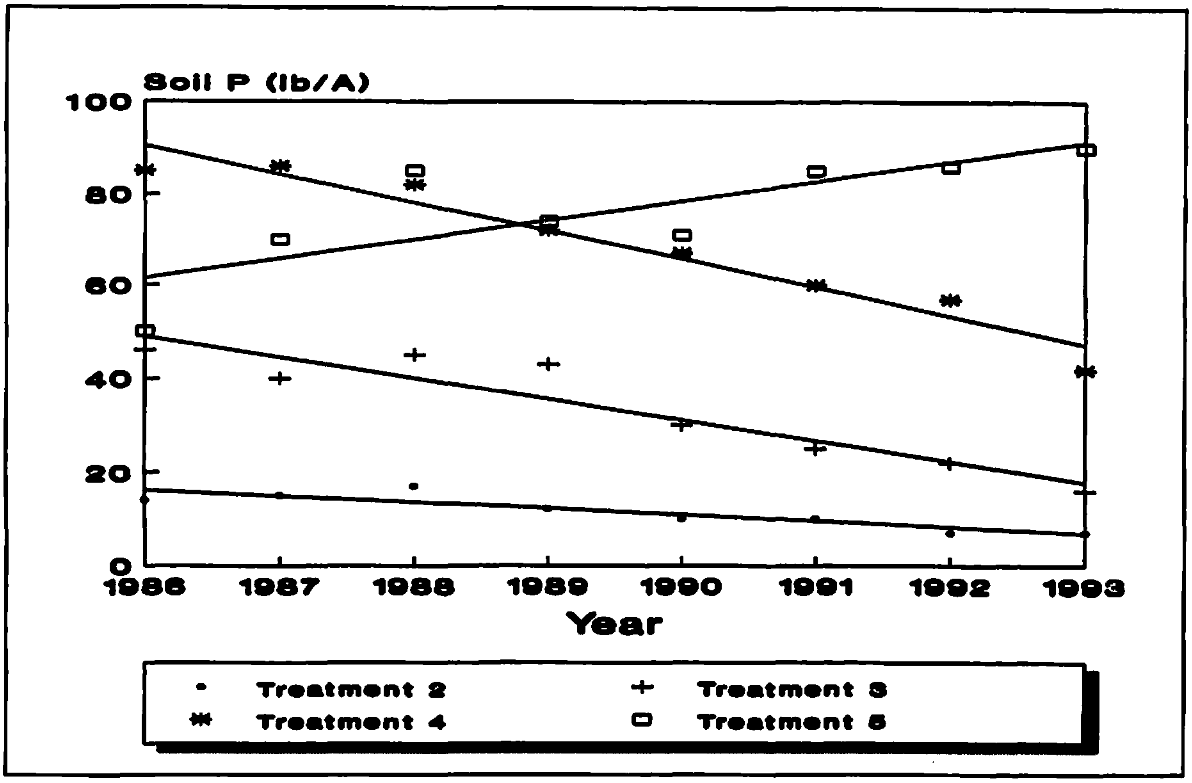

Figure 1 Decline rate of soil P over a 7-year period as influenced by P treatment at Waseca.

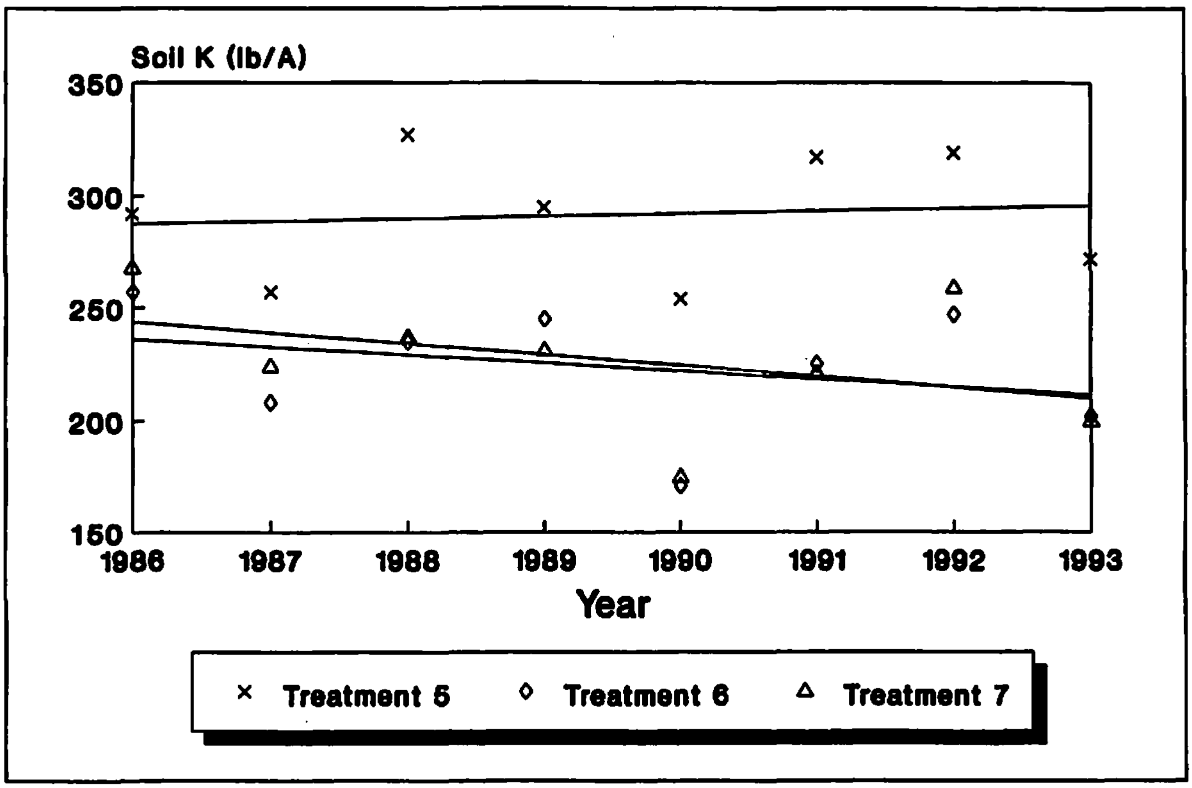

Figure 2 Decline rate of soil K over a 7-year period as influenced by K treatment at Waseca.

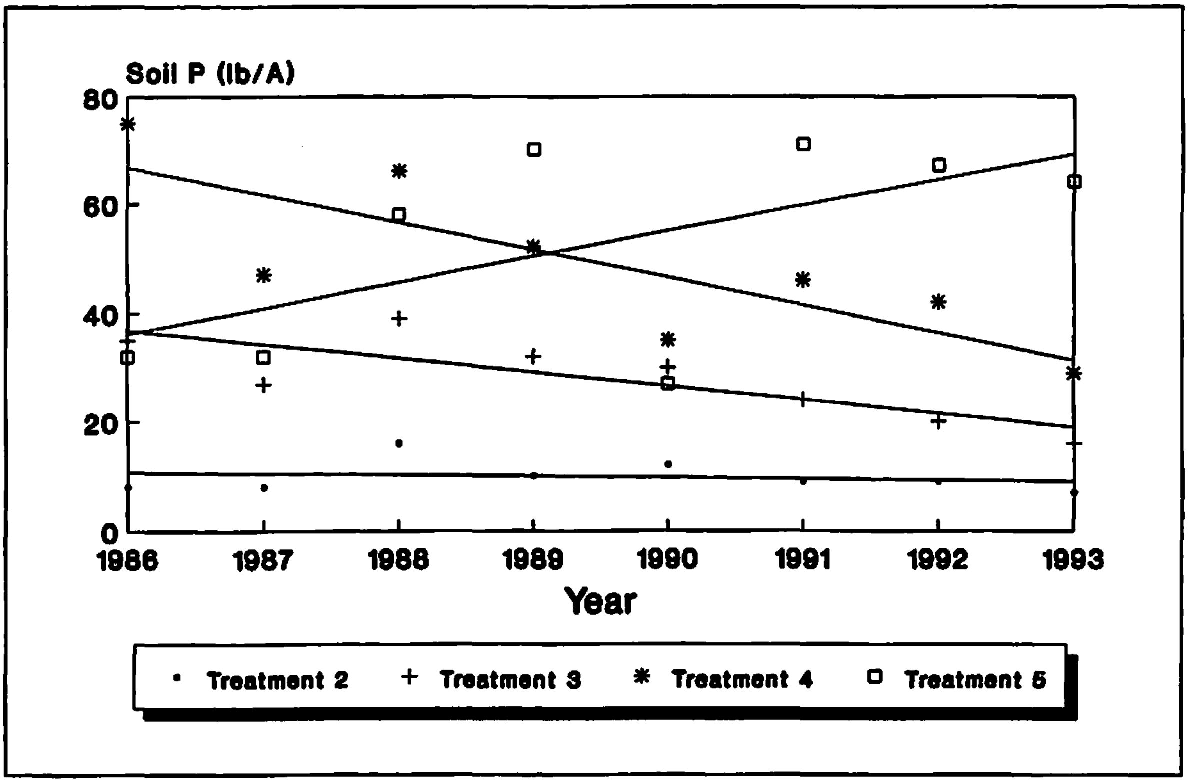

Figure 3 Decline rate of soil P over a 7-year period as influenced by P treatment at Morris.

Table 4. Linear regression equation and coefficient of determination (R^2) for the various P and K treatments at Waseca and Morris.

Location	Nutrient	Treatment	Regression Equation[1/]					R^2
Waseca	P	2	ST	+	16.1	-	1.33 X	66.3 **
"	P	3	ST	=	48.7	-	4.41 X	75.2 **
"	P	4	ST	=	90.2	-	6.13 X	88.2 **
"	P	5	ST	=	62.1	+	4.14 X	34.3 *
"	K	5	ST	=	287.1	+	1.26 X	5.0 NS
"	K	6	ST	=	235.7	-	3.40 X	5.7 NS
"	K	7	ST	=	243.8	-	4.88 X	8.9 NS
Morris	P	2	ST	=	10.3	-	0.23 X	3.1 NS
"	P	3	ST	=	36.7	-	2.59 X	14.4 *
"	P	4	ST	=	66.6	-	5.06 X	46.7 **
"	P	5	ST	=	35.9	+	4.73 X	20.9 **

[1/] ST = Soil Test (lb/A), X = Years

CONCLUSIONS

Long term (12-yr) additions to these two soils created a wide range in soil test P levels. Corn yields were optimized over the no P treatments at soil test P levels of 16 lb/A or higher at Waseca. Yields were not affected by the K soil tests. At Morris, corn yields were improved about 14 bu/A with soil test P levels of 29 lb P/A and higher. Soil test P declined by about 20% at both Waseca and Morris. Soil test K was decreased by about 10% at Waseca and increased by about 20% at Morris in 1993. Over the 7-year period (1986-93), soil Bray P_1 tests declined by 1.3, 4.4 and 6.1 lb/A/yr when no fertilizer P was applied to these soils initially testing 16, 49 and 90 lb/A, respectively, at Waseca. When 100 lb P_2O_5/A was added annually, soil Bray P_1 increased by 4.1 lb/A/yr when the initial test was 62 lb/A. At Morris, soil test P was more variable, but soil P declined by 2.6 and 5.1 lb/A/yr when the initial Bray P_1 was 37 and 67 lb/A, respectively. Soil test P was increased by 4.7 lb Bray P_1/A/yr when 100 lb P_2O_5/A was added annually at Morris. Because of extremely high soil test K variability from year to year, it was difficult to show a consistent soil test change over time. This information on soil test decline rates when fertilizer is not applied should be very helpful to farmers who are considering omitting fertilizer P for a few years when their soils test high in P.

DEVELOPMENT OF A SOIL N TEST IN ANIMAL-BASED SYSTEMS[1/]

1993

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

ABSTRACT: Field studies were conducted at eight sites to build a data base for the development of a soil N test for animal-based crop production systems. Wet conditions since 1990 resulted in very low soil nitrate values at all sites. Preplant soil nitrate-N at all sites was below the minimum critical concentration of 6 ppm used in the present soil N test for south-central and eastern Minnesota. Thus, no N credits would have been given. Corn yields were lower than expected at all sites but did respond to N. Optimum N rate at each site was similar to the rate recommended without the use of a soil N test. These data suggest that a soil nitrate-N test is not helpful in determining N credits in soil systems that have received abundant rainfall in previous seasons.

A soil N test was developed for Minnesota corn producers in 1993 based on research conducted at over 50 sites from 1989-1992. Because most of these sites did not have a manure or alfalfa history, we focused our 1993 soil N test investigations on animal-based crop production systems with alfalfa and/or manure histories. The purpose of this investigation was to obtain corn yield response data to fertilizer N as a function of various soil N indices. This information will be used to develop a data base for validation of our present N test and/or development of a N test specific for soils amended with organic sources of N.

Experimental Procedures

Site characteristics of each of the eight locations in south central and southeastern Minnesota are given in Table 1. Seven of the sites have a manure and/or alfalfa history. The NT-1 site did not but was amended in 1992 with 250 lb N/A for corn after soybean to theoretically provide a high level of residual N. Four replications of the treatments shown in Table 2 were established. Nitrogen was broadcast-applied as urea prior to planting. Sidedress N treatments were band-applied about 4" deep midway between the rows at the V6 stage at four sites. Corn management practices (hybrid, planting date and rate, weed control, etc.) were conducted by the farmer-cooperator at all off-Station locations. These practices were optimum for excellent production; however, rainfall amounts exceeded normal at all locations. Due to very wet conditions, yields were only taken from three replications at four sites.

Results and Discussion

The yields shown in Table 2 are below the yield goal at all locations. This was due to the very wet and cold conditions that limited corn growth. These wet conditions coupled with above-normal precipitation the three previous years also resulted in very low soil residual NO_3-N concentrations at all sites. The present Minnesota-N recommendations based on a 0-2' preplant NO_3 test give no N credit when NO_3-N concentrations are ≤ 6.0 ppm. None of the sites exceeded this level with a range of 2.4 - 4.6 ppm. In addition, 21 ppm is often cited as a threshold NO_3-N concentration for 0-1' samples taken at the V4 stage. None of these sites contained NO_3-N concentrations even close to this level – even the NT-1 site which had received excessive N in 1992. Therefore, it is unfortunate, but a realty, that this year's results were more affected by weather than soil N indices.

Corn responded to N at all sites although the variability was high and the response marginal at some sites (Table 2). Optimum N rates were close to those that would have been recommended without a soil N test, i.e., previous crop, soil OM level, and yield goal. This was encouraging given the poor growing conditions during the season. Split applications of N were superior to equal N rates applied preplant at two of four locations. This was expected given the wet conditions between the preplant and sidedress applications. Yields with the split applications at the NT-1 site were lower than when applied preplant. Apparently, the 30-lb preplant rate did not provide sufficient N early in the season at this site. Corn that received the 30-lb preplant N rate had started to show some yellowing and N deficiency at the time the sidedress applications were made. As a result, the plants were not able to recover satisfactorily from this temporary N deficiency condition and yields suffered.

Conclusions

Residual soil NO_3 concentrations were below current minimum critical levels for preplant and early sidedress soil sampling times at all eight sites. This was likely due to above-normal precipitation from 1990-1992. Corn yields were lower than expected but were optimized at N rates close to those that would have been recommended without the aid of a soil N test. In summary, 1993 was a poor year in which to develop a soil N test because credit for "available" N in these animal-based systems was not apparent.

1/ Funding provided by the USDA-CSRS Special Research Grants; Water Quality Program (Nitrogen Testing) and the Legislative Commission on Minnesota Resources.

2/ Professor, Southern Experiment Station and Asst. Professor, Dept. of Soil Science, Univ. of Minnesota

Table 1. Site characteristics at the eight locations used in 1993 to develop and/or validate a soil N test.

Parameters	Location							
	MC-1	MC-2	MC-3	MC-4	MC-5	MC-6	NT-1	NT-2
County:	Waseca	Olmsted	Olmsted	Nicollet	Martin	Martin	Waseca	Waseca
Location:	SES	Lawler	Griffin	Peters	Gronewald	Kosbab	SES	SES
Soil type	Webster cl	Port Byron sil	Port Byron sil	Nicollet cl	Nicollet cl	Canisteo cl	Nicollet cl	Webster cl
Prev. Crops								
1992	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn
1991	Alfalfa	Corn	Corn	Soybean	Soybean	Corn	Soybean	Alfalfa
1990	Alfalfa	Corn	Corn	Corn	Corn	Corn	Corn	Alfalfa
1989	Alfalfa	Corn	Alfalfa	Soybean	Sw. Corn	Soybean	Corn	Alfalfa
Manure history	10,000 gal/A Liq. Dairy 10/91	6200 gal/A Liq. Dairy 5/92	30 T/A Dairy annually	5000 gal/A Liquid Hog 11/91 & 10/89	3400 gal/A Liquid Hog 4/92 & 4/89	4000 gal/A Liquid Hog 4/92 & 4/90	None	None
N Fert. History (lb/A)								
1992	0	120	120	0	25	100	250	0
1991	0	180	120	0	0	130	0	0
1990	0	180	0	150	130	100	180	0

Table 2. Corn yield as influenced by N rate at each of the sites used for soil N test development/validation in 1993.

N rate & time		Location							
Preplant	Sidedress	MC-1	MC-2	MC-3	MC-4	MC-5	MC-6	NT-1	NT-2
------ lb/A -----		bu/A							
0	0	70.0	85.6	65.0	56.9	66.7	47.2	65.2	49.8
30	0	87.5	98.3	71.4	80.5	68.3	48.0	79.3	60.8
60	0	86.9	107.2	84.3	96.3	67.6	46.2	87.9	73.8
90	0	100.2	109.8	88.0	127.8	83.9	54.1	109.1	79.4
120	0	100.5	118.3	89.5	134.7	73.3	58.6	116.7	90.4
150	0	100.7	117.3	89.6	116.2	96.3	69.4	120.7	97.6
180	0	119.1	117.2	97.2	143.3	93.5	68.6	125.3	94.8
30	30	92.5	-	-	-	95.0	-	88.5	74.1
30	60	113.9	-	-	-	106.0	-	104.1	88.0
30	90	111.9	-	-	-	97.9	-	111.1	90.8
Soil NO_3-N test									
preplant, 0-2' (ppm)		2.7	4.6	2.5	3.8	2.4	2.4	3.8	3.4
V4 stage, 0-1' (ppm)		1.6	5.4	2.5	1.1	3.0	2.9	1.4	1.4

Impact of Turkey Manure Application on Corn Production and Potential Water Quality Concerns-Westport MN 1993.[1]

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

Abstract

A field study was continued at Westport, MN (begun in 1991) to study the impact of turkey manure application on irrigated corn and soybean production and nitrate-N movement below an Estherville sandy loam soil. Treatments included two rates of commercial fertilizer (70 and 140 lb N/A), two rates of turkey manure (4 and 8 tons/A--wet weight basis) and an untreated check. Manure rates were computed to provide an estimated equivalent amount of available N per acre as the fertilizer treatments. Treatments were planted to corn in 1993 following a previous crop of soybeans. Plant samples were collected at 8 leaf, silking, and physiological maturity. Plant samples obtained at physiological maturity were separated into grain and stover. Total dry matter production, N concentration and total N uptake were determined for each sampling. Water percolation, and movement of nitrate-N below the root zone was monitored utilizing 30 closed bottom non-weighing drainage lysimeters. Excess percolation was removed from the bottom of each lysimeter after each leaching event. Soil samples were collected from the soil profile prior to planting and at harvest. Soil samples were analyzed for nitrate and ammonium N. Grain yields and N uptake were significantly higher with turkey manure application than with fertilizer. Residual effects of manure application (1992) increase grain yields and N availability during the 1993 season. Fertilizer N application and low rates of turkey manure applied in 1993 had relatively little influence on the concentration of nitrate-N in leaching water. High application rates of turkey manure in 1992 (residual) produced elevated concentrations of nitrate-N in 1993.

Introduction

Turkey production in Minnesota is ranked second in the nation (Minnesota Statistics, 1990). In 1990, Minnesota's turkey farmers boosted their output to a new record of 43.6 million turkeys. A large portion of the turkey production is concentrated in the West Central and Northwest regions of the state. Many turkey producers have limited land area available for manure disposal. As production increases improved manure management skills will be required to meet the agronomic need and minimize groundwater contamination.

Increased emphasis on protection of surface water and ground water, and the farmers desire to reduce fertilizer cost have increased the need to evaluate the use of turkey manure. Turkey manure is rich in several nutrients. Recent survey done by University of Minnesota researcher (Moncrief et al.1991 unpublished data) revealed the nutrient composition of poultry manure on dry weight basis is 5.1% N, 2.2% P and 2.3% K respectively. The 860,000 tons (dry wt.) of turkey manure produced in Minnesota per year could supply approximately 87.7, 86.7 and 47.5 million pounds of N, P_2O_5 and K_2O respectively for crop production.

The objective of this field study was to compare two rates of turkey manure (4 and 8 T/A on wet weight basis) and two rates of fertilizer N (70 and 140 lb N/A) on dry matter production, N uptake, grain yields ,and leaching losses of NO_3-N within a corn-corn-soybean rotation.

Materials and Methods

In 1975, 30 non-weighing lysimeters were installed on the Rosholt farm Westport, Minnesota. Each lysimeter was 5.75 ft in diameter,and 4 feet 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. Each lysimeter was placed in the center of a 30' x 30' plot. Soil at the experimental site is an Estherville sandy loam (Typic Hapludoll) and the lysimeters were backfilled with that soil by depth. Selected chemical and physical properties of the soil are presented in Table 1.

This site did not have any previous history of manure application. Cropping history was corn following corn in a corn-corn-soybean rotation, and in 1990 corn was grown at this site without any fertilizers. This study was initiated in 1991 and corn was grown with urea fertilizer and manure treatments. In 1992 soybeans were grown with manure treatments only and in 1993 corn was planted into the experimental area with both fertilizer and manure treatments.

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1. Appreciation is expressed to the University of Minnesota Agricultural Experiment Station, Wes-Min RCD, Pope Co. SWCD, and Pioneer Hi-Bred International for supplying seed.
2. Professor, and Assistant Scientist respectively, Dept. of Soil Science, University of Minnesota.

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

Soil Depth	Gravel	Sand	Silt	Clay	Organic Matter	pH
inches	%					
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

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 pressure. The emission rate for each dripper was 0.35 gal/hr. Each lysimeter contained 4 drippers. Irrigation water was applied when less than 2 inches of water was available in the soil profile. Irrigation water was metered through 3 main irrigation lines.

The experimental design included three replications of nine treatments in a randomized complete block design. Treatments in 1993 consisted of a zero N control, two rates of turkey manure (4 and 8 T/A, wet weight basis) and two rates of commercial fertilizer N (70 and 140 lb N/A as urea) which were applied to the same plots as in 1991 (the five original 1991 treatments), two rates of manure (4 and 8 T/A) added to new plots in 1993, and the two residual (turkey manure applied in 1992) manure treatments. Turkey manure treatments were incorporated, immediately after application. The nutrient composition of the turkey manure is presented in table 2. Estimate of manure N availability was based on the assumption that 80% of the inorganic N and 30% of the organic N will be available during the first year of application. The manure rates applied were expected to provide approximately 70 and 140 lb. of available N/A. The entire study area was planted to corn (Pioneer 3787 - 95 day R.M.) on May 5th at a seeding rate of 29,600 seeds/A. A tank mix of Lasso (1.75 #/A) + Bladex (1.75 #/A) was applied on May 11th for weed control.

Table 2.Turkey Manure Composition

Nutrients	lb/T
Total N	45
Inorg. NH_4^+-N	13
NO_3^--N	1
Organic N	32
P_2O_5	---
K_2O	---
Moisture %	51

+ Nutrient composition presented in wet basis.
--- not available at this time

Dry Matter production and N uptake were determined July 6th (8-leaf), August 8th (silking) and September 24th. Due to a cool summer and early killing frost, grain yields were lower than expected. Grain yields were determined by harvesting two 20 foot rows. Corn grain yields were reported at 15.5% moisture.

Soil water percolate was collected through 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.

Soil samples collected prior to planting and at harvest (0-6, 6-12 and 12-18 inches), were analyzed for nitrate and ammonium N.

Results and Discussion

Significant differences in dry matter and N uptake between treatments were observed at both sampling dates (Table 3). In all cases but one, turkey manure application was more responsive than comparable urea fertilizer treatments. The N concentration in the whole plant at silking when 4 T/A of turkey manure was applied resulted in significantly higher concentrations than the comparable urea treatments, while the 8 T/A treatments did not reflect the higher concentration.

Turkey manure treatments produced higher corn grain yields than comparable urea-N applications. (Table 4). Turkey manure applied in 1992 increased grain yield in 1993 compared with either the control or urea treatments. Turkey manure applied in 1993 significantly increased corn grain yields over the use of commercial fertilizer.

Table 3. Dry matter production, and N utilization as influenced by turkey manure, fertilizer and residual manure treatments - 1993.

Treatments	Dry Matter 8-leaf	Dry Matter silking	N-Concentration 8-leaf	N-Concentration silking	N Uptake 8-leaf	N Uptake silking
	--------T/A--------		------ % N --------		----lb/A-----	
Control	0.34	1.57	3.33	1.12	23	35
70 lb N/A in '91,'93	0.32	2.04	3.21	1.41	20	57
140 lb N/A in '91,'93	0.35	2.17	3.68	2.09	25	91
TM 4 T/A in'91,'93	0.56	3.30	3.62	2.00	40	131
TM 8 T/A in'91, '93	0.61	3.23	3.47	2.23	42	144
TM 4 T/A TM'92 none '93	0.42	2.48	3.64	1.84	30	91
TM 8 T/A TM'92 none '93	0.54	3.08	3.85	2.03	42	124
TM 4 T/A in '93	0.49	3.04	3.64	2.18	35	133
TM 8 T/A in '93	0.58	3.20	3.72	2.31	42	147
P-Valve	99	99	33	99	99	99
LSD (0.05)	0.11	0.24		0.41	9	21

* TM is turkey manure.

Table 4. Grain and stover yields as influenced by turkey manure, fertilizer and residual manure treatments - 1993.

Treatments	Grain yield	N-Concentration Stover	N-Concentration Grain	Dry Matter Production Stover	Dry Matter Production Grain	Dry Matter Production Total	N-Removal Stover	N-Removal Grain	N-Removal Total
	bu/a	------%------		-------T/A-------			---------lb/a---------		
Control	66	0.85	1.03	5.76	1.57	7.33	98	32	130
70 lb N/A in '91,'93	87	1.06	1.17	5.64	2.06	7.70	119	48	167
140 lb N/A in '91,'93	90	1.14	1.39	5.93	2.15	8.08	135	59	195
TM 4 T/A in'91,'93	118	0.96	1.46	5.83	2.81	8.64	111	82	193
TM 8 T/A in'91, '93	115	1.07	1.52	5.83	2.73	7.84	109	83	192
TM 4 T/A TM'92 none '93	94	0.77	1.24	5.11	2.24	7.90	87	55	142
TM 8 T/A TM'92 none '93	109	1.08	1.35	5.66	2.60	7.87	113	69	183
TM 4 T/A in '93	116	0.94	1.36	5.27	2.75	8.20	102	74	177
TM 8 T/A in '93	114	1.29	1.62	5.46	2.71	8.28	143	88	231
P-Valve	99	99	99	99	99	99	99	99	99
LSD (0.05)	8	0.10	0.06	0.39	0.20	0.39	14	6	14

* TM is Turkey Manure

Fertilizer and manure treatments had no influence on the amount of water that percolated through the soil profile in 1993, but did influence the concentration and the amount of nitrate-N leached. Concentration of nitrate-N in the percolate water from manure applied in 1991 and 1992, reflected increased concentrations of nitrate-N in proportion to the rate of manure applied. Turkey manure and commercial fertilizer applied in 1993 had relatively the same concentration of nitrate-N. Data collected to date would suggest a relatively long impact associated with manure application as compared to fertilizer N. Turkey manure contains a relatively large amount of N in the organic form. This organic N must be broken down before it is available for crop utilization and/or leaching. Better methods for estimating available N from manure are needed, both during the year of application and in subsequent years.

Table 5. Water percolation amount during 1993.

Treatments	Planting 5/3	Planting to harvest 5/26	6/29	7/12	11/3	Total
	---------------------Inches of H_2O---------------------					
Control	1.2	1.5	1.7	1.2	0.0	7.4
70 lb N/A in '91,'93	1.6	1.6	2.2	1.4	0.4	8.1
140 lb N/A in '91,'93	1.0	2.3	1.7	1.1	0.2	7.2
TM 4 T/A in'91,'93	1.5	1.9	2.0	1.1	0.6	7.3
TM 8 T/A in'91,'93	1.3	2.3	2.0	1.2	0.5	9.5
TM 4 T/A TM'92, none'93	1.2	2.4	2.4	1.3	0.3	6.3
TM 8 T/A TM'92, none'93	2.3	2.6	2.0	1.3	0.6	6.7
TM 4 T/A in '93	1.2	2.7	2.2	1.0	0.3	7.4
TM 8 T/A in '93	1.8	1.7	2.0	1.0	0.3	6.8
P-Value	99	99	30	43	61	51
LSD (0.05)	0.7	0.7				

* TM is Turkey manure.

Table 6. Concentration of NO_3^--N in leachate as influenced by manure, fertilizer and residual manure treatments in 1993.

Treatments	Planting 5/3	Planting to harvest 5/26	6/29	7/12	11/3	Ave
	------------------ppm NO_3^--N------------------					
Control	5.6	6.4	9.0	10.0	0.0	7.7
70 lb N/A in '91,'93	5.1	6.3	6.2	8.7	9.8	7.2
140 lb N/A in '91,'93	3.5	7.4	8.0	4.5	3.2	5.3
TM 4 T/A in'91,'93	3.9	6.5	9.0	8.8	4.8	6.6
TM 8 T/A in'91,'93	9.2	14.5	14.6	14.1	6.7	11.8
TM 4 T/A TM'92 none '93	5.7	11.5	13.8	10.8	9.1	10.2
TM 8 T/A TM'92 none '93	16.8	21.2	17.2	14.6	6.3	15.2
TM 4 T/A in '93	3.9	9.8	9.6	6.5	5.0	6.0
TM 8 T/A in '93	6.5	5.1	7.3	6.3	4.1	5.9
P-Value	99	99	99	99	72	
LSD (0.05)	2.7	3.0	3.9	3.8		

* TM is Turkey manure.

Table 7. Nitrate-N leached as influenced by manure, fertilizer and residual manure treatments in 1993.

Treatments	Planting 5/3	Planting to harvest 5/26	6/29	7/12	11/3	Total
	----------------------lb/A NO_3^--N------------------					
Control	5.0	5.8	8.0	8.9	0.0	27.7
70 lb N/A in '91,'93	4.6	5.6	5.6	7.7	8.8	32.3
140 lb N/A in '91,'93	3.1	6.6	7.1	4.0	2.9	23.7
TM 4 T/A in'91,'93	3.5	5.8	8.0	7.8	4.3	29.4
TM 8 T/A in'91,'93	8.2	12.9	13.1	12.6	6.0	52.8
TM 4 T/A TM'92 none'93	5.1	10.3	12.3	9.6	8.1	45.4
TM 8 T/A TM'92 none'93	15.0	18.9	15.4	13.0	5.6	67.9
TM 4 T/A in '93	5.8	8.7	8.5	5.8	4.4	33.2
TM 8 T/A in '93	5.8	4.6	6.6	5.6	3.7	26.3
P-Value	99	99	99	99	72	93
LSD (0.05)	2.4	2.7	3.5	3.4		

* TM is Turkey manure.

Table 8. Soil N levels sampled before planting and at harvest 1993.

Treatments	Depth	Ammonium Planting	Ammonium Harvest	Nitrate Planting	Nitrate Harvest	Total Inorg. Planting	Total Inorg. Harvest
		-----ppm-----		------ppm------		------ppm------	
Control	1	3.8	2.0	7.1	2.3	10.9	4.3
	2	2.8	1.6	5.1	1.8	7.9	3.4
	3	2.9	2.1	3.4	0.8	6.3	2.9
70 lb N/A in '91, '93	1	5.2	2.3	5.9	2.9	11.1	5.3
	2	3.8	2.5	4.2	1.6	8.0	4.1
	3	3.7	2.3	2.9	0.9	6.6	3.1
140 lb N/A in '91,'93	1	4.8	3.1	6.2	4.4	11.0	7.4
	2	3.1	2.5	5.5	3.2	8.6	5.6
	3	2.9	2.1	3.9	1.4	6.9	3.5
TM 4 T/A in'91, '93	1	4.2	2.9	7.3	5.7	11.5	8.6
	2	3.5	1.8	5.6	3.6	9.2	5.4
	3	3.1	1.8	4.1	1.7	7.2	3.5
TM 8 T/A in'91,'93	1	4.4	2.9	8.3	27.1	12.8	30.0
	2	3.5	2.5	7.1	11.6	10.6	14.1
	3	3.4	2.3	4.4	8.7	7.8	11.0
TM 4 T/A TM'92 none'93	1	3.1	3.6	9.6	4.1	12.8	7.7
	2	2.7	2.2	7.1	2.2	9.8	4.4
	3	2.4	2.0	4.8	1.3	7.2	3.2
TM 8 T/A TM'92 none'93	1	4.4	2.7	13.9	5.9	18.2	8.5
	2	3.0	2.6	10.9	2.7	14.0	5.3
	3	3.2	2.5	10.1	1.8	13.2	4.3
TM 4 T/A in '93	1	4.1	1.6	7.6	5.0	11.6	6.6
	2	2.7	1.7	5.5	2.3	8.2	4.1
	3	3.7	1.7	4.0	1.5	7.7	3.2
TM 8 T/A in '93	1	4.1	1.9	7.0	31.0	11.2	32.9
	2	3.4	2.4	6.2	12.5	9.6	14.9
	3	2.9	2.7	3.8	12.8	6.7	15.4

* TM is turkey manure. Depth 1 ,2 and 3 correspond to (0-6), (6-12), and (12-18) inches.

EVALUATION OF LIMING MATERIALS AND RATE OF APPLICATION FOR ALFALFA PRODUCTION ON IRRIGATED SANDY SOILS

G. Rehm, T. Sellie, and A. Scobbie[1/]

ABSTRACT: The need for lime for profitable production of alfalfa on acid sandy soils is well established. There are several materials that can be used to meet these lime requirements. This study was conducted to evaluate the effect of various liming materials for the production of irrigated alfalfa and subsequent change in soil pH values. Lime increased the yield of alfalfa all sources had an equal effect on yield if applied to supply the same rate of ENP per acre.

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 (ag lime, finely ground ag lime, sugarbeet lime, Pel-Lime) were applied to supply 3 rates of ENP per acre (4,321; 8,640; 12,960 lb./acre). A control treatment was included but was not part of the complete factorial design. To provide another comparison, Pel-Lime was applied at a rate to supply 2,160 lb. ENP per acre. Each treatment was replicated four times. Plot size was 10 ft. x 15 ft.

The liming materials as well as adequate rates of phosphate, potash, and sulfur were broadcast and incorporated before planting. Alfalfa was seeded without a companion crop in April at a rate of 16 lb. per acre. Irrigation water was applied as needed for establishment and throughout the growing season.

Soil samples (0-6 in.) were collected from the experimental site in early April. The results are summarized in Table 1. Two cuttings were harvested in 1990. Soil samples were collected from each plot in the fall and pH (soil and water paste) was measured.

Procedures for harvest and soil sample collection were quite similar in 1991, 1992, and 1993. The first cutting was taken in early June. Two additional cuttings were harvested each year before September 6. Soil samples (0-6 inches) were taken from each plot periodically to monitor changes in soil pH. Appropriate statistical analysis procedures were used to separate treatment effects.

Results and Discussion:

Alfalfa yields for 1990 through 1993 are reported in Table 2. Yields are expressed on the basis of tons of dry matter per acre. Total growing season yields are reported. Total yields reflect the response shown by individual cuttings.

Except for the year of establishment (1990), the use of lime produced a substantial increase in alfalfa production. This increase was consistent for 1991, 1992, and 1993. When totaled over the four years of production the yield increase, due to the initial application in 1990, was approximately 2.5 tons/acre.

The application of 4,321 lb. ENP per acre was adequate for optimum production. Higher yields were expected from the higher rates applied. This, however, was not the case in any production year. The use of Pel-Lime at a half rate was not adequate for optimum yields.

Table 1. Relevant soil properties (0-6 inches) at the experimental site.

Property	Value
pH	5.4
phosphorus (Bray #1)	66 ppm
potassium	144 ppm
calcium	995 ppm
magnesium	128 ppm
sulfur	5.8 ppm
organic matter	3.0%

[1/] Extension Soil Scientist, Junior Scientist, and Assistant Scientist, Soil Science Department, University of Minnesota, respectively.

Table 2. The effect of lime source and rate of application on the dry matter yield of irrigated alfalfa.

Liming Material	ENP Rate	Year				
		1990	1991	1992	1993	Total
	lb./acre	pH				
-	0	1.45	4.17	4.10	4.13	13.85
ag-lime	4,321	1.62	5.05	4.64	5.20	16.51
	8,640	1.62	4.88	4.91	5.32	16.73
	12,960	1.47	4.96	4.64	4.82	15.89
finely ground ag lime	4,321	1.75	4.87	4.53	4.97	16.12
	8,640	1.76	4.91	5.08	5.12	16.87
	12,960	1.39	5.11	4.63	5.00	16.13
sugarbeet lime	4,321	1.71	5.02	4.72	4.95	16.40
	8,640	1.54	4.97	4.49	5.08	16.08
	12,960	1.56	5.22	5.03	5.07	16.88
Pel-Lime	2,160	1.39	4.44	4.41	4.76	15.00
	4.321	1.54	4.96	4.64	5.27	16.41
	8,640	1.53	4.68	4.73	5.19	16.13
	12,960	1.40	4.73	4.44	5.07	15.64

When liming materials are considered, all were equally effective if applied to supply equivalent amounts of ENP per acre. Even though there were substantial differences in particle size of the materials, these differences had no impact on alfalfa yields. If differences did exist, they could not be measured in this study. There are several materials that can be used for liming purposes. These results indicate that their effectiveness can be equal to the effectiveness of ag-lime if particle size and a measurement of Total Neutralizing Power is considered.

Soil samples were collected from each plot to a depth of 6 inches at 5 different times throughout the four years of the study. The results of the analysis are listed in Table 3.

Table 3. The effect of lime source and rate of application on soil pH measured at a depth of 0-6 inches.

Liming Material	ENP Rate	Fall 1990	Fall 1991	Spring 1992	Fall 1992	Fall 1993
	lb./acre	pH				
-	0	5.6	5.5	5.5	5.5	5.5
ag-lime	4,321	6.0	5.6	5.7	5.7	5.7
	8,640	6.1	5.9	6.0	5.9	5.8
	12,960	6.1	6.1	5.9	6.2	6.0
finely ground ag lime	4,321	6.2	5.7	5.8	5.8	5.9
	8,640	6.2	5.7	5.9	5.8	5.8
	12,960	6.5	5.9	6.1	5.9	6.0
sugarbeet lime	4,321	6.2	5.5	5.9	5.6	6.0
	8,640	6.4	6.1	6.1	5.7	6.0
	12,960	6.6	6.5	6.3	5.8	6.5
Pel-Lime	2,160	5.8	5.5	5.5	5.6	5.8
	4.321	5.9	5.8	5.8	5.7	5.8
	8,640	6.2	5.7	5.9	5.7	6.1
	12,960	6.2	5.8	5.9	5.6	6.0

Lime treatments were applied in mid-April and incorporated with a disk. In the fall of the same year (1990), there had been some change in soil pH. Except for the Pel-Lime source, the pH increased as the rate of ENP increased. This was expected. There were also expectations that soil pH would go higher with the application of 12,960 lb. ENP per acre. In the fall of 1990, there may not have been adequate time to reach an equilibrium.

It's obvious that there was a substantial drop in soil pH from the fall of 1990 to the fall of 1991. There were no substantial changes from the fall of 1991 through the summer of 1993 regardless of the treatment that was applied. This rapid decrease was not expected and could not be explained by our current understanding of the concepts of soil fertility and liming.

Through conversations with the cooperating farmer, it was learned that the irrigation well had been treated with acid in the spring of 1991 to improve pumping capacity. The irrigation system, itself, was immediately over the plot area when the irrigation system was started following the acid treatment. Consequently, water that was very acid was applied to the experimental area. This pumping caused a substantial decrease in soil pH.

Even though there was a substantial decrease in soil pH from the fall of 1990 through the summer of 1993, there was still an economic response to the liming materials that had been applied in the spring of 1990. Plots that did not receive lime were invaded by weeds and there was a considerable reduction in alfalfa stand. This is strong evidence that liming, when needed, can affect the stand as well as the seasonal growth of alfalfa.

Summary:

The results of this study, conducted over four growing seasons, illustrate the importance of liming for profitable alfalfa production. Total dry matter yield was increased by about 2.5 ton per acre when lime was applied. Neither the rate of application in excess of amounts of 4,321 lb. ENP per acre nor the source of lime had any significant effect on yield.

The soil pH, measured in the fall of 1990, changed as expected. However, this change did not last long because of the acid treatment of the irrigation well. After the pH reached a new equilibrium, it remained relatively constant through the 1993 growing season.

Even though there was a substantial decrease in soil pH, the early benefits were carried through the 1993 growing season. These results show that there are clearly residual benefits from the appropriate application of a liming material.

EVALUATION OF RATE OF LIME NEEDED FOR OPTIMUM PRODUCTION OF FIVE LEGUMES IN NORTH-CENTRAL MINNESOTA

G. Rehm, T. Sellie, A. Scobbie, C. Sheaffer, and N. Martin[1/]

ABSTRACT: Little is known about the lime requirements for legume crops that might be useful for hay and/or pasture crops in North-Central Minnesota. This study was conducted to measure the response of five legumes (alfalfa, birdsfoot trefoi, cicer milkvetch, kura clover, red clover) to the application of Ag-Lime (0, 2, 4 tons per acre). Total forage produced during the 1992 and 1993 growing season was affected by both legume and lime use. A rate of 2 tons per acre was optimum for each year for all legumes.

Introduction:

Legumes are a major component of a large number of farm enterprises in North-Central Minnesota. Therefore, it's essential that farmers use management practices that provide for optimum production of all legumes.

The majority of the soils in the region also have an acid pH. This means that lime will be needed for optimum production. Lime requirements for alfalfa are reasonably well established. Yet, there are other legumes that might be satisfactory substitutes for alfalfa in either pasture or hay situations. The lime requirements for these alternative legumes are not well defined. Therefore, this study was established to evaluate the need of alternative legumes for lime and compare these needs to those of alfalfa.

Experimental Procedure:

This study was established on an irrigated sandy soil in Wadena County in the spring of 1991. Results of the soil tests taken before lime application are listed in Table 1.

For this study, three rates of Ag-Lime (0, 2,000, 4,000 lb. ENP/acre) were broadcast and incorporated before legume seeding in early May. Five legumes were seeded on May 8, 1991 in each liming rate. Adequate phosphate, potash, and sulfur were also broadcast and incorporated before seeding. Forage yields were not measured in 1991.

The phosphate, potash, and sulfur rates were topdressed to the established stands in early spring of 1992 and again in early spring of 1993. The harvest schedules were the same for both years. The alfalfa was cut three times with the first cutting taken in early June. Subsequent cuttings were taken at 35-day intervals. The other legumes were harvested two times during each growing season. The first cutting was taken in mid-June. The second cutting was harvested in late August. All forage yields are reported on a dry matter basis.

Soil Samples (0-6 inches) were collected from each plot in the fall of both 1992 and 1993. These samples were dried and pH was measured with routine procedures.

Results and Discussion:

The forage yields for the 1992 growing season are summarized in Table 1. Total production was reduced by excessively dry weather in May and June combined with an irrigation system that did not function correctly. Even though total production was lower than anticipated, the application of lime increased the yield of all legumes. The yield increases were highest for alfalfa and red clover.

Table 1. The effect of rate of Ag-Lime on the total forage yield of five legumes. Wadena County. 1992.

	Lime Rate (lb. ENP/acre		
Legume	0	2,000	4,000
	------ ton dry matter/acre -----		
alfalfa	3.0	3.8	3.5
birdsfoot trefoil	2.8	3.0	3.1
cicer milkvetch	2.0	2.2	2.4
kura clover	1.7	2.1	2.0
red clover	3.0	3.6	3.8

Forage yields measured for the 1993 growing season are summarized in Table 2. The data from each cutting are included because the effect of timing varied with cutting.

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Table 2. The effect of rate of Ag-Lime on forage yield of five legumes. Wadena County. 1993.

Legume	Cutting		Lime Rate (lb. ENP/acre) 0	2,000	4,000
			------ ton dry matter/acre -----		
alfalfa	1		1.23a*	1.81b	2.04b
	2		2.42a	2.98a	2.10a
	3		1.01a	1.25b	1.32b
		Total:	4.66a	6.04b	5.46ab
birdsfoot trefoil	1		2.09a	2.55b	2.39ab
	2		2.10a	2.33b	2.34b
		Total:	4.19a	4.88b	4.73ab
cicer milkvetch	1		1.84a	1.84a	2.16a
	2		1.67a	1.90a	1.92a
		Total:	3.51a	3.74a	4.08a
kura clover	1		2.23a	2.60b	2.48b
	2		1.47a	1.61a	1.51a
		Total:	3.70a	4.21b	3.99ab
red clover	1		1.68a	1.97a	2.13a
	2		2.16a	2.74b	2.47b
		Total:	3.84a	4.71b	4.60b

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

When considering the legume yields averaged over the rate of lime applied, alfalfa produced the highest yield. Lowest yields resulted from the planting of both cicer milkvetch and kura clover. Yields resulting from the harvest of red clover and birdsfoot trefoil were intermediate.

First cutting yields of alfalfa were improved substantially by the use of lime. This was also true for the third, but not the second cutting. When total seasonal production is considered, the use of 2,000 lb. ENP per acre increased dry matter yield by approximately 1.5 ton per acre. Additional lime did not produce additional dry matter for this crop.

The response of birdsfoot trefoil was similar to the response of alfalfa. The application of 2,000 lb. ENP per acre was adequate for optimum yield. Compared to alfalfa, the lime increased dry matter production by about .7 ton per acre for this crop.

The application of lime had no effect on the yield of cicer milkvetch. This legume is apparently able to tolerate low soil pH values.

Lime usage increased the yield of the first, but not the second cutting of kura clover. Because of yield increases for the first cutting, lime had a significant effect on total forage produced for the season. The rate of 2,000 lb. ENP per acre was adequate for optimum production.

In contrast to other responsive legumes, the first cutting yield of alfalfa was not affected by the use of lime. The rate of 2,000 lb ENP per acre was adequate for optimum yield of the second cutting and this was also reflected in total yield.

Soil pH values are summarized in Table 3. The pH at the start of the study was 5.6. The application of lime did increase soil pH, but rates were not adequate for a pH of 6.5 The optimum yields, however, were associated with pH values in the range of 6.0.

The data also show that there was a consistent decrease in soil pH from the fall of 1992 to the fall of 1993. This decrease, however, was very small and was consistent for all legumes. The legume that was grown had no effect on the decrease in soil pH.

Table 3. The effect of rate of Ag-Lime on soil pH when five legumes were grown on an irrigated sandy soil.

Legume	Sampling Time	Lime Rate (lb. ENP/acre)		
		0	2,000	4,000
		pH		
alfalfa	1992	5.5	5.9	6.2
	1993	5.3	5.8	6.1
birdsfoot trefoil	1992	5.5	6.0	6.1
	1993	5.3	5.9	6.1
cicer milkvetch	1992	5.6	6.0	6.2
	1993	5.5	5.9	6.1
kura clover	1992	5.6	6.0	6.4
	1993	5.4	5.9	6.2
red clover	1992	5.4	5.9	6.0
	1993	5.3	5.7	6.2

Summary:

The results of this study conducted for a period of two years show that forage legumes that are adapted to the sandy soils of North-Central Minnesota will respond to the application of lime and a subsequent increase in soil pH. The magnitude of the response, however, varied with legume. Therefore, application of Ag-Lime should be a major consideration when all legumes are grown on the acid sandy soils of the region.

The application of Ag-Lime resulted in a change in soil pH. With the rates used, the pH did not rise above 6.5. There is every reason to believe that the use of higher rates would have produced higher pH values. There was no major drop in pH from one year to another. The data indicate that soil pH should remain relatively constant over a period of time if the recommended rate of lime is used.

DETERMINING POTASSIUM REQUIREMENTS OF ALTERNATIVE LEGUMES

G. Rehm, T. Sellie, and A. Scobbie[1]

ABSTRACT: This study was conducted to determine the need for potassium for five forage legumes grown on the sandy soils of North-Central Minnesota. Four rates of K_2O (0, 75, 150, 225 lb. per acre) were applied to five legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover). Forage yields were recorded and the concentration of potassium in plant tissue was measured. Potassium uptake was computed from yield and concentration data. Even though the soil test for potassium was considered to be low (87 ppm), there was no yield response to applied K in 1993. Potassium concentration and potassium uptake increased with rate of K_2O applied.

Background:

The sandy soils of North-Central Minnesota usually have a low soil test value for potassium (K). Past research has shown that alfalfa will respond to potash fertilizers applied to these soils. There are other legumes that might be adapted to the region and suitable for pasture and/or hay production. There is, however, very little information that describes the potassium requirements for these legumes. Therefore, this study was conducted to determine the response of alternative legumes to potassium.

Experimental Procedure:

This study was conducted in the field of a cooperating farmer in Todd County from 1991 through 1993. Soil samples (0-6 inches) were collected prior to planting and the results of the analysis are summarized in Table 1. Adequate amounts of lime, phosphate, and sulfur were broadcast to each plot and incorporated with a disk prior to planting.

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

Soil Property	Value
pH	6.6
P (Bray & Kurtz #1), ppm	92
K (1N ammonium acetate), ppm	87

Four rates of K_2O (0, 75, 150, 225 lb. per acre) were used. These rates were applied to alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, and red clover.

The experimental area was planted to corn in 1990 and a disk was used to prepare a uniform seedbed prior to seeding. The legumes were seeded on May 6, 1991. They were allowed to establish under irrigation in 1991. Appropriate post emergence herbicides were used for weed control.

The potash rates were topdressed to the established stand in early spring of 1992 and 1993 along with adequate phosphate and sulfur. The alfalfa was harvested 3 times. All other legumes were harvested twice. Whole plant samples were collected from each plot at each cutting and analyzed for K. Potassium uptake was computed from the dry matter yield and K concentration data. Soil samples (0-6 in.) were collected from each plot in September, but have not been analyzed for K.

Results and Discussion:

Dry matter yields are summarized in Table 2. Yield was not affected by the application of K_2O. This statement applies to yields of individual cuttings as well as total yield. With a soil test for K of 87 ppm, a response to potash fertilization would be expected. There is no apparent, easy explanation for this lack of response.

Considering the legumes, alfalfa produced the largest amount of dry matter. The kura clover produced the lowest amount of dry matter. The other legumes produced intermediate yields.

The effect of rate of applied K_2O on the K concentration in the legume tissue was highly significant (Table 3). In general, the K concentration increased linearly with rate of K_2O applied. From this data, it would appear that luxury consumption of K is a characteristic of all legumes included in the study.

As would be expected, the effect of rate of K_2O applied on K concentration is consistent with the effect of rate of K_2O applied on K uptake (Table 4). Potassium removal was highest for alfalfa followed by cicer milkvetch. The kura clover and red clover crops removed the lowest amounts of K.

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[1] Professor, Junior Scientist, Assistant Scientist, Soil Science Department, University of Minnesota, respectively.

Table 2. Effect of rate of applied potash on dry matter yield of five legumes grown on an irrigated sandy soil.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		----- ton dry matter/acre -----			
alfalfa	1	1.50	1.46	1.53	1.46
	2	1.41	1.69	1.57	1.60
	3	1.26	1.12	1.80	1.16
	Total	4.17	4.26	4.28	4.22
birdsfoot trefoil	1	2.02	1.96	1.92	1.90
	2	1.73	1.73	1.66	1.78
	Total	3.75	3.71	3.58	3.68
cicer milkvetch	1	2.04	2.01	2.07	2.44
	2	1.47	1.45	1.39	1.39
	Total	3.51	3.46	3.46	3.83
kura clover	1	2.05	1.99	2.03	2.14
	2	.59	.65	.76	.75
	Total	2.64	2.65	2.78	2.89
red clover	1	1.44	1.62	1.43	1.44
	2	1.63	1.69	1.71	1.59
	Total	3.07	3.31	3.14	3.02

Table 4. Effect of rate of applied potash on potassium uptake by five legumes grown on an irrigated sandy soil.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		-------- lb. K/acre --------			
alfalfa	1	62.5	77.2	87.6	90.3
	2	56.6	78.4	82.2	94.8
	3	56.3	63.4	73.2	76.6
	Total	175.3	219.0	243.0	262.7
birdsfoot trefoil	1	77.8	106.0	103.0	107.3
	2	67.1	85.8	92.0	98.7
	Total	144.9	191.8	195.0	206.0
cicer milkvetch	1	77.7	107.6	125.4	179.6
	2	65.6	89.0	82.7	109.2
	Total	143.3	196.6	208.1	288.8
kura clover	1	72.1	99.2	120.6	145.9
	2	27.1	37.9	47.7	53.5
	Total	99.2	137.1	168.3	199.4
red clover	1	49.2	72.7	76.9	82.0
	2	55.4	79.8	87.0	89.9
	Total	104.6	152.5	163.9	171.9

Table 3. Effect of rate of applied potash on % K in the tissue in five legumes grown on an irrigated sandy soil.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		---------- % K ----------			
alfalfa	1	2.07	2.66	2.87	3.04
	2	1.99	2.32	2.62	3.01
	3	2.25	2.81	3.09	3.31
birdsfoot trefoil	1	1.92	2.70	2.68	2.83
	2	1.95	2.45	2.79	2.77
cicer milkvetch	1	1.91	2.67	3.03	3.65
	2	2.20	3.07	2.96	3.93
kura clover	1	1.75	2.45	2.92	3.39
	2	2.27	2.89	3.13	3.57
red clover	1	1.71	2.24	2.71	2.86
	2	1.67	2.34	2.54	2.84

With K removal by unfertilized alfalfa of approximately 175 lb. per acre and a soil test of 87 ppm K, a response to potash fertilization would be expected. The identity of the source of K used by the crop from this irrigated sandy soil is open to speculation. The release of K from the feldspar minerals in an accelerated weathering process under irrigation is, at this time, the most probable explanation.

Soil samples (0-6 inches) were collected from each plot in the fall of 1993. These samples are currently being analyzed for K and the results were not available at the time of preparation of this report.

SULFUR FERTILIZATION AND GROWTH OF FORAGE LEGUMES

George Rehm, Andy Scobbie, Thor Sellie, Craig Sheaffer, and Neal Martin[1/]

ABSTRACT: The sulfur (S) requirements of forage legumes other than alfalfa are not well defined. This study was conducted to evaluate the effect of the application of three rates of fertilizer S (0, 25, 50 lb./acre) on the yield of five forage legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover) grown on an irrigated sandy soil. Total dry matter production for the 1992 growing season was affected by legume but not the rate of S applied. The same conclusions were reached from the analysis of yield data for 1993.

Sulfur (S) is known to be essential for fertilization of several crops grown on the sandy soils of Minnesota. Several research trials have shown that an annual application of 25 lb. S per acre is needed for optimum alfalfa production when soils are sandy. However, the S requirements of several alternative legumes have not been clearly defined. Therefore, this study was conducted to determine the response of birdsfoot trefoil, cicer milkvetch, kura clover, and red clover to S fertilization. Alfalfa was included as a standard for comparison.

Experimental Procedure:

This study was initiated in the field of a cooperating farmer in Wadena County in the spring fo 1991. Soil samples (0-6 inches) were collected prior to planting. The pH was 5.6; the Bray & Kurtz #1 soil test for P was 49 ppm; K by ammonium acetate extraction was 126 ppm; the SO_4-S measured was 1.7 ppm, and the organic matter content was 2.4%. Adequate amounts of Ag-Lime, phosphate, and potash were broadcast to the plot area and incorporated with a disk prior to planting.

Three rates of S (0, 25, 50 lb. per acre) were applied to each of five legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover) in a complete factorial design with four replications. A moldborad plow and disk were used for seedbed preparation. The legumes were seeded on May 6, 1991. The legumes were allowed to establish under irrigation in 1991 and no yields were recorded. Weed control was achieved with appropriate use of post emergence herbicides.

The S rates were reapplied to the established plots in the spring of 1992 and 1993. Granular gypsum was used to supply the S. Adequate rates of phosphate and potash were also topdressed to the established stand each year.

The alfalfa was harvested three times. The other legumes were harvested twice. Whole plant samples were collected from each plot at harvest, dried, and ground for analysis for S. That analysis has not been completed at the time of this writing.

Results and Discussion:

The total amount of forage produced in 1992 was significantly affected by legume, but not by the rate of S applied (Table 1). In 1992, the alfalfa and red clover produced the highest yield. Lowest yields resulted from the cicer milkvetch and kura clover. Yields from birdsfoot trefoil were intermediate.

Table 1. Effect of rate of applied sulfur on total dry matter production of five forage legumes in 1992.

Legume	S Applied (lb./acre) 0	25	50
	------- ton dry matter per acre -------		
alfalfa	3.08	3.30	3.20
birdsfoot trefoil	2.77	3.20	3.00
cicer milkvetch	1.63	1.73	1.98
kura clover	1.53	1.80	1.75
red clover	3.33	3.11	3.45

In 1993, yields were significantly affected by legume, but not the rate of S applied (Table 2). The lack of a response to fertilizer S is difficult to explain. This is especially true for alfalfa. Apparently, the excessively wet weather combined with widely fluctuating temperatures accelerated mineralization of soil organic matter. If mineralization is accelerated, more S is released and available to the crop.

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Table 2. Effect of rate of applied sulfur on forage yields of five legumes measured in 1993.

Legume	Cutting	0	25	50
		---------- ton dry matter/acre ---------		
alfalfa	1	1.06	.86	.94
	2	1.34	1.40	1.22
	3	1.14	1.18	1.51
	Total	3.54	3.44	3.67
birdsfoot trefoil	1	2.58	2.59	2.48
	2	2.03	2.26	2.08
	Total	4.61	4.85	4.56
cicer milkvetch	1	2.09	1.94	2.18
	2	1.72	1.58	1.60
	Total	3.81	3.52	3.78
kura clover	1	2.67	2.73	2.50
	2	1.28	1.40	1.41
	Total	3.95	4.13	3.91
red clover	1	2.04	2.23	1.96
	2	2.39	2.73	2.27
	Total	4.43	4.96	4.23

MATCHING PLANT POPULATION AND FERTILIZER MANAGEMENT FOR PROFITABLE CORN PRODUCTION

D. Allan, G. Rehm, J. Johnson, A. Scobbie, T. Sellie, and D. Hicks[1/]

ABSTRACT: This study was initiated to investigate the relationship between plant population and fertilizer management. The results from the 1993 growing season are summarized in this report. The response of corn to planted population and potash fertilizer management in 1993 was consistent with the response measured in 1992 even though corn growth and development was hindered by the excessively cool and wet growing season. A planted population of 33,000 plants per acre was adequate for optimum silage and grain yield. When soil test values were low, there was a strong response to K_2O use with 40 lb. K_2O per acre applied in a starter equivalent to the broadcast application of 200 lb. K_2O per acre. Root density at the low K site was affected by both planted population and potash fertilization. There was a general decrease in average root length per plant when the planting density was increased. The potash fertilization caused higher root densities and deeper development of roots in the inter-row area. Even though root development was probably hindered by cooler than normal soil temperatures, this observation has important implications for root development in dry years.

Introduction:

Corn plant populations used by Minnesota farmers have increased slightly during recent years. Research conducted in the Department of Agronomy and Plant Genetics over the last five years showed marked increases in grain yield when populations were increased to 40,000 plants per acre with high soil fertility levels. This population represents a 70% increase over current averages. Before recommendations can be made for higher plant populations, it is necessary to fine tune the plant density and fertilizer management interactions for a range of fertility conditions.

Objectives:

The broad objective of this research project is to determine the fertilizer use strategies that result in the most efficient use of P and K over a range of plant densities when corn is grown on soils testing either low or high for either P and/or K.

Specific objectives are to determine the effect of plant population and fertilizer management strategies on:

- total dry matter yield
- grain yield
- early growth of corn
- root distribution and density
- nutrient uptake early in the growing season
- residual NO_3-N in the soil after maturity

Results and Conclusions:

In 1993, the study was limited to the evaluation of potash fertilizer management in combination with five plant densities. Two sites with widely different soil test values for K were selected in Goodhue County. The results of analysis of soil samples collected before fertilizer application are summarized in Table 1.

Table 1. Relevant soil test values for the experimental sites used in 1993.

Test Parameter	Depth	Site: High K	Site: Low K
	in.		
pH	(0-6)	7.3	7.1
P (Bray #1,) ppm	(0-6)	70	21
K (1N $NH_4C_2H_3O_2$), ppm	(0-6)	226	92
	(6-12)	146	68
	(12-24)	98	96
	(24-36)	89	94

Soil test values for K were substantially different to a depth of 12 inches after which they were nearly equal for both sites. Broadcast fertilizer treatments were applied in late April and corn was planted on May 7. Each treatment received some phosphate (23 lb. P_2O_5/acre) in a starter band at planting. The N was supplied as 46-0-0 at a rate to supply 180 lb. N/acre that was incorporated along with the broadcast 0-0-60 before planting. Corn followed a 1992 soybean crop at both locations. The hybrid used at both sites was Asgrow RX578.

A detailed soil sampling pattern was used at 58 and 72 days after emergence in an effort to measure root density. Whole plants were also collected when root samples were taken. These samples were dried, weighed, ground, and analyzed for K. Potassium uptake was computed.

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Total dry matter at physiological maturity and grain yields were measured. Soil samples were collected to a depth of 3 feet after harvest and analyzed for NO_3N.

The stand count was taken approximately 50 days after planting and the results are summarized in Table 2.

Table 2. Measured stand at approximately 50 days after emergence.

Desired Population	Site: Low K	Site: High K
plants/acre	--- plants/acre ---	
23,000	22,542	23,850
28,000	28,641	29,730
33,000	31,418	33,324
38,000	35,120	37,462
43,000	39,912	42,689

For most densities, the measured emerged stand was close to the desired population.

Dry matter yields for the 1st and 2nd samplings for the site having a low soil test for K are summarized in Table 3. Similar yields for the site having the high K test are listed in Table 4.

Table 3. The effect of plant population and management of potash fertilizer and dry matter production of young plants at the low K testing site.

		Desired Population (plants/acre)				
K_2O Applied	Placement	23,000	28,000	33,000	38,000	43,000
lb./acre		----------- lb./acre -----------				
1st sampling:						
0	-	300	386	386	449	324
40	starter	342	412	426	493	481
100	broadcast	369	451	432	449	533
200	broadcast	309	380	472	435	528
2nd sampling:						
0	-	1948	2360	2026	2483	2256
40	starter	2074	2385	2468	2741	2522
100	broadcast	2023	2466	2673	2537	2909
200	broadcast	2126	2416	2171	2289	2931

At the low testing site, dry matter at the time of the 1st sampling was affected by both planted population and management of the potash fertilizer. When averaged over all fertilizer management options, the use of K_2O increased the dry matter production at the first sampling. When compared to the control, addition of potash increased dry matter production with starter being equivalent to broadcast applications.

For the 2nd sampling, treatment effects were similar to those measured for the first sampling. Again, use of 40 lb. K_2O per acre (Table 4) in a starter fertilizer produced dry matter that was equivalent to dry matter production resulting from broadcast applications. For both samplings, there was no significant interaction between planted population and management options for potash fertilizer.

Table 4. The effect of plant population and management of potash fertilizer and dry matter production of young plants at the high K testing site.

		Desired Population (plants/acre)				
K_2O Applied	Placement	23,000	28,000	33,000	38,000	43,000
lb./acre		----------- lb./acre -----------				
1st sampling:						
0	-	313	367	402	425	597
20	starter	307	425	454	499	564
2nd sampling:						
0	-	2265	2884	2777	2923	3438
20	starter	2445	2808	2784	3110	3383

Dry matter production by young plants was affected by the planted population, but not the use of K_2O in a starter, at the site with the high soil test for K (Table 4). There was no significant interaction between planted population and potash fertilizer use at this site.

All plant samples have been ground and submitted to the Research and Analytical Laboratory for K analysis. This analysis has not been completed at the time of preparation of this report.

Dry matter yields measured at physiological maturity are summarized in Tables 5 and 6. At the site with the low K test, both potash fertilization and planted population increased the total amount of dry matter produced (Table 5). Optimum dry matter production was achieved with a planted population of 33,000 plants per acre. When averaged over all planted populations, the use of 40 lb. K_2O per acre in a starter fertilizer was equivalent to the broadcast application of both 100 and 200 lb. K_2O per acre.

Table 5. The effect of planted population and application of potash fertilizer on total dry matter production at the site having a low soil test value for K.

K_2O Rate	Placement	Planted Population (plants/acre)				
		23,000	28,000	33,000	38,000	43,000
lb/acre		-------- ton dry matter/acre --------				
0	-	5.15	5.34	5.55	5.77	5.47
40	starter	6.22	6.34	6.16	6.53	6.14
100	broadcast	5.50	5.92	6.36	6.14	5.93
200	broadcast	5.41	6.19	6.77	6.70	6.23

For the site with the high K soil test, total dry matter yield was affected only by planted population (Table 6). As was the case with the site with the low K test, the optimum planted population was 33,000 plants per acre.

Table 6. The effect of planted population and use of potash in a starter fertilizer on total dry matter production at the site having a high soil test for K.

K_2O Rate	Placement	Desired Population (plants/acre)				
		23,000	28,000	33,000	38,000	43,000
lb./acre		------- ton dry matter/acre -------				
0	-	6.63	7.06	7.01	7.68	7.67
20	starter	7.00	6.93	7.41	6.95	7.21

The treatment effects on grain yield were consistent with the effects on total dry matter production at the site with the low soil test for K (Table 7). The highest yields were associated with a planted population of 33,000 plants per acre. Yields resulting from the use of 40 lb K_2O per acre in a starter were equivalent to yields resulting from the broadcast application of 100 and 200 lb. K_2O per acre. At this site, the effect of K_2O management option on early growth of corn was reflected in final dry matter and grain yields.

Table 7. The effect of planted population and application of potash fertilizer on corn grain yield at the site having a low soil test for K.

K_2O Rate	Placement	Planted Population (plants/acre)				
		23,000	28,000	33,000	38,000	43,000
lb/acre		---------- bu./acre ---------				
0	-	111.4	119.2	124.1	115.7	114.7
40	starter	122.0	123.7	130.6	130.3	124.4
100	broadcast	124.1	126.5	124.8	118.5	110.8
200	broadcast	122.2	128.9	129.2	125.5	112.5

Yields in 1993 were not as high as expected because of the cool, wet growing season. Yet, effects of plant population were consistent over three years including the highly productive year of 1991.

Grain yield at the site with the high soil test for K was not affected by either the plant population or the use of 20 lb. K_2O per acre in the starter fertilizer (Table 8). These results are not consistent with those of the previous two years. However, the excessively cool and wet growing season may have affected the yield response to plant population.

Table 8. The effect of planted population and use of potash in a starter fertilizer on corn grain yield at the site having a low soil test for K.

K_2O Rate	Placement	Desired Population (plants/acre) 23,000	28,000	33,000	38,000	43,000
lb./acre		-------- bu./acre --------				
0	-	138.3	141.5	144.8	141.8	133.5
20	starter	145.8	142.5	132.8	135.5	134.3

In 1993, core samples were taken at 58 and 72 days after planting for measurement of root density. At each sampling, cores were taken to a depth of 24 inches at 3, 6, and 12 inches from the row. The cores were subdivided into depth increments of 0-3, 3-6, 6-12, and 12-24 inches. Soil was washed from the roots and root length was measured. Root density was not measured for each treatment. Two plant densities (23,000, 33,000 plants per acre) were selected at both sites. At the low K site, the control, 100 lb. K_2O per acre, and 200 lb. K_2O per acre broadcast management options were sampled for each density. The control only at each of the two plant densities was sampled at the high K site. Sampling date was based on stage of growth rather than days after planting. The cool weather delayed growth in 1993. Consequently, the days after planting used for sampling were not consistent with those in 1992.

In both 1992 and 1993, there was a general increase in root density (root length per unit volume of soil, cm/cm^3) with the higher planted population for the first sampling date. The percentage increase was less in 1993 (20%) compared to 1992 (50%) at the low K site. This trend, however, was reversed at the high K site in 1993. At this site, the root density was 30% higher at the planted population of 23,000 plants per acre.

Root density can also be computed on an individual plant basis. When this calculation is made, there is a very different trend (Table 9). At 46 days after planting in 1992, the average length of root per plant increased only a few percent with the higher planted population. At 59 days after planting in the same year, the average root density decreased by 14% (high K site) to 41% (low K site) when the planted population increased from 23,000 to 33,000 plants per acre.

At 58 days after planting in 1993 (first sampling), root length per plant decreased by 16-18% when planted population increased from 23,000 to 33,000. The average root length per plant decreased by 30% (low K site) to 47% (high K site) sampling as planted population was increased. Thus, while there were more roots per unit volume of soil when population increased from 23,000 to 33,000 plants per acre, there were generally fewer roots when root length was expressed on an individual plant basis.

Table 9. Mean root length per plant as affected by plant population and relative soil test level in 1992 and 1993.

Year	Planted Population	Time of Sampling and Soil Test Level: 46 DAP High K	46 DAP Low K	59 DAP High K	59 DAP Low K
	plants/A	----------- m/plant* ---------			
1992	23,000	47.5	116.1	89.7	168.9
	33,000	51.5	121.4	77.3	99.3
		58 DAP High K	58 DAP Low K	72 DAP High K	72 DAP Low K
1993	23,000	100.3	116.1	216.4	110.9
	33,000	84.6	95.7	114.1	77.3

*Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position, then calculating the mean root length per plant to a depth of 2 ft.

There was a significant interaction between planted population and root density measured at various positions in 1993. At the low K site and the 1st sampling, the higher planting density had higher inter row root densities in the top 6 inches but lower inter row root densities at 6-24 inches (Table 10).

Table 10. Root density at 58 DAP for the low K site in 1993 as affected by fertilizer application.

K_2O Applied	Distance from row	Depth of Sample (inches) 0-3	3-6	6-12	12-24
lb/A	inches	cm/cm³			
0	3	0.55	0.65	0.18	0.02
	6	0.20	0.35	0.19	0.02
	12	0.01	0.12	0.04	0.01
100	3	0.67	0.68	0.22	0.06
	6	0.23	0.17	0.13	0.04
	12	0.03	0.17	0.13	0.01
200	3	0.42	0.66	0.38	0.05
	6	0.21	0.67	0.18	0.06
	12	0.07	0.19	0.07	0.03

Fert X Position p = 0.05

There was also a significant interaction between potash management and root density at this site in 1993. In general, there was more root development to greater depths and further from the row when broadcast potash was used. Fertilizer use appeared to have a smaller effect on root density close to the plant.

The average root density was enhanced by potash application at the low K site in both 1992 and 1993 (Tables 11, 12). The application of 100 lb. K_2O per acre always maximized root density with a bigger response recorded in 1992 compared to 1993. The broadcast application of 200 lb. K_2O per acre also increased root density when compared to the control. The increase, however, was generally not as great as the increase produced by the 100 lb. K_2O per acre rate.

Table 11. Mean root density in 1992 as affected by soil test level and fertilizer applied at the low K site when sampled at 46 and 59 DAP.

Soil Test Level	Fertilizer Applied	Sampling Time 46 DAP	59 DAP
	lb. K_2O/A	cm/cm³	
High	-	.11*	.19
Low	0	.15	.20
Low	100	.38	.36
Low	200	.27	.28
	Pr>F	.001	.01

* Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Table 12. Mean root density in 1993 as affected by soil test level and fertilizer applied at the low K site.

Soil Test Level	Fertilizer Applied	Sampling Time 58 DAP	72 DAP
	lb K_2O/A	cm/cm³	
High	-	0.21	0.36
Low	0	0.20	0.15
Low	100	0.27	0.23
Low	200	0.25	0.25
	Pr>F	0.008	0.0001

* Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Considering planted populations in 1993, there was a larger increase in average root density produced by fertilization at the higher population (Table 13). This is in contrast to 1992 when the trend was for a greater effect of fertilization at the lower plant population.

Table 13. Mean root density as affected by fertilizer application and plant population at the early sampling times in 1992 and 1993.

Fertilizer	1992 (46 DAP) Plant Population		1993 (58 DAP) Plant Population	
Applied	23,000	33,000	23,000	33,000
lb K_2O/A	---------- cm/cm^3 -----------			
0	0.11	0.20	0.21	0.18
100	0.31	0.43	0.25	0.29
200	0.22	0.32	0.19	0.32

Fert X Pop $p = 0.98$ in 1992 and 0.002 in 1993.

Interpretive Summary:

The response of corn to planted population and potash fertilizer management in 1993 was consistent with the response measured in 1992 even though corn growth and development was hindered by the excessively cool and wet growing season. When the soil test for K was in the low range, early growth was increased as plant population increased to about 33,000 plants per acre. This early growth response was reflected in total dry matter production and grain yield. As might be expected, there was a strong response to potash fertilization. The use of 40 lb. K_2O per acre in the starter was highly efficient and yields from this potash management option were equivalent to yields produced by higher broadcast rates of K_2O.

Potash fertilizer use had no impact on early growth and yield when the soil test K was high. At this site, dry matter production, but not grain yield, was optimum when the planted population was 33,000 plants per acre.

Root density at the low K site was affected by both planted population and potash fertilization. There was a general decrease in average root length per plant when the planting density was increased. The potash fertilization caused higher root densities and deeper development of roots in the inter-row area. Even though root development was probably hindered by cooler than normal soil temperatures, this observation has important implications for root development in dry years.

USE OF IN-SEASON NIR PLANT N TEST TO PREDICT N REQUIREMENTS FOR HARD RED SPRING WHEAT[1]

J.A. Lamb, G.W. Rehm, S.D. Evans, N. Martin, G.L. Malzer, G. Nelson, J. Cameron, and B.J. Holder[2]

ABSTRACT: This report is on the third year of research to determine in-season nitrogen need for hard red spring wheat by utilizing a predictive plant or soil test. Nine locations in western Minnesota were established with three soil N levels (50, 100, and 150 lb A^{-1}; 0 to 2 foot nitrate-N plus fertilizer) and five topdress N application (0, 15, 30, 45, and 60 lb N A^{-1}) at tiller growth stage. Results indicate in seven of nine sites the topdress application of N did improve grain yield. Chloropyll meter readings did indicate grain responses in six locations. The relationship between chlorophyll meter readings and grain yield increase was -0.46. The soil nitrate-N test for the 0 to 1 foot depth did characterize the soil N levels. The correlation between soil nitrate-N and grain yield increase was -0.42.

Nitrogen fertilizer management is important for optimum grain yield and protein of hard red spring wheat in western Minnesota. Efficient use of nitrogen fertilizers has direct effects on farm profitability as well as environmental quality. Because of soils with silty clay loam textures and spring moisture conditions, nitrogen fertilizers are typically applied in the fall when soil conditions are more suited to application. Currently, the combination of a soil nitrate-N test and an estimated yield goal is used to arrive at fertilizer N recommendations. There are two problems with this method of arriving at nitrogen recommendations for this production system. First, it is very difficult to arrive at a realistic yield goal in the fall because of changing climatic conditions during the winter and before spring planting. Secondly, there is the potential for the loss of N either from poor application techniques, leaching, or denitrification. The use of a quick and simple diagnostic test shortly before tillering would allow the producers to adjust the amount of N fertilizer needed in the growing season based on a better knowledge of plant stand, soil moisture conditions, and a more accurate weather forecast. The diagnostic test would allow wheat growers to apply 50 to 60 percent of the N fertilizer in the fall and determine how much of the remainder to apply at the tiller stage.

The objective of this study is to develop the use of diagnostic tools such as NIR (near infrared reflectometry) plant analysis for N content, a soil nitrate-N test, or a chlorophyll meter to adjust N fertilizer application to spring wheat during the growing season.

Materials and Methods

Nine experimental sites were established in western Minnesota in 1993 (Table 1). The initial soil nitrate-N at the sites ranged from 14 to 118 lb A^{-1} at the 0 to 2 foot depth. To meet the objective the treatments included a factorial design of three soil nitrate-N levels (0 to 2 foot of 50, 100, and 150 lb A^{-1}) and five topdress N application rates (0, 15, 30, 45, and 60 lb N A^{-1}). The soil N levels were established by applying fertilizer preplant. This was ammonium nitrate (33-0-0) at all sites. At locations with initial soil nitrate-N contents greater than 50 lb/A 0-2 foot (Wagner and Brandt S) 20, 70, and 120 lb N/A were added. Norm hard red spring wheat was seeded at 100 lb A^{-1} in six inch rows with a double disk press wheel drill. Topdress application of ammonium nitrate was made at the late tiller growth stage. Just before application whole plant samples, soil samples, and chlorophyll meter measurements were taken. Whole plants were taken from two feet of row for Kjeldahl total N, NIR total N, and NIR crude protein analyses. Soil samples to a two foot depth were taken and divided into one foot increments. These soil samples were analyzed for nitrate-N. Chlorophyll meter readings were taken from random plants in each plot. Weed control was obtained with post emergence application based on weed species and density at each location. The plots were harvested with a plot combine. The grain yield was then corrected to 13.5 % moisture. All locations in 1993 were infected with scab. No attempt was made to separate scabby kernels from the yield sample.

Table 1. Initial characteristics of 1993 NIR wheat experiment locations.

	Nitrate-N 0-24 in.	Phosphorous	Potassium	pH	Organic Matter
			0 - 6 in.		
Location	lb A^{-1}	--------- ppm ---------			%
Bring	28	7	165	7.7	3.7
Widner	20	7	366	7.9	3.2
Knutson	14	13	326	8.0	3.6
Wagner	94	27	131	8.1	
Cassavan	16	14	313	7.7	4.2
Brandt N	37	16	173	7.8	5.2
Brandt S	118	43	149	7.9	
Morris N	18	12	226	7.7	4.8
Morris S	20	17	152	7.8	4.1

[1] This report is for the third year of this study which has been partially funded by Minnesota Wheat Research and Promotion funds.

[2] J.A. Lamb, G.W. Rehm, and G.L. Malzer are Associate Professor and Professors in the Soil Science Department at the University of Minnesota; N. Martin is a Professor in the Department of Agronomy and Plant Genetics at the University of Minnesota, St. Paul, MN; S.D. Evans and G. Nelson are Professor and Assistant Scientist at the West Central Experiment Station, University of Minnesota, Morris, MN; B.J. Holder and J. Cameron are Associate Professor and Field Plot Technician at the Northwest Experiment Station, Crookston, MN 56716.

Grain Yields

At five of the nine locations there was no interaction between the soil N level and topdress N application for grain yield (Table 2). At the Brandt S location soil N level did not effect grain yield and topdress N application significantly decreased grain yield. This location has had a history of manure application which caused the nonresponse to soil N. The other four locations had increases to grain yield from soil N level. These increases ranged from 2.7 to 9.4 bu/A.

Four locations had a significant soil N by topdress N interaction (Tables 3 and 4). At Wagner, Morris N, and Morris S, at the 50 soil N level, topdress N application of 30, 60, and 45 lb/A, respectively, was needed to maximize grain yield. Although 60 lb N/A was needed at Morris N for maximum yield, the largest part of the increase came with only 15 lb N/A. For the 100 and 150 soil N levels for Wagner, Morris N, and Morris S, topdress N did not significantly increase yields. At the Cassavan site, grain yield responses to topdress N application occurred at all soil N levels. The grain yields were the largest at 60 lb/A topdress N application for the 50 and 100 soil N levels. At the 150 soil N level, grain yield was maximized at 45 lb N/A.

Table 2. Grain yield at locations with no statistical significant interactions in 1993.

Soil N	Bring	Widner	Knutson	Brandt N	Brandt S
lb/A			bu/ A		
50	29.6	21.1	33.2	44.7	46.8
100	32.4	26.6	36.8	47.0	47.7
150	33.9	30.5	37.3	47.4	46.7
Topdress N					
0	30.2	22.2	31.4	43.4	49.7
15	31.4	23.9	34.3	47.2	47.4
30	32.0	26.2	36.3	46.7	47.7
45	33.1	27.6	38.4	47.7	46.1
60	32.9	30.5	38.6	46.9	44.4
Statistical Analyses					
Soil N (SN)	**	**	**	*	NS
Topdress N (TN)	+	**	**	*	**
TN linear	*	**	**	*	**
TN quadratic	NS	NS	+	*	NS
SN X TN	NS	NS	NS	NS	NS
C.V. (%)	9.4	21.8	9.7	7.0	6.5

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

Table 3. Grain yield at locations with a soil N by topdress N interaction.

	Topdress N (lb/A)				
Soil N	0	15	30	45	60
lb/A		Grain Yield (bu/A)			
		Wagner			
50	49.7	56.6	58.2	56.6	60.8
100	62.3	59.6	62.5	61.3	61.9
150	62.1	62.0	59.0	61.2	63.9
		Cassavan			
50	29.3	36.6	39.6	43.6	46.3
100	39.8	44.2	48.0	48.2	50.9
150	48.0	48.2	50.5	52.5	52.4
		Morris N			
50	33.0	39.6	40.3	42.1	42.8
100	40.3	42.8	43.3	40.7	40.3
150	39.8	38.1	40.1	39.5	35.9
		Morris S			
50	29.2	28.5	29.0	36.6	32.0
100	36.6	36.0	37.1	36.8	37.6
150	39.9	37.0	37.2	35.4	35.2

Table 4. Statistical analyses for grain yield at locations with soil N by topdress N interaction in 1993.

	Wagner	Cassavan	Morris N	Morris S
Soil N (SN)	**	**	NS	**
Topdress N (TN)	*	**	++	NS
TN linear	**	**	+	NS
TN quadratic	NS	+	**	NS
SN X TN	**	*	**	**
C.V. (%)	4.8	6.6	7.8	7.5

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

Table 5. Soil nitrate-N and chlorophyll meter readings at tiller in 1993.

Site	Soil N	Chlorophyll Meter	Soil Nitrate-N 0-1 ft.	1-2 ft.	0-2 ft.
	lb/A	units	lb/A		
Bring	50	43.2	20.8	10.3	31.1
	100	43.5	40.2	21.0	61.2
	150	45.3	104.4	20.3	124.7
Statistic		**	*	NS	**
Widner	50	39.9	23.9	11.3	35.2
	100	41.3	43.3	13.2	56.5
	150	41.6	93.9	20.9	114.8
Statistic		++	**	++	**
Knutson	50	36.9	14.9	5.9	20.8
	100	38.8	36.7	7.9	44.6
	150	39.1	79.8	8.0	87.8
Statistic		NS	*	NS	*
Wagner	50	40.0	39.5	8.6	48.2
	100	40.9	149.8	17.4	167.2
	150	41.5	168.9	15.4	184.3
Statistic		*	*	*	*
Cassavan	50	40.3	26.1	8.2	34.3
	100	41.4	46.5	14.6	61.1
	150	41.5	122.2	18.3	140.5
Statistic		+	**	*	**
Brandt N	50	39.9	57.7	7.6	74.9
	100	40.8	55.5	9.5	65.0
	150	40.9	92.7	12.0	104.7
Statistic		+	NS	NS	NS
Brandt S	50	41.2	23.6	8.4	32.0
	100	42.1	53.0	9.3	62.3
	150	42.9	105.7	13.4	119.1
Statistic		++	**	++	**
Morris N	50		15.7		
	100		30.4		
	150		53.2		
Statistic			**		
Morris S	50		30.6		
	100		36.9		
	150		45.9		
Statistic			*		

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

In Season Tests

Chlorophyll Meter

Chlorophyll meter readings were taken at seven of the nine locations in 1993 at tiller stage before the topdress N application was made (Table 5). At six locations significant differences (P= 0.20) occurred. As the amount of soil N increased the chlorophyll (greenness of the plant) readings increased. The differences in the readings are smaller than expected and observations are depended on the location on the leaf that the reading is taken. The relationship between chlorophyll meter units and grain yield increase from topdress N has a correlation of -0.46.

Soil Nitrate-N at Tiller Growth Stage

Soil nitrate-N was also measured at tiller growth stage before the topdress N treatments were applied. A significant increase occurred at eight of nine locations from soil nitrate-N at the 0 to 1 foot depth. As soil N level was increased so was the soil nitrate-N content. The increase was best measured in the 0 to 1 foot depth. The 0 to 2 foot depth nitrate-N content was similar in response to soil N level. Figure 2. shows the relationship between soil nitrate-N and grain yield increase from topdress N application. Because of the prior manure history Brandt S was omitted from the analysis. The correlation between grain yield increase and soil nitrate-N at 0 to 1 foot depth is - 0.42.

IMPROVING FERTILIZER RECOMMENDATIONS FOR PRODUCTION OF EDIBLE BEANS IN MINNESOTA

George Rehm, Thor Sellie, and Andy Scobbie[1/]

ABSTRACT: This research project was initiated in 1991 in an effort to improve fertilizer recommendations for edible bean production. The results from sites at this Irrigation Center at Staples are summarized in this report. When N rates were studied, the application of 120 lb. N per acre produced optimum yield. This N was applied at two times during the growing season. There was no response to potassium and sulfur applied in a fertilizer program in 1993.

A research project was initiated in 1991 to improve fertilizer recommendations for the production of edible beans in Minnesota. The project was continued in both the 1992 and 1993 growing seasons. The information gathered during the 1993 growing season is summarized in this report. Data collection was curtailed by the excessively cool and wet growing season. Because of these conditions, information was not gathered from sites in Renville, and Yellow Medicine Counties. Treatments were applied at each site but the test sites were flooded and the edible beans were destroyed. Useful data were gathered from the experimental sites at the Staples Irrigation Center.

Objectives:

As in 1991 and 1992, the objectives of the research project are:

1. To improve nitrogen fertilizer recommendations for edible bean production. For much of the production area, this means improving N fertilizer recommendations by adjusting for residual or carryover NO_3-N. Where production occurs on sandy soils, improvement of nitrogen recommendations means that more emphasis should be placed on nitrogen credits from previous legume crops used in the rotation.
2. To determine the rate of phosphate needed when the crop is grown on fine-textured soils and relate the rate needed to soil test values for P.
3. To determine the response of edible beans grown on sandy soils to the application of both potash and sulfur.

Experimental Procedure:

Original plans called for an evaluation of nitrogen rates at 4 sites, an evaluation of phosphate rates at 3 sites, potash rates at 1 site, and sulfur rates at 1 site. Because of the excessively wet growing season, N rate evaluations were lost at 2 sites and phosphate rate evaluations were lost at all 3 sites. Yields were measured from a N rate site in Renville county, but they were variable and were of no use. Consequently, data from the plots at the Irrigation Center are summarized in this report.

For the potassium study, adequate rates of phosphate and sulfur were applied to each treatment. The various rates of potash supplied as 0-0-60 were also broadcast before planting. All materials were incorporated with a disk.

For the sulfur study, adequate rates of phosphate and potash were applied to each treatment. The various rates of sulfur supplied as granular gypsum were also broadcast before planting. All of these fertilizer materials were incorporated with a disk.

Each treatment in the nitrogen trial received adequate phosphate, potash, and sulfur. These fertilizers were broadcast and incorporated with a disk before planting.

For the potassium and sulfur studies, the N rate was constant for all treatments at 120 lb. per acre. A split application of nitrogen was used for all studies. The first half of the nitrogen was applied at approximately 2 weeks after emergence. The remaining half was applied at approximately 4 weeks after emergence.

Soil samples (0-6 in.) were collected from the site before fertilizer was applied. The relevant soil properties are summarized in Table 1. The red kidney beans were planted in late May, irrigated as needed throughout the summer, and harvested in September.

Table 1. Relevant soil properties for the experimental site at the Irrigation Center at Staples.

pH	6.8
Bray and Kurtz #1P, ppm	34
soil test K, ppm	100

Results and Discussion:

The excessively cool and wet conditions during the 1993 growing season destroyed the edible beans that were planted on the fine textured soils at the experimental sites in Renville and Yellow Medicine Counties. Therefore, results presented in this report are limited to the experimental site at the Irrigation Center at Staples.

Nitrogen fertilization produced a significant increase in yield. The rate of 120 lb. per acre was adequate for optimum yield (Table 2). These results are consistent with those recorded from nitrogen trials on the sandy soils in 1991. The major portion of the response occurs with the use of the first 30 lbs. N per acre.

[1/] Extension Soil Scientist, Junior Scientist, and Assistant Scientist, Soil Science Department, University of Minnesota, respectively.

Table 2. Effect of rate of fertilizer nitrogen on yield of red kidney beans in 1993. Irrigation Center.

N Applied	Yield
lb./acre	lb./acre
0	2353
30	2630
60	2830
90	2953
120	2999
150	2968

The yield of the red kidney beans was not significantly affected by the rate of K_2O applied (Table 3). Even though the soil test for K would be considered to be in the low range (Table 1), there was apparently enough K supplied by the soil to meet the needs of the crop. The results recorded in 1993 are consistent with those reported in both 1991 and 1992.

Table 3. Effect of rate of applied potash on yield of red kidney beans in 1993. Irrigation Center.

K_2O Applied	Yield
lb./acre	lb./acre
0	3058
60	3004
120	3015
180	2960
240	3071

Sulfur fertilization also had no significant effect on the yield of red beans (Table 4). These results are also consistent with the conclusions reached in 1991 and 1992. In the past, sulfur fertilization has increased the yield of corn and alfalfa grown on the sandy soil. However, sulfur uptake by edible beans is in the range of 5 to 10 lb./acre. This amount of sulfur can be easily mineralized from the soil organic matter. Therefore, a major response to sulfur fertilization should not be expected.

Table 4. Effect of rate of applied sulfur on the yield of red kidney beans in 1993. Irrigation Center.

S Applied	Yield
lb./acre	lb./acre
0	2813
10	2951
20	2952
30	2792

EVALUATION OF BROILER MANURE AS AN N SOURCE FOR POTATO[1]

C.J. Rosen, J.F. Moncrief, and M.J. Blaine[2]

Abstract: Broiler manure, on average, resulted in higher potato yields than a commercial nitrogen program. Manure reduced the amount of knobby potatoes and hollow heart. Scab was not affected by fumigation or manure. When manure was used in combination with fumigation yields were 100 cwt higher than without fumigation. However, This treatment also had significantly higher soil water concentrations of nitrate.

The objective of this experiment is to evaluate broiler manure as an N source for Russet Burbank potatoes. There has been some concern that manure will increase the incidence of scab on potatoes and is not as reliable a source of N as commercial fertilizer.

Methods and Materials: Pen pack, scraped, and piled manure was applied in the spring (April 19, 1993) before discing. The previous crop was corn. The rate of manure was based on a chemical analysis to result in an estimated available N of about 200 pounds per acre. The analysis of samples taken the day of application are shown in Table 1. The moisture content was quite variable and responsible for most of the variability in the chemical analysis. Most of the N in the manure was in the organic form (75% vs 25% for organic and mineral N respectively). It is assumed that all of the mineral N is available in the year of application and 0.35 of the organic N. This results in an average of 26.5 pounds of estimated available N per ton of manure. Manure was applied with a beater type solid manure spreader. Three calibration checks over an area of 300 ft.x 27 ft. resulted in an application of 8.4, 7.8, and 8.9 tons per acre with an average of 8.4 tons per acre. This resulted in an application of **223 lbs/A of estimated available N** as broiler manure. The manure treatment also received 30 pounds of N at planting and 69 pounds of fertigation N resulting in a total N application of **322 lbs/A** (Table 2). The manure treatment was contrasted to a conventional fertilizer program with a total N application of **275 lbs/A.**

Nitrogen sources were evaluated on soil that had been fumigated in the fall of 1992 and soil that was not. It was hypothesized that fumigated soil would result in slowed microbial nitrogen transformations that could affect crop N availability and/or leaching losses. The experimental design was a randomized complete block with split plots. Main plots were fumigation, subplots were N source. Plots were 300 ft.x 54 ft. Ceramic suction samplers were placed in the row at a depth of 4 feet.

Results and Discussion: Potato yields are shown in Table 3. There was only statistical significance for fumigation for the 6-14 oz size. Generally, fumigation main effects were absent for potato yield and quality parameters. There was a consistent effect of manure and a manure by fumigation interaction for most of the measured yield categories. The manure N source resulted in higher potato yields when applied in combination with fumigation. A significant manure effect was absent when applied without fumigation. Precise reasons for this interaction are not known, but may be due to excessive N applications on the nonfumigated side due to an application error. Manure affected several quality parameters. When manure was applied with fumigation, knobby potatoes were significantly reduced. Manure with or without fumigation reduced hollow heart. The incidence of scab was not affected by fumigation or manure addition. This is contrary to common grower belief that manure increases scab. The effect of fumigation and N source on soil water concentrations of nitrate at 4 ft. depth are shown in Figure 1. The manure N source resulted in higher concentrations of soil water nitrate throughout the season. The manure in combination with fumigation showed a "spike" between 12 and 14 weeks after planting.

In addition to the manure/fumigation study, a comparison of N timing and amount was done on a split center pivot with the conventional grower program on one half and an N conservative program on the other half. Applications of N were generally reduced and the last application based on a petiole sap test for nitrate. The results of this study are shown in table 4. There was a 40 cwt increase in total yield with the alternative N program. Of course statistics can not be used due to the lack of replication.

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1. This project was supported by the Legislative Commission on Minnesota Resources, the Anoka Sand Plain Project, the Soil Conservation Service, and the Minnesota Extension Service. Their support is greatly appreciated.

2. C.J. Rosen and J.P. Moncrief are Extension Specialists in the Soil Science Department, University of Minnesota, St. Paul, MN. M.J. Blaine is a Best Management Consultant with the Soil Conservation Service, Becker, MN.

Table 1. Nitrogen content of Jack Frost broiler manure applied on 4/19/93.

Slds	NH_4^+	NO_3^-	Min.	Org.[1]	Total	Est.Aval[2]
--%--				lbs/Ton		
54.3	18.2	-	18.2	48.0	66.3	32.6
51.9	18.3	-	18.3	49.7	68.0	33.2
67.5	13.9	-	13.9	41.7	55.6	26.4
82.3	13.3	-	13.3	50.6	63.9	28.5
74.6	9.4	-	9.4	33.7	43.1	19.5
81.9	10.2	-	10.2	27.4	37.6	18.5
68.8	**13.9**	**-**	**13.9**	**41.9**	**55.8**	**26.5**

1. Organic nitrogen = Total nitrogen - Total mineral nitrogen.
2. Estimated available nitrogen=(Org.-Nx.35) + Tot.Min.-N. It is assumed that all of the mineral N and 30% of the Org.N is available during the first year of application.
3. The rate of manure was 8.4 tons/acre.

Table 3. Tillage pesticide application at Becker MN, 1993, previous crop was corn and soil is Hubbard loamy sand.

date	operation
10/7/92	Fall Chisel
10/92	Fumigation on half of the plots with Vapam (Sodium methyldithiocarbamate)
4/19/93	manure applied
4/25/93	Disc finisher
4/30/93	planting 14-16,000 seeds per acre
5/15/93	Dual/Sencor
5/28/93	Row cultivator
6/8/93	Hilling
6/10 to 8/19/93	Monitor, Mancozeb, Bravo, and Ridomil applied in multiple applic.

Table 2. Timing, source, and amount of N applied to the fertilized check, Becker, MN, 1993.

date	application	rate of material	N rate
		------pounds per acre-------	
4/30/93	Starter at planting	455 of 6.5-29.2-19.5	30
5/28/93	Cultivation at Emergence	250 of 33.5-0-0	84
6/8/93	Cultivation at Hilling	200 of 46-0-0	92
7/5/93	fertigation	10.4 gpa of 28% UAN	31
7/16-17/93	fertigation	12.5 gpa of 28% UAN	38
		total	275

Table 3. Effect of Manure and fumigation on potato yield and quality.

Treatment		knobs	<6 oz	6-14oz	>14oz	total	gravity	% hollow heart	% Scab
				cwt/A					
Fumigated	Manure								
-	-	36	236	250	13	535	1.0821	9.3	15.9
-	+	34	251	200	23	508	1.0802	6.7	1.3
+	-	50	214	227	14	505	1.0827	16.0	9.3
+	+	10	295	292	21	618	1.0807	5.3	2.7
Statistics									
Fumigation		NS	NS	++	NS	NS	NS	NS	NS
Manure		*	*	NS	NS	++	NS	++	NS
Fum. x manure		++	++	**	NS	**	NS	NS	NS

NS = nonsignificant, ++ = significant at 10%, * = significant at 5%, significant at 1%.
Estimated N applied for each treatment:
- - = 275 lb N/A
- + = 400 lb N/A (some N fertilizer applied by mistake at emergence and hilling)
+ - = 275 lb N/A
+ + = 322 lb N/A

Table 4. Effect of nitrogen management on potato yield and quality.

Treatment	knobs	<6 oz	6-14oz	>14oz	total	gravity	% hollow heart
			cwt/A				
Conventional	33	217	255	11	516	1.0846	2.0
Alternative	24	201	299	32	556	1.0885	1.3

Timing of application	Conventional N management	Alternative N management
	lb N/A	
Planting (April 20)	31	31
Emergence (May 28)	85	73
Hilling (June 7)	92	70
Post-hilling (July 16)	72	36
Total N applied	280	210

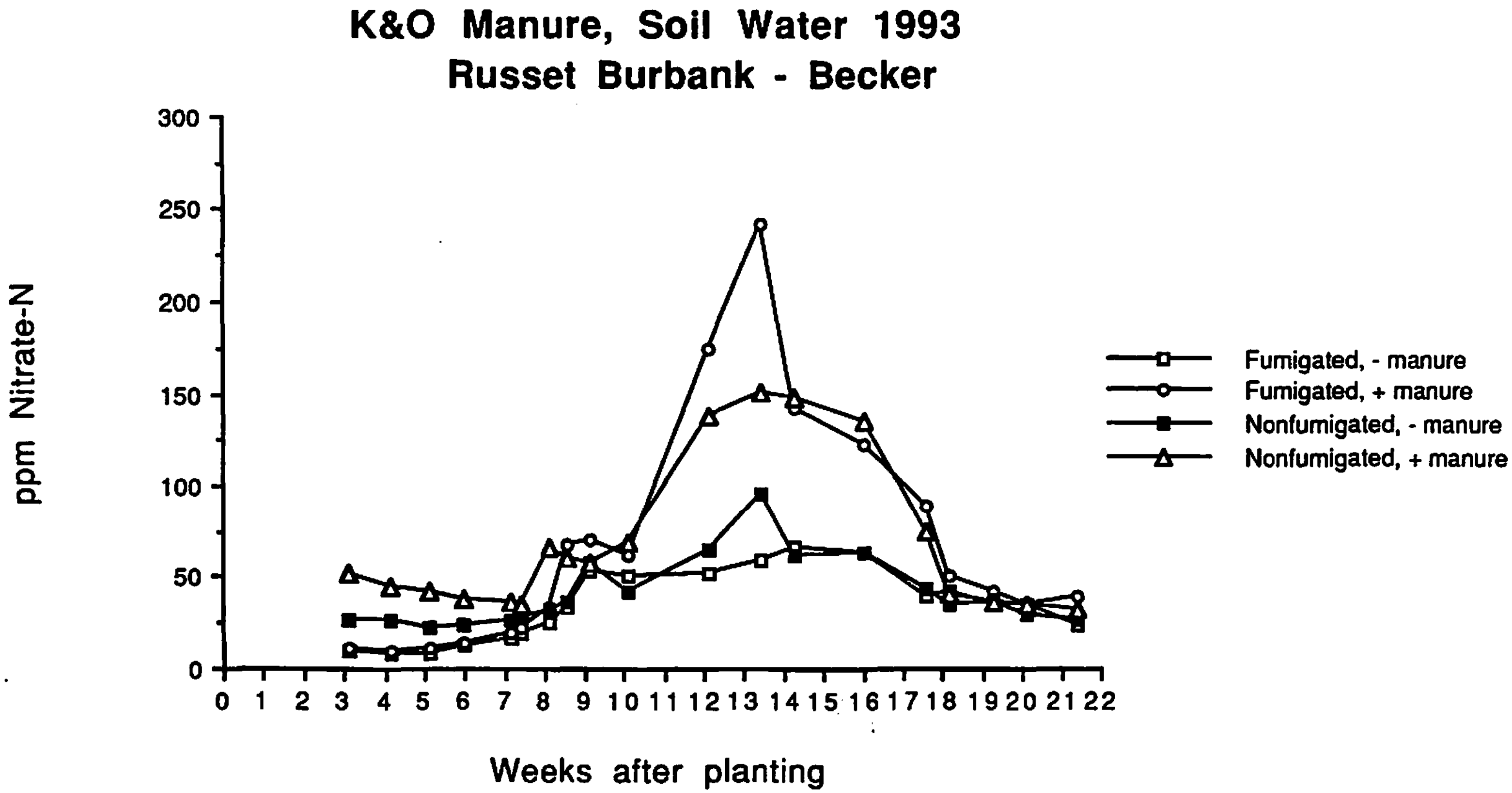


Figure 1. Nitrate-N concentrations in soil water at the 4 ft. depth through the 1993 growing season.

SITE SPECIFIC MANAGEMENT OF CORN HYBRIDS AND PLANT POPULATIONS[1]

D.J. Fuchs, D.R. Huggins, D. Fairchild, and P.C. Robert[2]

Abstract

A field experiment was conducted at the Southwest Experiment Station, Lamberton, MN to evaluate the effect of different soil types on the yields of two corn hybrids (Pioneer 3702 & 3563) and three populations (26,000, 32,000, and 38,000 seeds/ac). The lowest yields and stand counts occurred for both hybrids on the Webster soil when adjacent to the Ves (3-6 % slope) soil. Erosion in those areas reduced stands and yields. Stand counts were relatively consistent in areas without soil erosion. Higher yields across all treatments occurred on soils that had adequate drainage. Yields decreased with target populations greater than 32,000 seeds/ac.

Introduction

Few studies have evaluated corn hybrid and plant population effects on yield across soil types that occur in a landscape setting. This is the second year of an ongoing experiment, the first year's data was corrupted by mechanical problems with the planter and will not be included in this report.

Materials and Methods

A six-row (30-inch spacing) John Deere 7000 planter was used to plant the treatments across a landscape with variable soil types. The main plots were four replications of three target plant populations of: 26,000 seeds/ac, 32,000 seeds/ac, and 38,000 seeds/ac. Each population was split into two corn hybrids, Pioneer 3702 (P3702) and Pioneer 3563 (P 3563), to give a subplot that was 3 rows wide. The area had three major soil types; 1) Ves loam (Udic Haplustols), with slopes ranging from 1-6 percent , 2) Canisteo clay loam (Typic Haplaquolls), and a Webster clay loam (Typic Haplaquolls).

Stand Counts were taken on July 29, 1993. All mechanical weed control was completed before this date, and no factors effected the stand counts after this date. Stand counts, measuring 40-feet of row (2 rows by 20 feet). were taken in 100 foot increments across the field for each subplot (hybrid). Two row plots were harvested on October 28 and 29, 1993 with an Almaco plot combine. The yield samples, approximately 50 feet in length, were collected continuously across the field for each subplot.

Figure 1 and 2 show the yields, stand counts, and soil map of soils for the area. Additional management information is shown in Table 1.

Results and Discussion

Hybrids

Hybrid stand counts and yields varied in a similar pattern across the landscape. Pioneer hybrid 3702 yielded higher at all population levels, averaging 10 bu/ac more than Pioneer 3563.

Plant Populations

The stand counts for both hybrids were less than the targeted population. The Pioneer hybrid 3563 averaged 1770 plants/ac more than Pioneer 3702. For both hybrids there was a trend of increasing yield loss with targeted populations greater than 32,000 plants/ac.

Soil

The soil type had an effect on both corn population and yield. The lowest stand counts and yields occurred where Webster was adjacent to Ves soil (3-6 % slope). Soil erosion occurred in the concentrated flow areas as a result of heavy rains that fell in May and June. Yields were also lower on the poorly drained Canisteo soil. Yields decreased as the transect transitioned into Webster and Canisteo. These poorly drained soils had high moisture levels for the first half of the growing

[1] Support for this project was provided by a grant from the USDA-CSRS, and Soil Teq Inc.

[2] D.J. Fuchs and D.R. Huggins are Scientist and Assistant Professor at the Southwest Experiment Station, Lamberton, MN 56152. D. Fairchild is president of Agri-information Services, Inc., White Bear Lake, MN, 55110. P.C. Robert is Associate Professor of Soil Science Department at the University of Minnesota, St. Paul, MN 55108.

season, which was correlated with poor corn yields. Under the wet conditions of 1993, soil drainage probably had a greater effect on yields than plant population.

Table 1. Management information.

Item	Type	Rate	Date
Primary Tillage	No tillage		
Secondary Tillage	Field Cultivator	2 passes	5/20/93
Fertilizer	Anhydrous	125 lbs N/ac	10/14/92
Herbicides	Eradicane and Bladex	2.5 lbs ai /ac 1.5 lbs ai /ac	5/20/93
Planting	JD 7000 6-row	Variable	5/21/93
Row Cultivation		1 pass	6/20/93
Soil Test	P_2O_5 K_2O pH	35 ppm 175 ppm 6.5	Fall 1992

Figure 1. Corn yields and stand counts across the landscape.

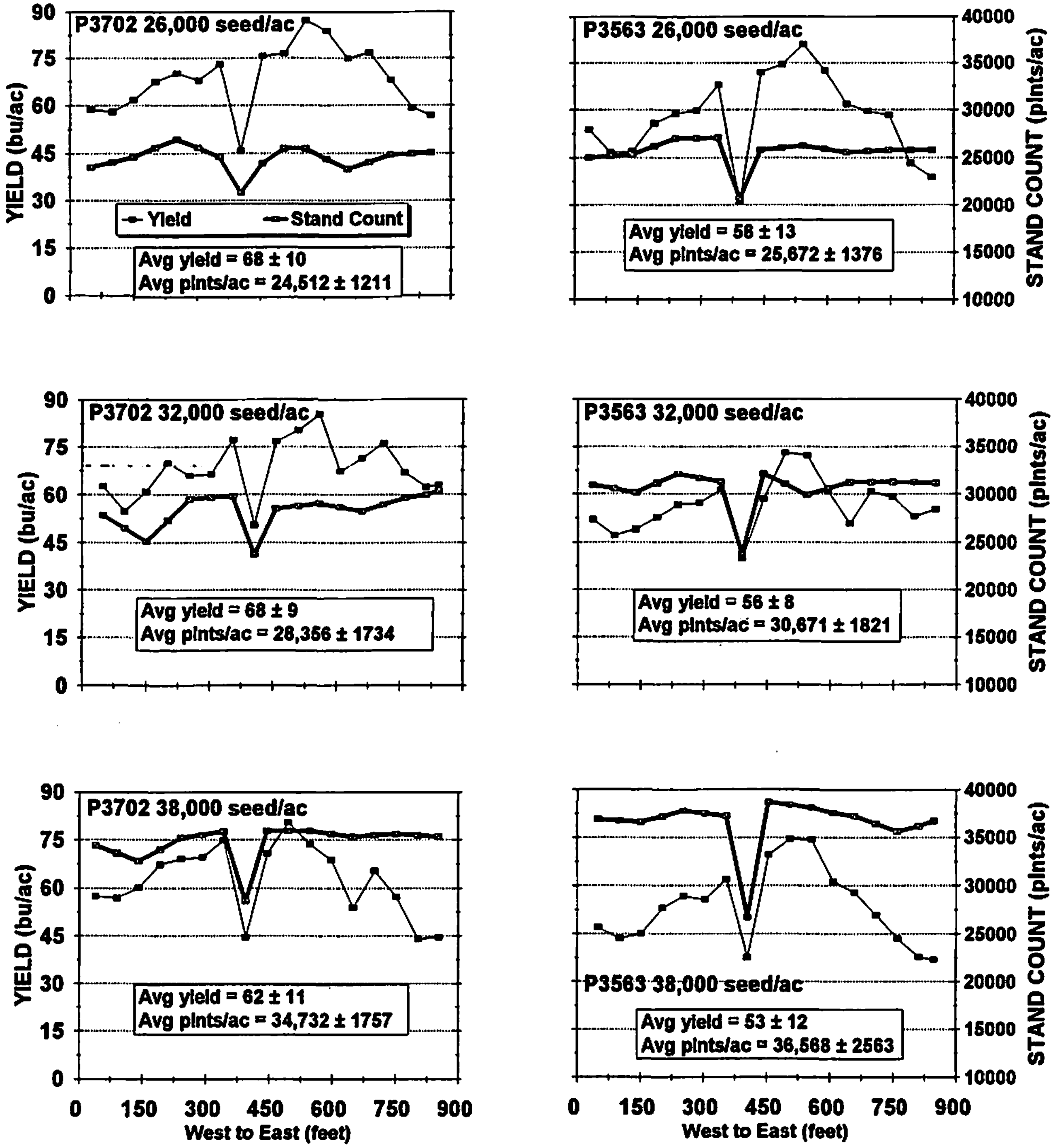
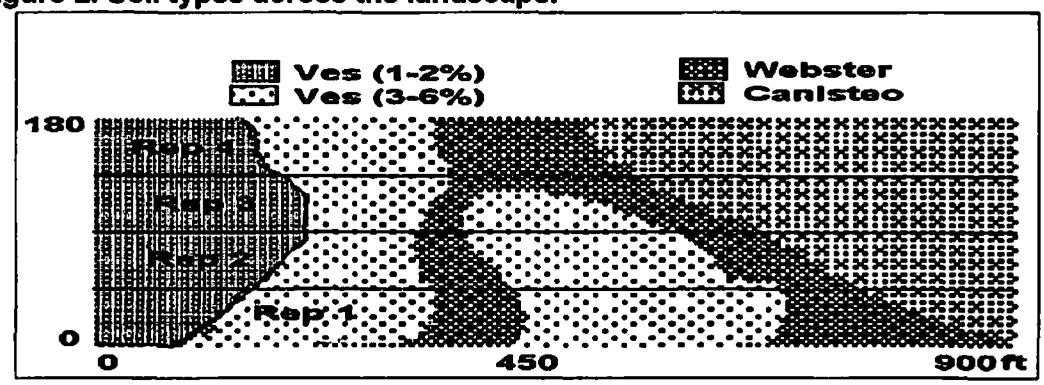


Figure 2. Soil types across the landscape.



SITE SPECIFIC CROP MANAGEMENT: N-SERVE RESPONSES AT HILDRETH SITE 1993[1]

G.L. Malzer, T.J. Graff, D.R. Huggins, D.J. Fuchs, P.C. Robert, W.H. Thompson, C.L. Gaalaas, S. Tomer and T.W. Bruulsema[2]

Abstract

Effectiveness of the nitrification inhibitor N-Serve is influenced by a number of soil factors. Soil specific management has potential for identifying these factors to predict where N-Serve may be useful in minimizing N losses. This study was conducted to relate corn yield response to N fertilizer with and without N-Serve to soil factors varying spatially within a field. Yields were extremely low due to excess moisture through the growing season. Both positive and negative yield responses to N-Serve occurred, and appeared to be spatially clustered. Positive N-Serve responses appeared to occur predominantly on well drained areas of the field.

Introduction

Soil factors including texture, pH, organic matter and temperature have been shown to influence the effectiveness of the nitrification inhibitor N-Serve. These factors vary within fields and may be mapped using soil specific management technologies to predict where N-Serve may be useful in minimizing losses of N in the nitrate form. The objective of this study was to determine how corn yield and N uptake response to N fertilizer with and without N-Serve was related to soil and landscape factors varying spatially within a field.

Experimental Procedures

The field was at the Southwest Experiment Station at Lamberton, MN. Five treatments, consisting of two N rates (60 and 120 lb acre^{-1}) with and without N-serve at 0.5 lb a.i. acre^{-1} and a control without N fertilizer, were applied preplant on May 21 across the field in strips (transects) 15 feet wide and 1240 feet long. Treatments were arranged in a nested randomized complete block design with 6 replications. N-Serve treatments were nested within the two N rates. Corn (Pioneer 3861) was planted on May 25 with 30 inch row spacing. Weed control was accomplished using Lasso plus Bladex (3 lb acre^{-1} + 2 lb acre^{-1}, respectively) at planting.

A detailed soil survey was obtained on a scale of approximately 1:5,000. Soil samples were taken on May 27 from the control treatment strips at 100 foot intervals to a depth of two feet in one foot increments. Soils were analyzed for NO_3-N, NH_4-N, total N, total carbon, mineralizable N and soil water. Grain yields were determined on September 29 by harvesting two rows in 50 foot increments down the entire strip with a plot combine, producing 24 yield samples per strip. Nitrogen uptake was calculated as grain dry matter multiplied by grain N concentration and represents N uptake into grain rather than whole plant N uptake.

Analysis of variance was performed on overall means of N treatments and on means of N treatments by soil series using SAS. Grain yield, N uptake and responses to N-Serve were kriged using simple kriging to generate maps showing spatial trends at each level of N fertilizer. Kriging is one of the more reliable methods for estimating unmeasured points between measured points within a field area.

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1 The assistance and financial support of the Minnesota Agricultural Experiment Station, USDA-CSRS, Dow Elanco, Soil Teq Inc., and DMI is gratefully acknowledged.

2 Professor, and Assistant Scientist, Dept. of Soil Science; Soil Scientist and Scientist, Southwest Experiment Station; Associate Professor, Assistant Scientist, Jr. Scientist, Jr. Scientist and Post-Doctoral Research Associate, Dept. of Soil Science, respectively.

Results

The overall means for corn grain yield and grain N uptake are presented in Table 1. Due to a wet spring, cool wet summer and flooding of some of the plot area, yield and N uptake were very low (0 to 90 bu acre^{-1} and 0 to 60 lb acre^{-1}, respectively) . The only difference detected between N treatments was significantly lower yield and N uptake on the check plot.

Analysis of variance indicated that variation due to soil series was as significant as that due to N treatment. Within each treatment Glencoe soil series had the lowest yield (Table 2). This soil has the poorest drainage of the soils in this plot area (Fig 1a) and is found in the lower elevation areas of the field (Fig 1b). Within each soil series the control produced significantly lower yields than the other treatments on all but two soils. On the Glencoe and Seaforth series no differences were detected between N treatments.

Both grain yields and N-Serve responses were highest in the areas of the field with higher elevation (Fig 2a,b,c,d). However, some of the higher elevation areas with relatively high grain yields had negative N-Serve responses (Fig 2c,d). Spatial variation in grain N uptake (nitrogen removal) followed a pattern similar to that of grain yield (Fig 3a,b,c). N-Serve effects on grain N uptake (nitrogen removal) were less clearly spatially clustered (Fig 4a,b) than were N-Serve effects on grain yield.

Discussion and Conclusions

The observation of spatially contiguous clusters of positive and negative N-Serve responses indicates potential for site specific management. At the high rate of N fertilizer, approximately one quarter of the field area had a positive yield benefit from N-Serve, and the area with a negative yield effect was about equally as large. Further work will focus on predicting the areas likely to show positive responses.

Table 1. Corn grain yield and grain N uptake averaged over the whole field for each N treatment.

N-Rate lb acre^{-1}	N-Serve	# of obs	Grain Yield bu acre^{-1}	Grain N Uptake lb acre^{-1}	
0	without	144	31.6±20.1	18.9±11.7	a
60	without	144	53.4±28.0	33.9±17.8	b
60	with	144	54.8±28.2	33.9±17.2	b
120	without	144	54.4±29.6	35.0±18.7	b
120	with	144	54.3±30.5	34.7±19.1	b

Table 2. Corn grain yield treatment means arranged by soil series.

Trt #	Soil	# of obs	N Rate lb acre^{-1}	N-Serve	Grain Yield bu acre^{-1}	
1	Canisteo	20	0	without	25.9 ± 14.0	a
2	Canisteo	15	60	without	39.5 ± 24.1	b
3	Canisteo	17	60	with	47.4 ± 23.6	b
4	Canisteo	21	120	without	51.0 ± 22.7	b
5	Canisteo	17	120	with	43.9 ± 27.2	b
1	Glencoe	5	0	without	4.4 ± 11.0	a
2	Glencoe	5	60	without	5.9 ± 10.5	a
3	Glencoe	6	60	with	8.0 ± 14.6	a
4	Glencoe	4	120	without	3.9 ± 8.7	a
5	Glencoe	5	120	with	5.7 ± 12.9	a
1	Normania	15	0	without	33.7 ± 13.0	a
2	Normania	22	60	without	64.8 ± 8.3	b
3	Normania	21	60	with	67.6 ± 10.0	b
4	Normania	17	120	without	68.6 ± 10.1	b
5	Normania	15	120	with	67.3 ± 9.5	b
1	Seaforth	2	0	without	33.3	a
2	Seaforth	1	60	without	38.1	a
3	Seaforth	2	60	with	49.8	a
4	Seaforth	1	120	without	44.8	a
5	Seaforth	2	120	with	45.2	a
1	Swanlake	10	0	without	43.0 ± 10.1	a
2	Swanlake	6	60	without	64.7 ± 3.1	b
3	Swanlake	8	60	with	69.6 ± 5.9	b
4	Swanlake	7	120	without	66.8 ± 7.2	b
5	Swanlake	6	120	with	69.1 ± 3.2	b
1	Ves	43	0	without	47.3 ± 11.7	a
2	Ves	47	60	without	72.1 ± 8.6	b
3	Ves	46	60	with	72.9 ± 8.5	b
4	Ves	48	120	without	74.7 ± 7.1	b
5	Ves	50	120	with	75.6 ± 7.1	b
1	Webster	22	0	without	39.1 ± 11.9	a
2	Webster	25	60	without	65.3 ± 19.7	b
3	Webster	21	60	with	65.8 ± 19.2	b
4	Webster	20	120	without	66.9 ± 18.3	b
5	Webster	21	120	with	70.0 ± 16.3	b

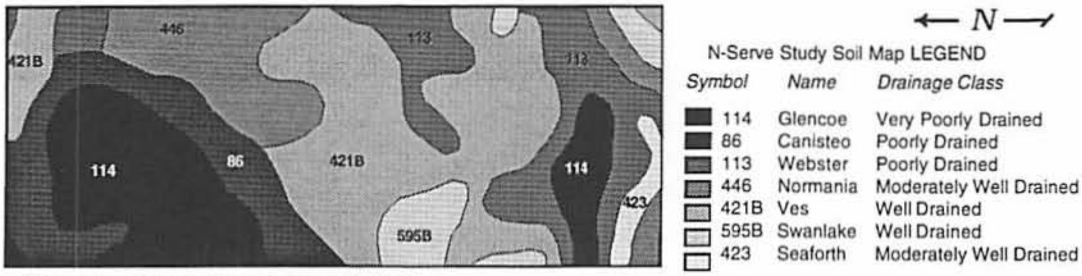

Figure 1a. Soil survey map of study area.

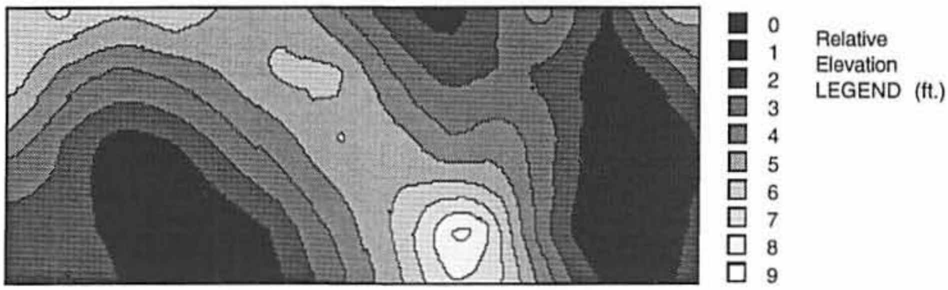

Figure 1b. Digital Elevation Model (DEM) illustrating relative topographic variations across the study area.

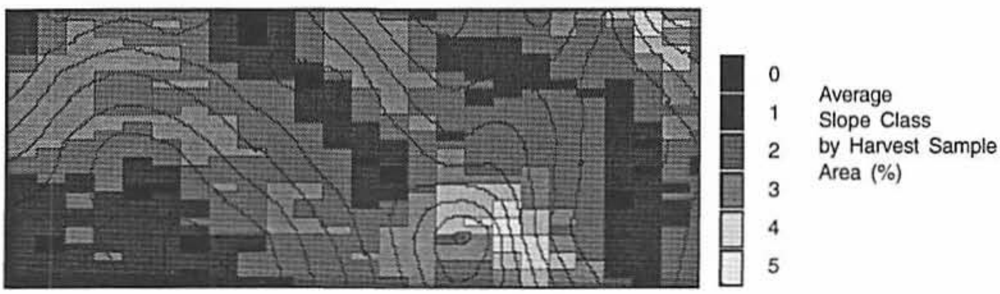

Figure 1c. Slope class map. Average slope (%) was calculated for each 51x15' harvest sample area. Slope was derived from the DEM for the site (Fig 1b).

Figure 1. N-Serve Response Study. The experiment was conducted on a 13.7 acre field at the U of MN Southwest Experiment Station. Soils in the plot area (Fig 1a) varied from very poorly drained concave landscape positions to well drained sloping soils (Fig 1c). Relative elevation ranged from 0 to > 9 feet (Fig 1b). The experimental design included six blocks and five treatments. Treatment (1): control strip receiving no nitrogen application; (2): transects receiving 60 lb N acre^{-1} without N-Serve; (3): transects receiving 60 lb N acre^{-1} with N-Serve; (4): transects receiving 120 lb N acre^{-1} without N-Serve; (5): transects receiving 120 lb N acre^{-1} with N-Serve. Treatment strips were paired by N-rate within each block. Harvest samples were collected at 51 foot intervals accross each transect. N-Serve response was approximated for both grain yields and nitrogen removal by adjacent N-rate pairs. A centroid coordinate was determined for each sample pair and the parameters were kriged to illustrate spatial variability of N-Serve effects at different landscape positions and soil conditions.

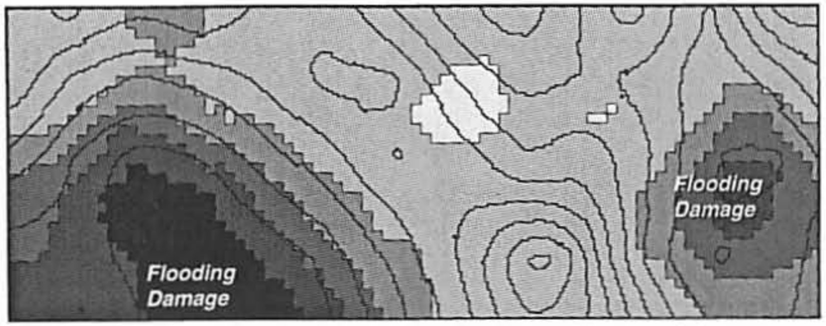

Figure 2a. Kriged estimates of corn grain yields (bu acre^{-1}) across plot area; N-Rate = 60 lb N acre^{-1} (treatment 3).

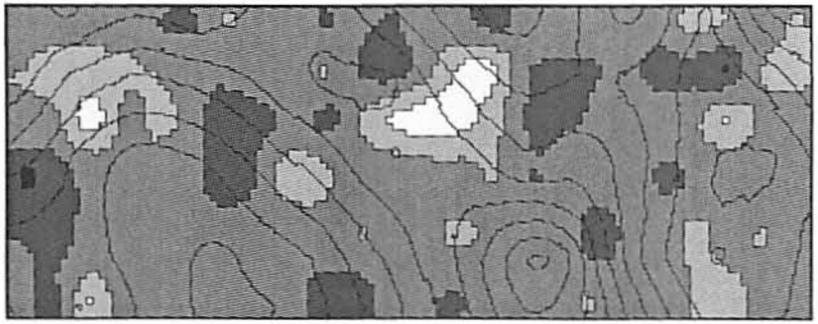

Figure 2c. Kriged estimates of N-Serve response (bu acre^{-1}) across plot area; N-Rate = 60 lb N acre^{-1} (treatment 3 minus treatment 2).

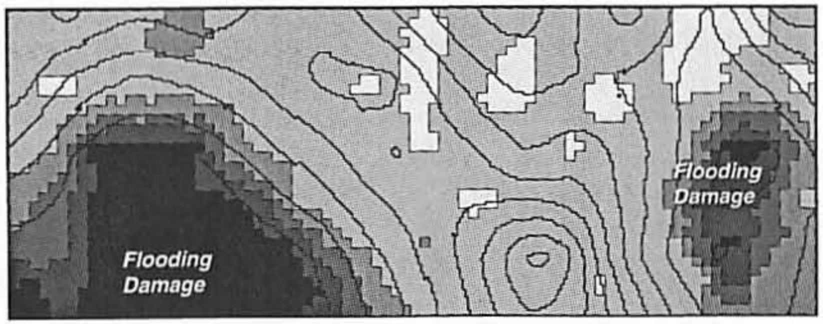

Figure 2b. Kriged estimates of corn grain yields (bu acre^{-1}) across plot area; N-Rate = 120 lb N acre^{-1} (treatment 5).

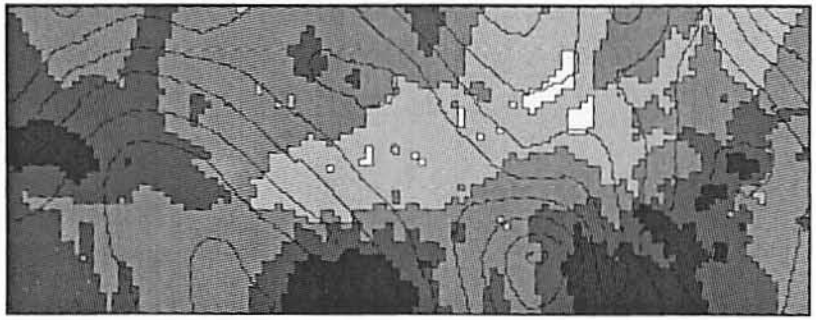

Figure 2d. Kriged estimates of N-Serve response (bu acre^{-1}) across plot area; N-Rate = 120 lb N acre^{-1} (treatment 5 minus treatment 4).

Corn Grain Yield (bu acre^{-1}) LEGEND

N-Serve Response (bu acre^{-1}) LEGEND

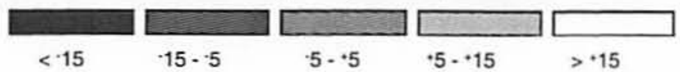

Figure 2. Spatial models of corn grain yields using two different nitrogen application rates (Figs 2a and 2b) and variable N-Serve responses at different landscape positions (Figs 2c and 2d). Contour lines represent one foot increments of the digital elevation model (DEM) from the study area (Fig 1b). Flooding damage occurred within closed, concave landscape positions (Glencoe soils; Fig 1a).

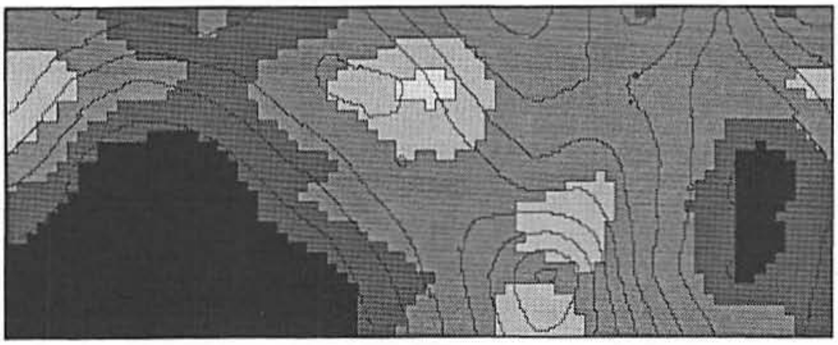

Figure 3a. Nitrogen Removal (lb N $acre^{-1}$; N-Rate = 0 lb N $acre^{-1}$)

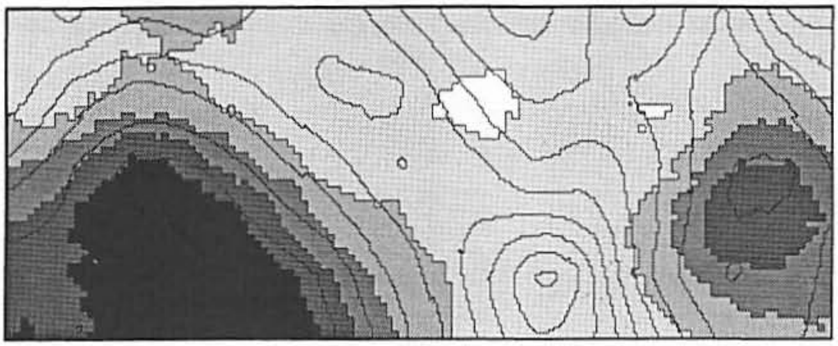

Figure 3b. Nitrogen Removal (lb N $acre^{-1}$; N-Rate = 60 lb N $acre^{-1}$)

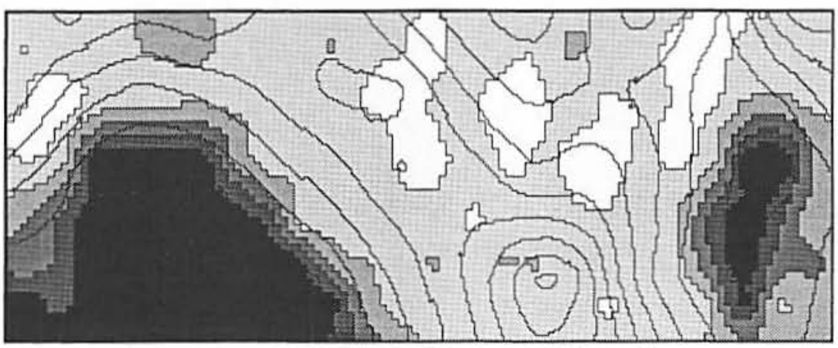

Figure 3c. Nitrogen Removal (lb N $acre^{-1}$; N-Rate = 120 lb N $acre^{-1}$)

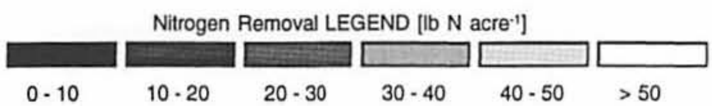

Figure 3. Spatial variations of nitrogen removal at three nitrogen application rates.

Figure 4a. N-Serve effect on nitrogen removal (N-Rate = 60 lb N acre^{-1})

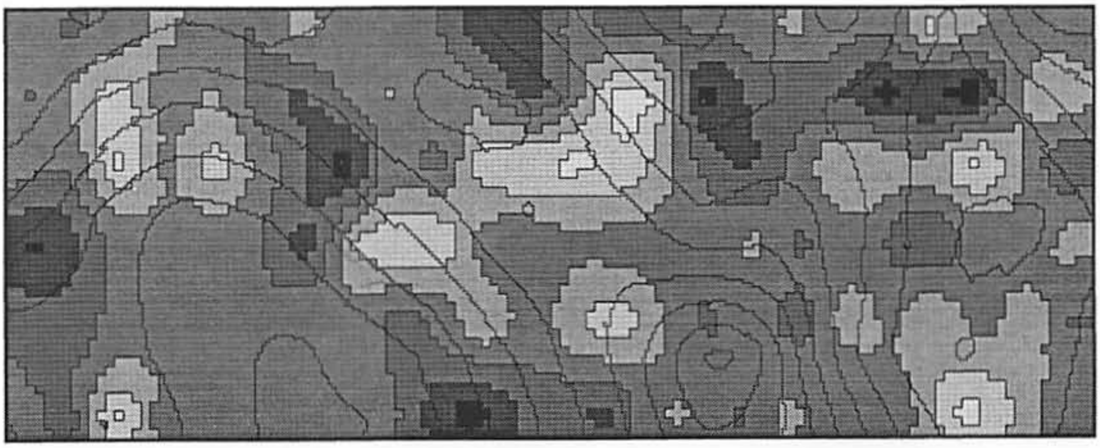

Figure 4b. N-Serve effect on nitrogen removal (N-Rate = 120 lb N acre^{-1})

N-Removal Difference LEGEND [lb N acre^{-1}]

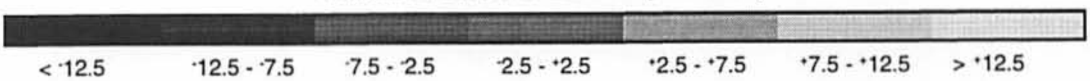

Figure 4. Spatial variations of N-Serve effects on N-removal. Adjacent paired harvest samples were used to calculate differences in nitrogen uptake for each nitrogen application rate. A centroid coordinate (x, y) was calculated for each sample pair and the resulting N-removal differences kriged to illustrate the spatial variability.

SITE SPECIFIC CROP MANAGEMENT: N-RESPONSE BY SOIL CONDITION AT HILDRETH SITE 1993[1]

G.L. Malzer, T.J. Graff, P.C. Robert, D.R. Huggins, D.J. Fuchs, W.H. Thompson, C.L. Gaalaas, and T.W. Bruulsema[2]

Abstract

Corn N responses vary spatially with site properties. This study was conducted to relate corn yield responses to soil factors varying spatially within a field. Six N fertilizer rates were applied in transects over the length of the field. Corn growth was severely delayed by cool, wet weather to the extent that maturity did not occur before the killing frost. Therefore yields were taken as silage. Silage yields at the critical N rate showed substantial spatially related variation. Maximum yields in much of the field area did not occur at the highest N rate.

Introduction

Corn responses to N fertilizer vary spatially with soil properties and landscape position. Variable rate application of nitrogen fertilizers is now possible because of recent advances in variable rate technologies (VRT), geographic information systems (GIS) and positioning technology. This study was conducted to examine the spatial variability of N response curves and their relationships to soil properties and landscape position. The goal was to ascertain which parameters are best suited for making site specific N recommendations.

Experimental Procedures

The field, previously cropped to soybean, was at the Southwest Experiment Station at Lamberton, MN. Six N fertilizer treatments, consisting of five constant N rates (0, 60, 90 120, and 150 lb acre^{-1}) and one variable N rate, were applied as anhydrous ammonia on May 21 in strips (transects) 15 feet wide and 1150 feet long (Fig 1c). The variable rate was determined by existing extension recommendations and the soil map unit equivalency rating. Treatments were arranged in a randomized complete block design with six blocks each containing 23 N response replicates. Corn (Pioneer 3563) was planted on May 22 and 25 (interrupted by rain) with 30 inch row spacing. Weed control was accomplished using Lasso plus Bladex (3 lb acre^{-1} and 2 lb acre^{-1}, respectively) on May 25.

A detailed soil survey was obtained on a scale of approximately 1:6,000. Soil samples were taken on May 21 from the control treatment strips at 100 foot intervals to a depth of two feet in one foot increments. Soils were analyzed for NO_3-N, NH_4-N, total N, total carbon, mineralizable N and soil water. Due to the cool wet summer and early frost, the corn did not reach maturity. Silage yields were determined on October 13 and 14 by harvesting one row in 50 foot increments down the entire strip with a mechanical silage harvester, producing 23 yield samples per strip.

Analysis of variance was performed on overall means of N treatments and on means of N treatments by soil series using SAS. Responses to N rates were fitted to linear-plateau models (Fig 5). The response models were calculated on a moving average basis for centroid points between adjacent replicates within transects. Silage yield, N uptake and response curve parameters were kriged using simple kriging to generate maps showing spatial trends. Kriging is one of the more reliable methods for estimating unmeasured points between measured points within a field area.

Results

Silage dry matter yield and N uptake were low but did respond to N fertilizer (Table 1). Silage yield and N uptake varied considerably among soil series, especially at the zero rate of N fertilizer (Table 2). Variability in percent dry matter was also high, likely resulting from wide variation among plants in maturity stage at the first killing frost. Maximum silage yields were fairly uniform across the field except in one of the three map units with Glencoe soil and low relative elevation (Fig 2a). However, silage yields at the critical N rate (i.e. model plateau yields) varied to a greater extent (Fig 2b). Variation in silage yield without N fertilizer was greater yet (Fig 2c). The model estimates of silage yield without N fertilizer (β_0; Fig 2d) agreed closely with the measured yields without N (Fig 2c) indicating validity of the fitted linear plateau models.

Nitrogen rates corresponding with maximum observed silage yields were less variable than critical N rates, and were spatially more contiguous (Fig 3a and 3b). This was unexpected, as the N rate at which maximum yield occurred was expected to be more affected by random error than the model estimated critical N rate. Nitrogen response rates (β_1) varied strongly across the field (Fig 4), ranging from zero to more than 180 pounds of silage dry matter per pound of N applied.

[1] The assistance and financial support of the Minnesota Agricultural Experiment Station, USDA-CSRS, Soil Teq Inc., and DMI is gratefully acknowledged.

[2] Professor, Assistant Scientist, and Associate Professor, Dept. of Soil Science, Soil Scientist and Scientist, Southwest Experiment Station; Assistant Scientist, Jr. Scientist and Post-Doctoral Research Associate, Dept. of Soil Science, respectively.

Discussion and Conclusions

Critical nitrogen rate can be treated as an approximation of the N rate above which no yield response is expected. The critical rate estimates had substantial spatially related variation (Fig 3b) that would warrant variable rate application of N fertilizer, if the critical N rates could be predicted in advance. Further analysis of the data will be performed to evaluate the possibility of such prediction.

The map of N rates that correspond with maximum silage yield shows that more than half of the field did not produce the highest yield at the highest N rate. Most of the field area produced the highest yield at the 80 to 120 lb acre^{-1} N rate. The practical interpretation is that adding extra N fertilizer to a given recommendation does not maximize yield and most certainly does not maximize profit.

Table 1. Corn silage yield responses to N fertilizer rates averaged over soil series. Means ± standard deviations.

N-Rate lb acre^{-1}	# of obs	%Dry Matter of Silage	N uptake lb acre^{-1}	Dry Matter Yield ton acre^{-1}
0	138	46 ±10	54 ±17	3.2 ±1.0
60	218	52 ±08	81 ±21	4.4 ±1.0
90	196	52 ±10	87 ±27	4.5 ±1.2
120	138	53 ±08	92 ±23	4.7 ±1.0
150	138	51 ±11	96 ±27	4.7 ±1.3

Table 2. Corn silage yield responses to N fertilizer rate by soil series. Means ± standard deviations.

Soil Map Unit	N Rate lb acre^{-1}	# of obs	Dry Matter % of Silage	N Uptake lb acre^{-1}	Silage Yield ton acre^{-1}
Glencoe	0	11	36 ± 13	42 ± 19	2.3 ± 1.2
Glencoe	60	15	41 ± 14	60 ± 31	3.2 ± 1.7
Glencoe	90	8	37 ± 16	52 ± 30	2.7 ± 1.5
Glencoe	120	11	48 ± 7	75 ± 20	4.0 ± 1.1
Glencoe	150	9	47 ± 6	87 ± 19	4.0 ± 1.0
Normania	0	17	45 ± 6	58 ± 17	3.1 ± 0.8
Normania	60	15	48 ± 5	73 ± 14	3.9 ± 0.6
Normania	90	39	52 ± 7	89 ± 19	4.5 ± 0.9
Normania	120	19	53 ± 6	93 ± 17	4.7 ± 0.6
Normania	150	22	55 ± 5	102 ± 21	5.2 ± 0.8
Swanlake	0	7	52 ± 5	53 ± 13	3.5 ± 0.8
Swanlake	60	12	58 ± 4	82 ± 20	4.7 ± 0.6
Swanlake	90	7	59 ± 4	85 ± 16	4.6 ± 0.5
Swanlake	120	7	59 ± 4	101 ± 26	5.2 ± 0.8
Swanlake	150	6	60 ± 5	109 ± 31	5.2 ± 0.5
Ves	0	59	49 ± 7	58 ± 15	3.6 ± 0.8
Ves	60	132	54 ± 6	86 ± 17	4.8 ± 0.7
Ves	90	54	56 ± 6	102 ± 20	5.2 ± 0.6
Ves	120	56	54 ± 6	97 ± 19	5.0 ± 0.6
Ves	150	58	53 ± 7	103 ± 19	5.0 ± 0.7
Webster	0	44	44 ± 12	50 ± 18	2.8 ± 1.0
Webster	60	44	49 ± 10	73 ± 24	4.0 ± 1.1
Webster	90	88	50 ± 12	82 ± 29	4.3 ± 1.4
Webster	120	45	52 ± 10	87 ± 28	4.5 ± 1.4
Webster	150	43	46 ± 16	83 ± 36	4.2 ± 1.8

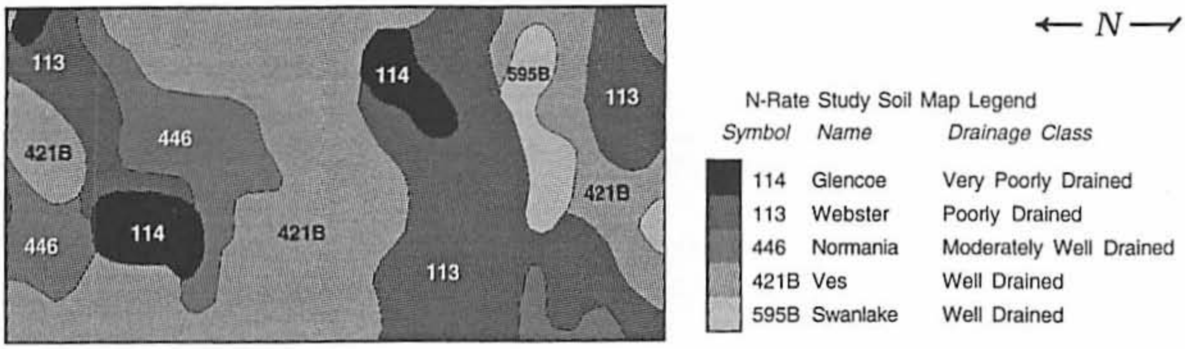

Figure 1a. Soil map of study area. The map is based on a detailed survey of the field plot; approximate scale = 1:6,000.

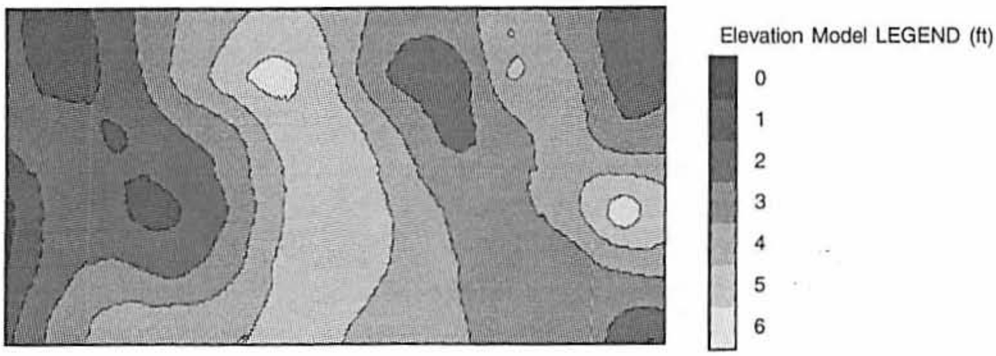

Figure 1b. Elevation model of study area. Elevation data was collected with a laser theadolite and kriged using simple kriging. The continuous elevation estimates were partitioned at one foot contour intervals.

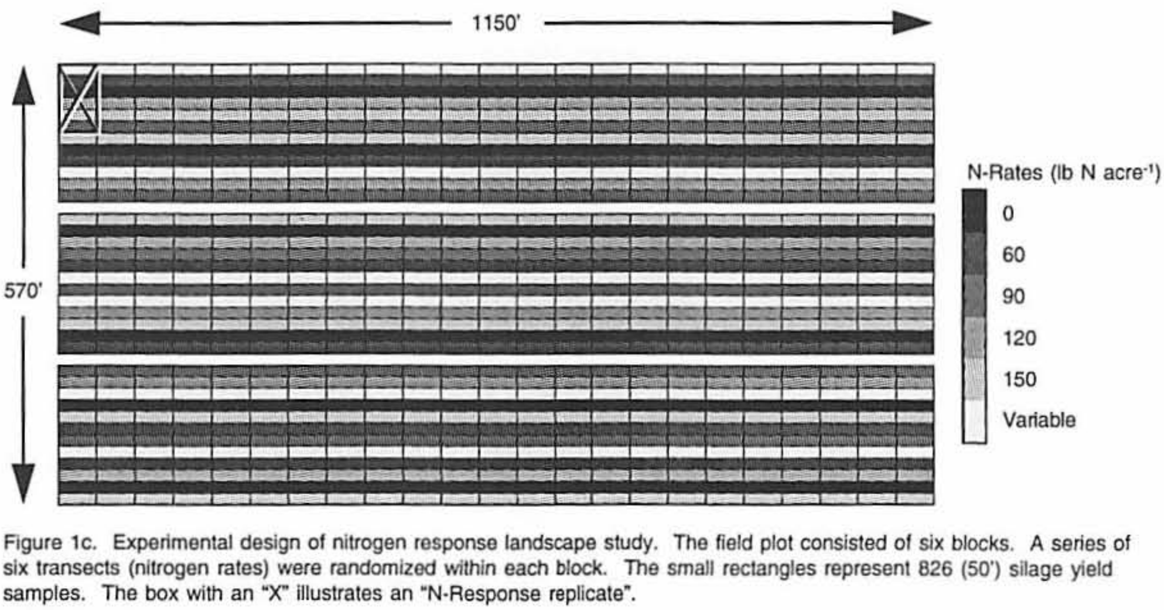

Figure 1c. Experimental design of nitrogen response landscape study. The field plot consisted of six blocks. A series of six transects (nitrogen rates) were randomized within each block. The small rectangles represent 826 (50') silage yield samples. The box with an "X" illustrates an "N-Response replicate".

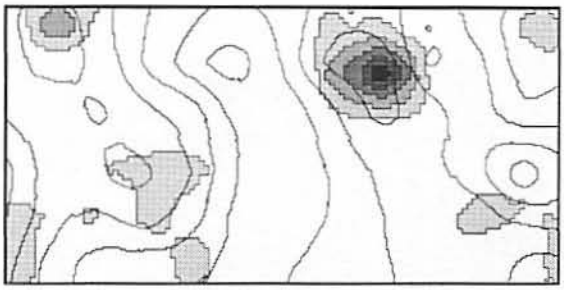

Figure 2a. Maximum silage yields. (kriged estimates from N-response replicates) [ton acre^{-1}].

Figure 2b. Silage yields at critical N-rate (*P*). (kriged estimates from moving averages of linear plateau N-response models by paired replicate) [ton acre^{-1}].

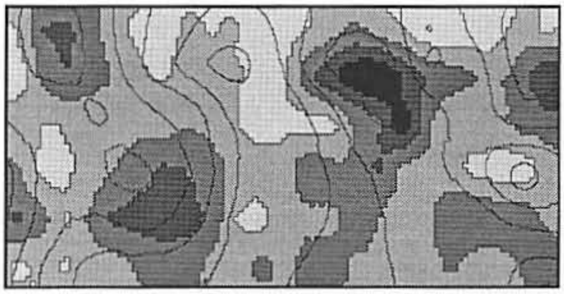

Figure 2c. Silage yields without applied nitrogen (kriged estimates from control treatment; N-rate = 0 lb N acre^{-1}).

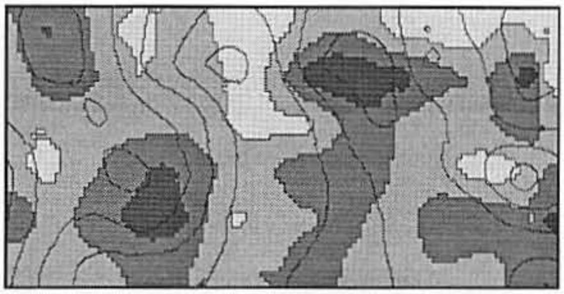

Figure 2d. Silage yield without N (kriged estimates from linear plateau model; β_0) [ton acre^{-1}].

Silage Yields LEGEND [ton acre^{-1}]

< 1   1 - 2   2 - 3   3 - 4   4 - 5   > 5

Figure 2. Comparison of spatial variations in silage yields. Simple kriging was used to interpolate silage yields across the plot area for each parameter. Fig 2a represents measured maximum yields by N-response replicate. Fig 2b indicates potential yields that would result from an optimum (critical) application of variable N-rates. Control treatment harvest data is presented in Fig 2c. Integrity of the linear plateau model estimates of potential silage yields without applications of nitrogen (β_0) is shown by close agreement of spatial patterns in Figs 2c and 2d. Black lines in each figure represent one foot contour intervals (Fig 1b).

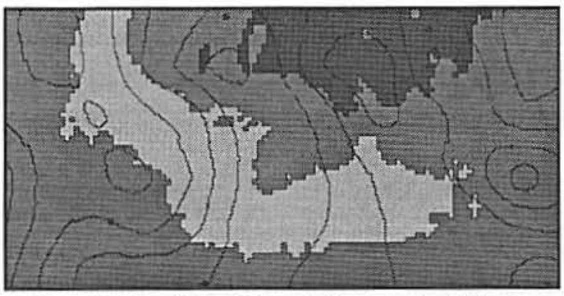

Figure 3a. Spatial variation of nitrogen rates that correspond with maximum silage yields (Fig 2a).

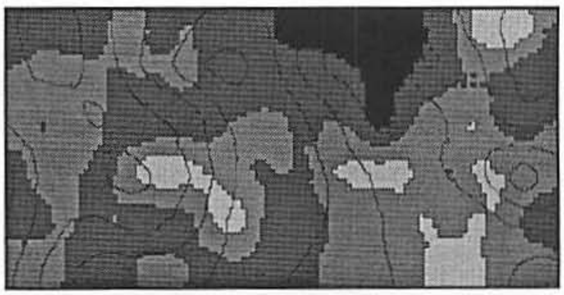

Figure 3b. Spatial variation of critical nitrogen rates (*C*) that correspond with silage yields (Fig 2b).

Nitrogen Application Rate LEGEND [lb N acre^{-1}]

0 - 40   40 - 80   80 - 120   120 - 150

Figure 3. Spatial variation of maximum (Fig 3a) and critical (Fig 3b) nitrogen application rates. The maximum nitrogen rates correspond with measured maximum silage yields (Fig 2a) from each N-response replicate (Fig 1c). The spatial variability map of critical nitrogen rates (Fig 3b) was generated by kriging the moving averages of linear plateau model estimates from paired adjacent N-response replicates. Black lines in each figure represent one foot contour intervals (Fig 1b).

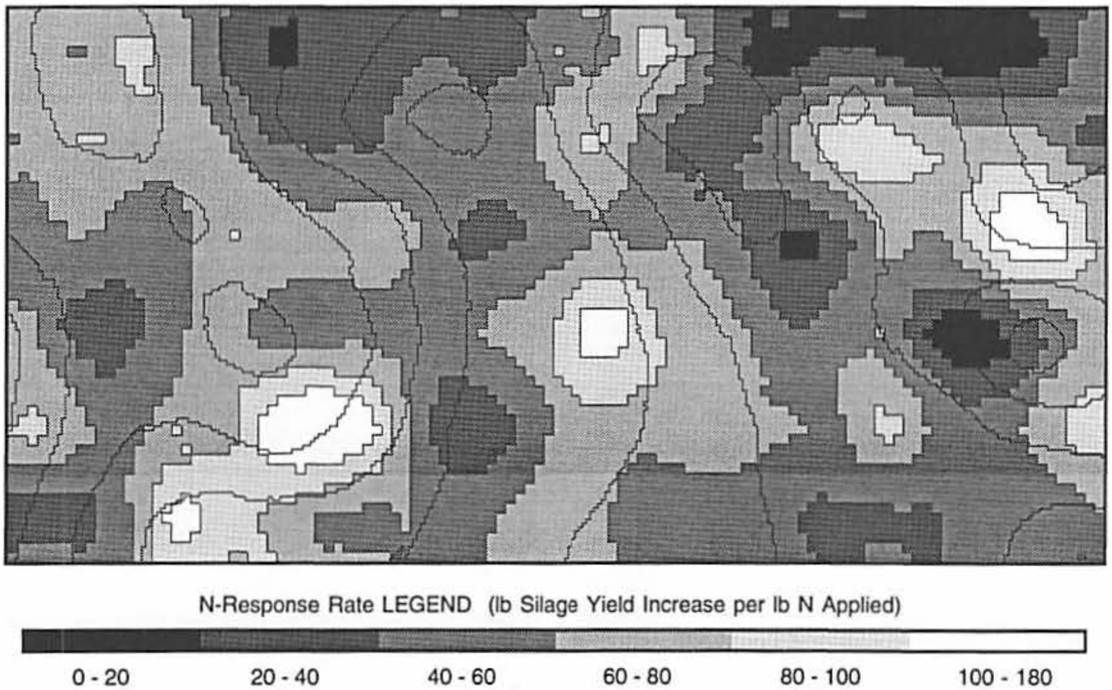

Figure 4. Spatial variability of nitrogen response rates (β_1). Response rates vary from 0 to > 180 (lb lb^{-1}) across the field.

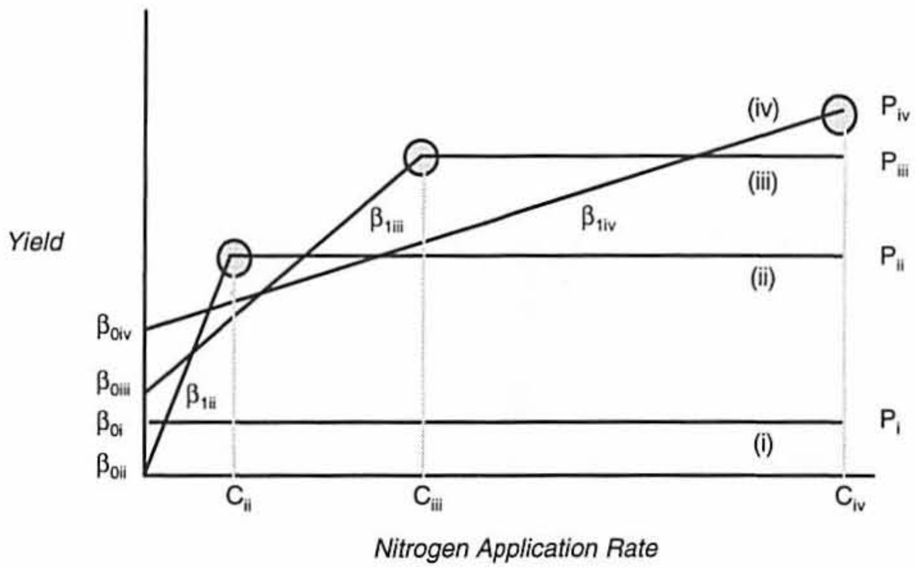

Figure 5. Four examples of nitrogen response rate functions. Linear plateau models are presented to describe four N-response scenarios (i, ii, iii and iv). where, β_0: yield without nitrogen applied [Fig 2d]; β_1: N-response rate [Fig 4]; *C:* Critical N-rate [Fig 3b]; and *P:* crop yield at critical N-rate [Fig 2b]. N-response scenario (i): no yield response to N applications; (ii): rapid N-response with low critical N-rate and moderate yield increase; (iii): moderate N-response with moderate critical N-rate and large yield increase; (iv): continuous yield increase with increasing N-rates.

EVALUATION OF A VARIABLE TILLAGE IMPLEMENT ON CORN AND SOYBEAN YIELDS[1]

D.J. Fuchs, D.R. Huggins, and P.C. Robert[2]

Abstract

A study to determine the performance of a variable tillage implement (VTI) was conducted in corn and soybean residues in 1992 and 1993. By controlling disc depth and angle, the implement was designed to vary the amount of crop residues incorporated in the soil. For purpose of comparison, this study included the following conventional tillage systems: no-tillage, fall no-tillage with spring secondary tillage, chisel plow, and moldboard plow. In 1992, the corn and soybean yields with VTI treatments were not significantly different than other tillage treatments for both soil types. In 1993, corn and soybean yields on the well drained Ves soil were significantly lower with no tillage as compared to the other tillage treatments. The VTI, for the two years evaluated, resulted in corn and soybean yields that were comparable to other treatments with tillage (moldboard plow, chisel plow, and spring cultivation).

Introduction

The objective of this study was to dynamically control the amount of residue left on the surface, according to soil type. A variable primary tillage implement (VTI), a prototype built by DMI Inc., was tested in corn and soybean residues at the Southwest Experiment Station, Lamberton, MN in 1992 and 1993. The VTI implement was a modified 12.5-wide DMI Tiger II®. The first and second gang of concave discs were 20-inch in diameter with 15-inch spacings. The front and rear gang were offset by 7.5 inches. The discs for the first gang were at a 15 degree angle. Modifications were made to the second gang, that allowed the disc angle to be changed, from 15 to 30 degrees. The angle of the second gang of discs and the depth of both sets of gangs were hydraulically and independently controlled from the tractor and changed "on the go" over the field. The two gangs of discs are followed by 5 shanks with 30-inch spacing. Each shank had a 10-inch wide "Tiger Point" tip. The depth of the shanks was also controlled from the tractor. The shanks were followed with smaller discs that helped level the soil.

Materials and Methods

1992

The study with soybean residue included the following tillage treatments: four different settings of the VTI unit, field cultivation, and no-tillage (Table 1). VTI shanks were set at a working depth of 10 to 12 inches for all VTI settings. The different settings were accomplished by changing the working depth and angle of the front gang of discs. The four different settings for the VTI unit were: 1) no disc action, 2) discs at 15 degree angle and 5 inch working depth, 3) discs at 15 degree angle and 10 inch working depth, 4) discs at 30 degree angle and 5 inch working depth. These treatments in turn divided three replicated mainplots of a poorly drained Webster clay loam (Typic Haplaquolls) and a well drained Ves loam (Udic Haplustolls). **The tillage treatments were applied in early spring.**

The study with corn residue included subunits of chopped and unchopped residue treatment that were stripped across three replicated mainplots of a poorly drained Webster clay loam and a well drained Ves loam. The residue was chopped in the fall of 1991. Each subunit was divided into the following tillage treatments: five different VTI settings, moldboard plow, and no-tillage (Table 1). **The tillage treatments were applied in early spring.**

1993

The study with soybean residue included tillage treatments of: two VTI settings, chisel plow, no-tillage in the fall with spring tillage using a field cultivator, and no-tillage (Table 3). The treatments were subdivided into 5 replicated mainplots of a poorly drained Webster clay loam and a well drained Ves loam.

The study with corn residue included subunits of chopped and unchopped residue treatments that were stripped across three replicated mainplots of poorly drained Webster clay loam and well drained Ves loam. The residue was chopped in the fall of 1992. Each subunit was divided into the following tillage treatments: three VTI settings, moldboard plow, and no-tillage (Table 3).

Additional management information may be found in Tables 2 and 4. Yield results are presented in Tables 5, 6, 7, and 8. For both years corn and soybean yields were collected in the fall, using an Almaco plot combine.

[1] Support for this project was provided by a grant from the USDA-CSRS, and Soil Teq Inc.

[2] D.J. Fuchs and D.R. Huggins are Scientist and Assistant Professor at the Southwest Experiment Station, Lamberton, MN 56152. P.C. Robert is Associate Professor at the Soil Science Department at the University of Minnesota, St. Paul, MN 55108.

Results

1992
The tillage treatments did not have a significant effect on the corn or soybean yields for either soil type (Table 5 and 6). Chopping the corn stalks in the fall before tillage did not significantly effect soybean yields.

1993
Soybean Residue. Tillage treatments had a significant effect on corn yields on well drained Ves loam, but not on Webster clay loam (Table 7). No-tillage was the lowest yielding treatment for both soil types, yielding 4.4 to 10.1 bu/ac less than the other tillage treatments on the well drained soil, and 1.9 to 9.1 bu/ac less than the other tillage treatments on the poorly drained soil (Table 7). There was no significant difference in yields between tillage treatments that disturbed the soil surface prior to planting (Table 7).

Corn Residue. No yields were collected on the poorly drained soil. The area was severely flooded several times, destroying the soybean crop. On the well drained area, the tillage treatment had a significant effect on soybean yield. No-tillage yields were 7.5 to 11.5 bu/ac less than the other tillage treatments (Table 8). There was not a significant difference in yields between the moldboard plow and the three VTI rates (Table 8). Chopping the corn stalks in the fall before tillage had no significant effect on soybean yields.

Table 1. 1992 Tillage treatments in corn and soybean residue.

Soybean Residue		Corn Residue	
Spring Primary Tillage	Spring Secondary Tillage	Spring Primary Tillage	Spring Secondary Tillage
No-tillage	none	No-tillage	none
No-tillage	1 pass with field cult.	Moldboard plow	2 passes with field cult.
VTI 0 deg. 0 in.	1 pass with field cult.	VTI 0 deg. 0 in.	2 passes with field cult.
VTI 15 deg. 5 in.	1 pass with field cult.	VTI 15 deg. 5 in.	2 passes with field cult.
VTI 15 deg. 10 in.	1 pass with field cult.	VTI 15 deg. 10 in.	2 passes with field cult.
VTI 30 deg. 5 in.	1 pass with field cult.	VTI 30 deg. 5 in.	2 passes with field cult.
		VTI 30 deg. 10 in.	2 passes with field cult.

Table 2. Management information for 1992.

Crop	Item	Type	Rate	Date
Corn	Fertilizer	Urea	150 lbs N/ac	4/13/92
	Herbicides	Lasso and	3.0 lbs ai /ac	5/8/92
		Bladex (preemergent)	1.5 lbs ai /ac	
		Accent and	0.031 lbs ai/ac	6/5/92
		Buctril and	0.25 lbs ai/ac	
		28 % N	4 % v/v	
	Planting	Pioneer 3615	29,000 seeds/ac	5/6/92
		JD 7000 15-ft 6-row		
	Row Cultivation		once	6/4/92
	Soil Test	P_2O_5	17 ppm	Fall 1988
		K_2O	131 ppm	
		pH	3	
Soybean	Fertilizer	none		
	Herbicides	Poast Plus and	0.19 lbs ai/ac	6/10/92
		COC	1.3 % v/v	
		Pinnacle and	0.004 lbs ai/ac	6/11/92
		Surfactant and	0.125 % v/v	
		28 % N	1.0 % v/v	
	Planting	Hardin	160,000 seeds/ac	5/7/92
		JD 750 10-ft notill drill		
	Row Cultivation		none	
	Soil Test	P_2O_5	35 ppm	Fall 1990
		K_2O	175 ppm	
		pH	6.5	

Table 3. 1993 Tillage treatments in corn and soybean residue.

Soybean Residue		Corn Residue	
Fall Primary Tillage	Spring Secondary Tillage	Fall Primary Tillage	Spring Secondary Tillage
No-tillage	none	No-tillage	none
No-tillage	1 pass with field cult.	Moldboard plow	2 passes with field cult.
Chisel Plow	1 pass with field cult.	VTI 0 deg. 0 in.	2 passes with field cult.
VTI 0 deg. 0 in.	1 pass with field cult.	VTI 15 deg. 5 in.	2 passes with field cult.
VTI 30 deg. 10 in.	1 pass with field cult.	VTI 30 deg. 10 in.	2 passes with field cult.

Table 4. Management Information for 1993.

Crop	Item		Type	Rate	Date
Corn	Fertilizer		Urea	150 lbs N/ac	5/6/93
	Herbicides		Eradicane and Bladex	2.5 lbs ai /ac 1.5 lbs ai /ac	5/20/93
	Planting		JD 7000 6-row	29,000	5/21/93
	Row Cultivation			once	
	Soil Test:	Ves loam	P_2O_5 K_2O	22 ppm 105 ppm	Fall 1992
		Webster clay loam	pH P_2O_5 K_2O pH	6.0 68 ppm 269 ppm 7.3	 Fall 1990
Soybean	Fertilizer		none		
	Herbicides		Roundup (spot spray) Lasso and Sencor and Ranger Poast Plus and Pursuit and Basagran and Surfactant and 28 % N	1.0 lbs ai /ac 3.0 lbs ai /ac 0.25 lbs ai /ac 0.5 lbs ai/ac 0.16 lbs ai/ac 0.031 lbs ai/ac 0.5 lbs ai/ac 0.013 % v/v 0.013 % v/v	5/26/93 5/28/93 7/21/93
	Planting		Hardin JD 750 10-ft notill drill	195,000 seeds/ac	5/26/93
	Row Cultivation			none	
	Soil Test		P_2O_5 K_2O pH	12.5 ppm 135 ppm 7.1	Fall 1988

Table 5. Corn yields by soil type and tillage treatment in 1992.

Tillage treatment	Well drained soil[1]		Poorly drained soil[2]		Average
	(bu/ac)	(std. dev.)	(bu/ac)	(std. dev.)	(bu/ac)
No-tillage	128.7	15.9	114.0	18.3	121.4
No-tillage (w/spr cult.)	124.1	13.4	119.9	7.7	122.0
VTI 0 deg. 0 in.	130.0	13.5	126.5	5.4	128.3
VTI 15 deg. 5 in.	133.2	15.5	129.5	9.3	131.3
VTI 15 deg. 10 in.	139.1	12.2	114.6	19.2	126.8
VTI 30 deg. 5 in.	144.0	8.0	131.7	4.3	137.8
Average	133.2		122.7		127.9

[1] No significant difference between tillage treatments.

[2] No significant difference between tillage treatments.

Table 6. Soybean yields by soil type and tillage treatment in 1992.

Tillage treatment	Well drained soil[1]		Poorly drained soil[2]		Average
	(bu/ac)	(std. dev.)	(bu/ac)	(std. dev.)	(bu/ac)
No-tillage	40.7	3.4	45.2	6.3	**42.9**
Moldboard plow	35.8	2.5	44.2	2.9	**40.0**
VTI 0 deg. 0 in.	39.6	3.0	46.9	1.9	**43.3**
VTI 15 deg. 5 in.	38.8	1.8	40.0	3.8	**39.4**
VTI 15 deg. 10 in.	38.3	3.2	44.0	2.4	**41.2**
VTI 30 deg. 5 in.	40.7	1.3	47.2	3.9	**44.0**
VTI 30 deg. 10 in.	40.1	1.7	42.7	3.9	**41.4**
Average	**39.1**		**44.3**		**41.7**

[1] No significant difference between tillage treatments.

[2] No significant difference between tillage treatments.

Table 7. Corn yields by soil type and tillage treatment in 1993.

Tillage treatment	Well drained soil[1]		Poorly drained soil[2]		Average
	(bu/ac)	(std. dev.)	(bu/ac)	(std. dev.)	(bu/ac)
No-tillage	80.4	2.7	96.7	9.5	**88.6**
No-tillage (w/. sec till.)	89.3	7.5	101.0	5.7	**95.2**
Chisel plow	90.5	5.0	98.6	8.5	**94.5**
VTI 0 deg. 0 in.	84.9	7.0	105.8	4.0	**95.4**
VTI 30 deg. 10 in.	90.0	5.5	103.8	7.9	**96.9**
Average	**87.0**		**101.2**		**94.1**

[1] LSD $_{(0.05)}$ = 6.1 bu/ac for the tillage treatments in the well drained soil.

[2] No significant difference between tillage treatments.

Table 8. Soybean yields by tillage treatment in 1993.

Tillage treatment[1]	(bu/ac)	(std. dev.)
No-tillage	21.0	2.9
Moldboard plow	32.5	2.8
VTI 0 deg. 0 in.	28.5	2.3
VTI 15 deg. 5 in.	28.7	1.1
VTI 30 deg. 10 in.	29.2	1.7
Average	**28.0**	

[1] LSD $_{(0.05)}$ = 4.4 bu/ac for the tillage treatments in the well drained soil.

PERFORMANCE OF A VARIABLE TILLAGE IMPLEMENT IN CORN RESIDUE[1]

D.S. Long, P.C. Robert, D.J. Fuchs, and D.R. Huggins[2]

Abstract

A study to determine the performance of a variable tillage implement (VTI) was initiated in corn residue in fall 1992. By controlling blade depth and angle, the implement was designed to vary the amount of crop residue incorporated in soil. For purpose of comparison, this study included conventional no-till and moldboard tillage systems. Residue cover was initially 100 percent as measured for no-till. Residue cover decreased to about 60 percent after tillage with the VTI and to about 10 percent with the moldboard. The different blade settings of the VTI were not significantly different in residue cover left after tillage. Mechanical problems or the heavy residue conditions of the 1992 growing season may have rendered the VTI ineffective.

Materials and Methods

A variable tillage implement (VTI), a prototype built by DMI Inc., was tested in corn residue at the Southwest Experiment Station, Lamberton, MN in fall 1992. By controlling the blade angle and blade depth, the VTI is designed to vary the amount of crop residue incorporated in soil. Corn residue was from a crop that was harvested in fall 1992. The experimental design was randomized complete block.

The experiment consisted of subunits of the following tillage treatments: VTI with zero blade angle and depth (VTI00), VTI with intermediate blade angle of 15 degrees and depth of 5 inches (VTI155), VTI with maximum blade angle of 30 degrees and depth of 10 inches (VTI3010), moldboard plow, and no-till (Table 1). Tillage treatments were stripped across three replicated mainplots of poorly drained Webster soils and well drained Ves soils. Each subunit was divided into chopped and unchopped residue treatments. The residue was chopped in fall 1992.

Table 1. Tillage treatments in corn residue.

Tillage Treatment	Timing
No Till	Fall
Moldboard	Fall
VTI 0 deg. 0 in.	Fall
VTI 15 deg. 5 in.	Fall
VTI 30 deg. 10 in.	Fall

Ultra-large scale (1:13) vertical photographs were taken to record the residue cover in each plot before and after tillage. A 35 mm camera was mounted to a frame such that 1 m^2 of the ground surface was photographed from overhead. Each plot was subsampled four times in separate places. The film type used was KODAK Kodachrome Gold.

The percentage of cover was determined from the photographs using image processing techniques. The photographs were electronically scanned at a resolution of 100 pixels per linear inch. Then an image processing system was used to analyze the tonal contrast between soil and residue features. Dark toned soil features were separated from light toned residue features in a procedure termed density slicing. Some photographs were carefully retouched to enhance poor contrast in areas of dry, light colored soils. A binary image resulted that consisted of black residue features (pixel value = 0) and white soil features (pixel value = 255). The steps in computing the percentage of residue cover for each image were twofold: (1) computing a mean pixel value by summing the pixel values and dividing by the total number of pixels, and (2) dividing the mean pixel value by 255 followed by subtraction from unity and multiplication by 100. Percent residue cover left after tillage was calculated by dividing the residue cover after tillage by the residue cover before tillage then multiplying this ratio by 100. The resulting data were then statistically analyzed with the analysis of variance (ANOVA).

For purpose of comparison, measurements of residue cover were made using the common line transect method. The line transect method consists of a 100 foot cable, with beads evenly spaced at 6 inch intervals, stretched diagonally across an area to be sampled. Four transects were obtained by diagonally stretching the cable across each plot from corner to corner (twice) and from a corner in a 45 degree angle to the middle of the length of a plot and from this middle in a 45 degree angle to another corner

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(twice). Percent residue cover was determined by counting the number of beads that contacted residue as vertically viewed from overhead.

Results and Discussion

The residue cover before tillage in fall was 100 percent in all plots. The high cover was due to the luxurious and rank vegetative growth of the crop under the cool and wet growing conditions of the 1992 season. Table 2 presents the summary statistics for percent corn residue cover left after tillage. In general, the results show that corn residue cover was maximum for no-till, followed by the VTI method and moldboard.

Table 3 presents the ANOVA for percent corn residue left after tillage. The F statistic is significant for tillage treatments and hence, there is sufficient evidence to reject the null hypothesis of equal treatment means. Residue and soil are insignificant and hence, there is not sufficient evidence to reject the null hypothesis of equal treatment means for these factors. The soil-by-tillage interaction is insignificant indicating that there is not sufficient evidence to conclude that the effect of tillage on residue cover is different between well drained and poorly drained soils. Likewise, the soil-by-residue interation is insignificant indicating that there is not sufficient evidence to conclude that the effect of chopping on residue cover is different between soils.

Table 4 shows the effect of the tillage treatments on percent corn residue cover as measured across all soils. All VTI treatments incorporated significantly less residue than the moldboard method. However, the VTI treatments are not significantly different in mean residue cover left after tillage. Hence, changing the blade angle and depth with the VTI implement did not effect levels of incorporated corn residue for it is about 60 percent for the three VTI treatments.

The heavy residue conditions resulting from the rank vegetative growth may have overloaded the VTI thus rendering it ineffective. In addition, mechanical problems with the VTI may have occurred.

Figure 2 plots residue cover measured by the photographic method versus residue cover measured by the line transect method. There is a strong one-to-one relationship between both methods. The regression equation (R^2=0.95) relating the photographic method with the line transect method is

$$Y = 0.893(X)$$

where Y is photographic measured residue cover and X is line transect measured residue cover.

Table 2. Summary statistics of percent corn residue left after tillage.

Treatment	Mean	Standard Deviation	Min.	Max.	n
		All Treatments			
No Till	100	-	-	-	12
Mold Brd.	9.9	4.7	4.3	18.7	12
VTI 0 0	61.8	6.8	53.4	69.8	12
VTI 15 5	60.7	7.7	48.8	74.8	12
VTI 30 10	65.1	9.1	48.9	80.5	12
		Poorly Drained Soils, Chopped and Unchopped Residue			
No Till	100	-	-	-	6
Mold Brd.	11.8	6.2	5.2	18.7	6
VTI 0 0	61.5	8.1	53.4	69.7	6
VTI 15 5	56.9	8.0	48.8	69.1	6
VTI 30 10	61.7	12.3	48.9	76.2	6
		Well Drained Soils, Chopped and Unchopped Residue			
No Till	100	-	-	-	6
Mold Brd.	8.1	3.2	4.3	12.8	6
VTI 0 0	62.2	5.4	54.2	69.8	6
VTI 15 5	60.9	7.5	49.0	74.8	6
VTI 30 10	68.5	6.0	56.5	80.5	6

Table 2. Continued.

Treatment	Mean	Standard Deviation	Min.	Max.	n
		Poorly Drained Soils, Chopped Residue			
No Till	100	-	-	-	3
Mold Brd.	11.2	6.9	5.2	18.7	3
VTI 0 0	60.0	8.6	53.4	69.7	3
VTI 15 5	56.7	10.9	48.8	69.1	3
VTI 30 10	59.2	14.8	48.9	76.2	3
		Poorly Drained Soils, Unchopped Residue			
No Till	100	-	-	-	3
Mold Brd.	12.3	5.5	8.4	18.7	3
VTI 0 0	62.9	7.6	54.2	67.4	3
VTI 15 5	57.1	5.0	54.1	62.9	3
VTI 30 10	64.2	9.7	53.0	70.2	3
		Well Drained Soils, Chopped Residue			
No Till	100	-	-	-	3
Mold Brd.	6.7	3.3	4.3	10.5	3
VTI 0 0	63.5	8.2	54.2	69.8	3
VTI 15 5	54.7	7.4	49.0	63.1	3
VTI 30 10	62.3	6.7	56.5	69.7	3
		Well Drained Soils, Unchopped Residue			
No Till	100	-	-	-	3
Mold Brd.	9.4	3.1	6.7	12.8	3
VTI 0 0	60.9	2.6	59.1	63.8	3
VTI 15 5	67.1	7.5	59.8	74.8	3
VTI 30 10	74.6	5.3	70.3	80.5	3

Table 3. Analysis of variance for percent corn residue cover left after tillage.

Source of Variation	df	Sum of Squares	F Statistic	P Value
Soil	1	37.1	0.8	0.37
Residue	1	174.2	3.8	0.058
Tillage	4	49619.8	269.2	0.0001
Soil*Residue	1	34.7	0.8	0.39
Soil*Tillage	4	191.6	1.0	0.40
Error	48	2212.3		
Total	59	52269.8		

Table 4. Effect of tillage treatments on percent corn residue cover.

Treatment	Residue Left After Tillage	Residue Loss From Tillage	Standard Deviation	n
No Till A	100	0	-	12
VTI 30 10 B	65.1	34.9	9.1	12
VTI 0 0 B	61.8	38.2	6.8	12
VTI 15 5 B	58.9	41.1	7.7	12
Mold Brd. C	9.9	90.1	4.7	12

Means with the same letter are not significantly different at the 5 percent level of probability.

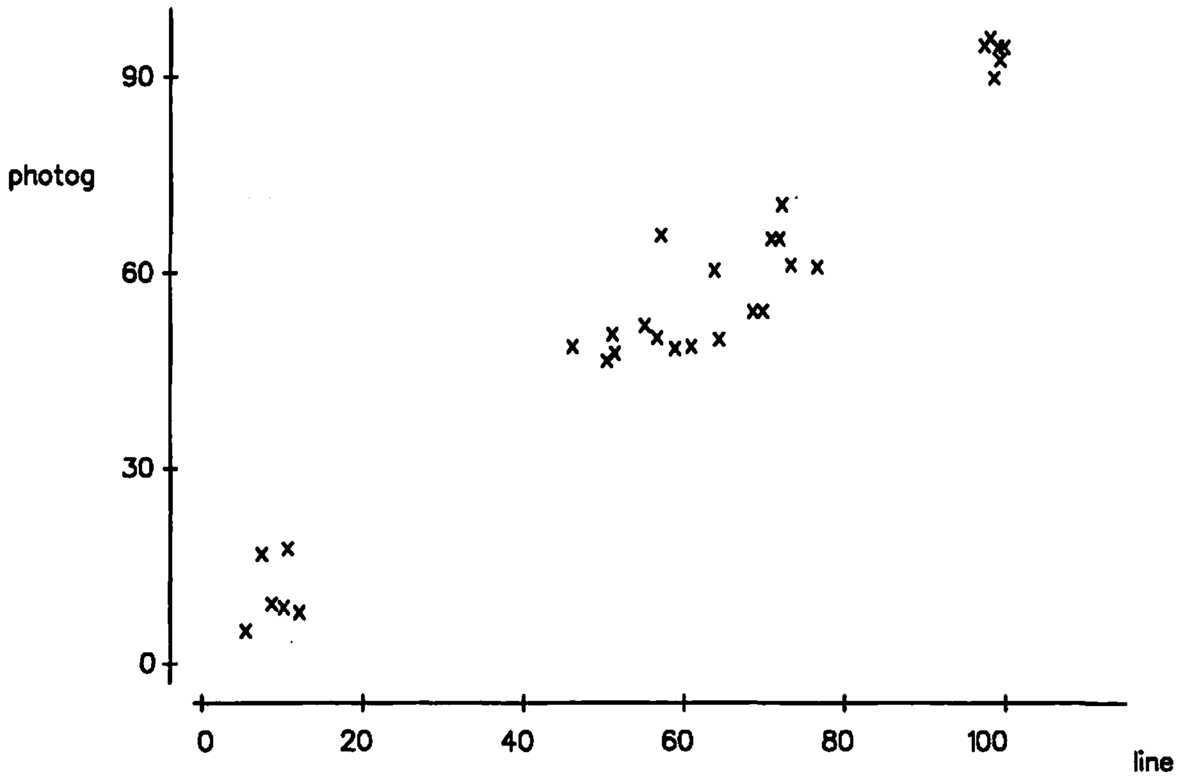

Figure 1. Relationship between photographic measured residue cover and line transect measured residue cover.

PERFORMANCE OF A VARIABLE TILLAGE IMPLEMENT IN SOYBEAN RESIDUE[1]

D.S. Long, P.C. Robert, D.J. Fuchs, and D.R. Huggins[2]

Performance of a variable tillage implement (VTI) was studied in soybean residue. This work was carried out between fall 1992 and spring 1993. By controlling blade depth and angle, the implement was designed to vary the amount of crop residue incorporated in soil. For purpose of comparison, the conventional chisel and field cultivation tillage systems were measured. Residue cover left after tillage with the VTI was 33 percent with zero blade settings to 23 percent with maximum blade settings of 30 degree angle and 10 inch depth. Residue cover after the VTI with zero blade settings was equal to that of chiseling. Residue cover after spring field cultivation was equal to that of the VTI with maximum blade settings.

Materials and Methods

A variable tillage implement (VTI), a prototype built by DMI Inc., was tested in soybean residue at the Southwest Experiment Station, Lamberton, MN in 1992 and 1993. By controlling blade angle and blade depth, the VTI is designed to vary the amount of crop residue incorporated in soil. Soybean residues were from a crop that was harvested in fall 1992. The experimental design was completely randomized block.

The experiment included the following tillage treatments: fall VTI with zero blade angle and depth (VTI 0 0), fall VTI with maximum blade angle of 30 degrees and depth of 10 inches (VTI 30 10), spring field cultivation, fall chisel, and no-till (Table 1). These treatments in turn subdivided five replicated mainplots of poorly drained Webster soils (Typic Haplaquolls) and well drained Ves soils (Udic Haplustolls). The chisel and VTI tillage treatments were applied and measured in fall 1992. The field cultivation treatment was applied and measured in spring 1993.

Table 1. Tillage treatments in soybean residue.

Treatment	Timing
No-till	n/a
Chisel	Fall 1992
Field Cultivator	Spring 1993
VTI 0 deg. 0 in.	Fall 1992
VTI 30 deg. 10 in.	Fall 1992

Ultra-large scale (1:13) vertical photographs were taken to record the residue cover in each plot before and after tillage. A 35 mm camera was mounted to a frame such that 1 m^2 of the ground surface was photographed from overhead. Each plot was subsampled four times in separate places. The film type used was KODAK Kodachrome Gold.

The percentage of residue cover was determined from the photographs using image processing techniques. The photographs were electronically scanned at a resolution of 100 pixels per linear inch. Then an image processing system was used to analyze the tonal contrast between soil and residue features. Dark toned soil features were separated from light toned residue features in a procedure termed density slicing. Some photographs were carefully retouched to enhance poor contrast in areas of dry, light colored soils. A binary image resulted that consisted of black residue features (pixel value = 0) and white soil features (pixel value = 255). The steps in computing the percentage of residue cover for each image were twofold: (1) computing a mean pixel value by summing the pixel values and dividing by the total number of pixels, and (2) dividing the mean pixel value by 255 followed by subtraction from unity and multiplication by 100. Percent residue cover left after tillage was calculated by dividing the residue cover after tillage by the residue cover before tillage then multiplying this ratio by 100. The resulting data were then statistically analyzed with the analysis of variance (ANOVA).

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For purpose of comparison, measurements of residue cover were made using the common line transect method. The line transect method consists of a 100 foot cable, with beads evenly spaced at 6 inch intervals, stretched diagonally across an area to be sampled. Four transects were obtained by diagonally stretching the cable across each plot from corner to corner (twice) and from a corner in a 45 degree angle to the middle of the length of a plot and from this middle in a 45 degree angle to another corner (twice). Percent residue cover was determined by counting the number of beads that contacted residue as vertically viewed from overhead.

Results and Discussion

The residue cover before tillage in fall 1992 averaged 77 ± 9 for the well drained soils and 79 ± 9 percent for the poorly drained soils as measured in all plots (n=75). In spring 1993 residue cover averaged 42 ± 5 percent for the well drained soils and 36 ± 12 percent for the poorly drained soils as measured in field cultivation plots (n=15). The residue at the time of tillage was fresh in fall 1992 and decomposed in spring 1993. Table 2 presents the summary statistics for percent soybean residue cover left after tillage. The results show that residue cover is 33 percent for the fall VTI with zero blade settings, 32 percent for fall chiseling, 23 percent for the fall VTI with maximum blade settings, and 22 percent for spring field cultivation.

Table 3 presents the ANOVA for percent soybean residue left after tillage. The F statistic is significant for tillage treatments and hence, there is sufficient evidence to reject the null hypothesis of equal treatment means. The F value is significant for the soil factor, however, statistical inference for this treatment cannot be made because the experiment was limited to only one field. The soil-by-tillage interaction is insignificant indicating that there is not sufficient evidence to conclude that the effect of tillage on residue cover is different between well drained and poorly drained soils.

Table 4 shows the effect of tillage treatments on percent soybean residue cover as measured across all soils. Residue cover after the VTI with zero settings and chiseling is significantly greater than that after the VTI with maximum blade settings and spring field cultivation. These results indicate that nonzero VTI blade settings decrease the amount of soybean residue left on the soil surface after tillage. Residue cover is highest at 33 percent for the VTI method with zero blade settings and decreases to 23 percent with increasing blade angle to 30 degrees and blade depth to 10 inches. There is little practical difference in residue levels between the fall chisel and fall VTI with zero blade settings, and between spring field cultivation and the fall VTI with maximum blade settings.

Figure 2 plots residue cover measured by the photographic method versus residue cover measured by the line transect method. There is a strong one-to-one relationship between both methods. The regression equation (R^2=0.91) relating the photographic method with the line transect method is

$$Y = 1.12*(X)$$

where Y is photographic measured residue cover and X is line transect measured reside cover.

Table 2. Summary statistics for percent soybean residue cover left after tillage.

Treatment	Mean	Variance	Max.	Min.	N
		----------%----------			
No Till in Fall	100.0	n/a	n/a	n/a	29
No Till in Spring	48.8	27.4	62.4	41.0	29
Fall Chisel	31.7	224.5	58.1	10.0	30
Spring Fld. Cult.	22.3	130.6	65.4	5.6	30
Fall VTI 0 0	33.1	139.9	52.7	13.0	30
Fall VTI 30 10	23.7	106.2	54.9	7.0	30

Table 3. Analysis of variance for percent soybean residue cover (all soils).

Source of Variation	Sum of Squares	F Statistic	P Value
Blocks	2472.7	5.23	0.0007
Soil	1918.2	16.23	0.0001
Tillage	2752.8	7.77	0.0001
Soil*Tillage	318.3	0.90	0.4449
Error	12642.6		
Total	20017.9		

Table 4. Effect of tillage treatments on percent soybean residue cover (all soils).

Treatment	Residue Left After Tillage †	Standard Deviation	N
	----------%-----------		
Spring Fld. Cult.	22.3 A	11.4	30
Fall VTI 30 10	23.4 A	10.3	30
Fall Chisel	31.6 B	15.0	30
Fall VTI 0 0	33.1 B	11.8	30

† Means with the same letter are not significantly different at the 5 percent level of probability.

Table 5. Descriptive statistics for percent soybean residue cover left after tillage (well drained soils).

Treatment	Mean	Variance	Max.	Min.	N
		------------------%------------------			
No Till in Fall	100.0	n/a	n/a	n/a	14
No Till in Spring	51.2	26.4	62.4	43.9	14
Fall Chisel	27.6	177.4	54.0	10.0	15
Spring Fld. Cult.	20.2	65.7	32.8	5.6	15
Fall VTI 0 0	26.5	84.7	41.1	13.0	15
Fall VTI 30 10	20.6	66.5	34.5	9.9	15

Table 6. Descriptive statistics for percent soybean residue cover left after tillage (poorly drained soils).

Treatment	Mean	Variance	Max.	Min.	N
		------------------%------------------			
No Till in Fall	100.0	n/a	n/a	n/a	15
No Till in Spring	46.6	19.6	56.1	41.0	15
Fall Chisel	35.9	251.4	58.1	11.6	15
Spring Fld. Cult.	24.5	195.0	65.4	13.1	15
Fall VTI 0 0	39.7	112.7	52.7	14.4	15
Fall VTI 30 10	26.7	131.0	54.9	7.0	15

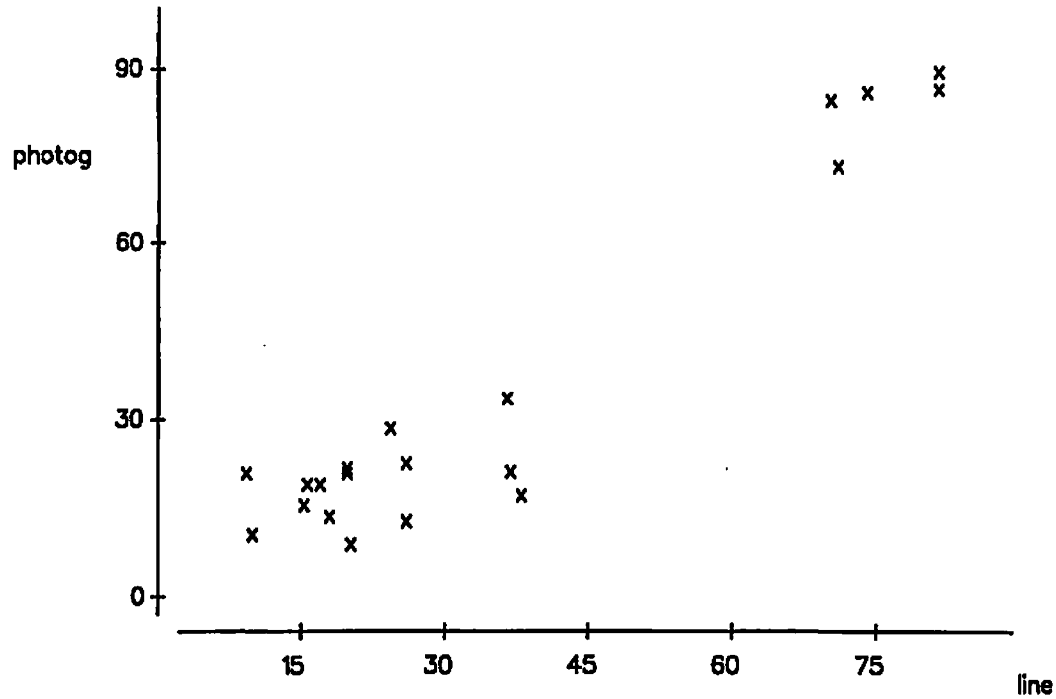

Figure 1. Relationship between photograph measured residue cover and line transect measured residue cover.

MUNICIPAL SOLID WASTE COMPOST USE ON AGRICULTURAL SOILS[1]

M. MAMO, C. J. ROSEN, T. R. HALBACH, J. F. MONCRIEF[2]

ABSTRACT

Field experiments were conducted at Staples and Becker to assess corn yield and nitrate leaching on soils amended with municipal solid waste (MSW) compost. The MSW composts (Truman, Swift, and St. Cloud) were applied in the spring of 1992. The Becker location received Truman and Swift composts, while Staples received Truman and St. Cloud composts. The compost rates were 0, 20,40, and 80 T/A with either 0, 220, or 440 lbs/A N fertilizer. Residual effect of compost treatments were determined in 1993 at both locations. In 1993 at Becker, MSW compost from Truman and Wright Counties were also applied on new plots to see the effect of split vs one time application. The compost rate was 40 T/A (yearly application) and 120 T/A (one time application) with either 0, 110, or 220 lbs/A N fertilizer. In 1992, nitrate leaching was high on non-amended soils compared to compost amended soils. Among the composts, the Truman compost gave lower corn yield but lower NO_3-N leaching. In 1993, yield was relatively high on residual plots compared to the control. The 1993 established plot gave reasonable yield at all compost rates with N application. Yield was lower at all compost rates when N was not applied.

INTRODUCTION

Application of MSW compost (MSW) to agricultural soils could be a beneficial alternative for recycling of solid waste. Minnesota is one of the states that has an expanded production of composted municipal solid waste. We conducted experiments at the Sand Plain Research Farm, Becker, MN, and at the Irrigation center, Staples, MN, in 1992 and 1993. The objectives of this waste management/fertility research were to evaluate the effects different MSW compost and nitrogen rate application on agricultural soils and assess the potential for improving soil fertility and physical properties.

MATERIALS AND METHODS

The experiments were conducted at two locations during the 1992 and 1993 growing seasons.

1992

Composted municipal solid waste (Truman, Swift, and St Cloud) was incorporated in plots at two experimental locations. The Staples location received composts from Truman and St Cloud, while the Becker location received composts from Truman and Swift. The experimental design was a split plot arranged in factorial and replicated four times. Compost at Becker was moldboard plowed and disced at Staples. The compost rates on a dry weight basis were 0, 20, 40, and 90 T/A. The N rate applied as urea was 0, 220, and 440 lbs/A.

Field corn (*Zea mays* L.) variety Pioneer 3921 was planted at a rate of 28600 kernels per acre on 5/29/92 at Staples and on 6/1/92 at Becker. A starter fertilizer at a rate of 150 lbs N/A was applied at planting at Becker. Nitrogen fertilizer was sidedressed in two split applications. Ceramic suction cup tubes were installed in two of the four replications of each plot at the 3 and 6 foot depth. Solid set and pivot irrigation was used at Becker and Staples, respectively.

Whole plant samples at the 8-10 leaf stage and ear leaves at initial silking were taken from harvest rows. Final yield was harvested as grain and stover at Becker, and as silage at Staples. Tissue nutrient analyses were done on each harvested plant part.

1993

The 1993 compost utilization project (CUP) is a follow up of the study initiated in 1992 on municipal solid waste (MSW) compost. In addition to residual effect from the 1992 experiment, an additional experiment was established to evaluate split and annual compost application. The new field site utilized MSW compost from Truman, MN (Prairieland composting facility) and Buffalo, MN (Wright county composting facility). The experimental design was a split plot arranged in a complete factorial. The compost rates were 40 T/A as an annual application and 120 T/A as a one time application. The N rates were 0, 110, and 220 lbs/A. Suction ceramic cups were installed in three of the four replications. Weekly soil water sampling was done to analyze for nitrate and trace metals. All other methods and procedures are the same as the 1992 experiment.

Table 1. Chemical characteristics of Hubbard loamy sand and Verndale sandy loam at 0-15 cm depth.

Soil	pH	O.M.	Ca	K	Mg	Zn	B	S	P
		%	mg/kg						
Hubbard	5.8	1.4	463	77	78	0.9	0.4	1.2	20
Verndale	6.3	3.2	960	137	133	2.7	0.6	5.0	23

[1]Support for this project was provided by the Minnesota Office of Waste Management and the Minnesota Pollution Control Agency. Their support is greatly appreciated.

[2]M. Mamo, C. J. Rosen, T. R. Halbach, and J. F. Moncrief are Graduate student, Associate Professor, Extension Specialist, and Associate Professor, respectively.

Table 2. Initial NH_4-N and NO_3-N concentration of Hubbard loamy sand and Verndale sandy loam soils.

Depth	Hubbard			Verndale		
	mg/kg					
	NH_4-N	NO_3-N	Total	NH_4-N	NO_3-N	Total
0-30	2.5	1.5	4.0	4.6	6.7	11.3
30-60	1.0	0.4	1.4	1.0	2.8	3.8
60-90	0.8	0.4	1.2	1.1	1.7	2.8
Total	4.3	2.4	6.7	6.7	11.2	17.9

Table 3. Chemical characteristics of the composts.

Compost Source	pH	O.M.	Total C	Total N	C:N	NH_4-N	NO_3-N
		%				mg/kg	
Truman	7.2	50.2	22.8	0.7	32.6	81.2	6.2
Swift	7.4	39.5	21.9	1.6	13.6	33.8	7.0
St. Cloud	7.7	43.3	10.9	0.8	13.6	100.4	5.0

Table 4. Elemental analysis of the municipal solid waste composts.

Compost	Na	K	Mg	Ca	Fe	P	S	Zn	Pb	Cd	Mo	B
	g/kg							mg/kg				
Truman	4.7	3.6	3.6	24.1	22	2.1	6.2	1260	265	9.6	10.7	70
Swift	6.4	10.6	5.3	42.4	7.1	4.2	4.4	960	390	4.7	8.3	50
St.Cloud	2.6	6.6	4.2	27.0	13.3	2.7	5.0	480	250	7.5	6.7	60

RESULTS

Table 5. Effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population at Becker, MN., 1992.

Compost type	N rate LBS/A	Compost rate T/A	Grain BU/A	Stover T/A	Plant/A x 1000
Control	0	0	63.0	1.5	27.2
Control	220	0	103.5	2.4	28.9
Control	440	0	99.3	2.3	29.6
Truman	0	20	72.5	1.8	30.6
Truman	220	20	106.3	2.6	29.4
Truman	0	40	72.4	1.1	28.8
Truman	220	40	86.4	2.4	27.8
Truman	440	40	96.6	2.5	29.0
Truman	0	80	86.6	1.4	28.6
Truman	220	80	79.0	2.0	29.7
Swift	0	40	110.0	3.0	30.5
Swift	220	40	104.8	2.9	29.5
Significance			**	**	NS
BLSD			21.3	0.4	---

BLSD-Duncan Waller
** Highly significant (p=0.01)
NS Not significant

Table 6. Effect of compost type, compost rate, and nitrogen rate on silage yield, and plant population at Staples, MN., 1992.

Compost type	N rate LBS/A	Compost rate T/A	Silage Yield BU/A	Plant/A x1000
Control	0	0	2.7	28.3
Control	220	0	6.1	29.4
Truman	0	20	1.6	26.7
Truman	220	20	4.6	26.4
Truman	0	40	1.3	24.9
Truman	220	40	4.3	27.0
Truman	440	40	4.6	28.1
Truman	0	80	1.4	25.8
Truman	220	80	3.5	25.7
St Cloud	0	40	4.4	28.0
St Cloud	220	40	6.3	29.9
St Cloud	440	40	6.8	28.4
Significance			**	**
BLSD			1.3	3.5

BLSD-Duncan Waller
** Highly Significant (p=0.01)
NS Not significant

Table 7. Elemental analysis of grain at Becker in 1992.+

Compost	N rate LBS/A	Compost rate T/A	N %**	Na	K	Ca	Mg	Fe	Mn	Cu	Zn	Mo	B	P
				mg/kg										
Control	0	0	1.2	5.9	4432	47.8	1071	12.4	4.0	0.9	16.4	0.2	2.8	3140
Control	220	0	1.5	4.7	4289	43.7	1113	18.3	5.1	1.1	18.8	0.2	2.8	2967
Control	440	0	1.4	4.0	4103	46.2	1114	19.1	5.5	1.2	18.5	0.2	2.1	2848
Truman	0	20	1.2	5.1	4531	47.7	1070	12.5	4.1	0.9	18.1	0.2	2.8	3194
Truman	220	20	1.5	6.4	4208	40.9	1115	17.3	4.8	1.1	21.0	0.2	2.5	3088
Truman	0	40	1.4	5.7	4667	52.7	1096	13.9	4.4	1.1	18.9	0.2	2.8	3265
Truman	220	40	1.3	5.8	4611	51.5	1156	18.8	5.1	1.2	21.6	0.2	2.7	3229
Truman	440	40	1.4	4.3	4248	46.4	1098	18.9	5.2	1.2	20.8	0.2	2.3	2922
Truman	0	80	1.2	5.6	4550	43.3	1057	14.3	4.3	0.9	19.8	0.2	2.8	3190
Truman	220	80	1.4	5.8	4533	54.0	1072	18.2	4.7	1.2	20.9	0.2	2.9	3097
Swift	0	40	1.5	5.2	4258	37.8	1127	18.6	4.9	1.0	20.7	0.3	2.5	3267
Swift	220	40	1.7	6.7	4155	39.1	1148	20.6	5.2	0.9	21.7	0.3	2.4	3271
Significance			*	NS	**	**	NS	**	**	**	**	*	**	*
BLSD			0.4	-	446	10.5	-	2.8	0.7	0.3	2.9	0.04	0.3	421

+Pb and Cd were not significant with average values of <1.7 and <0.1 mg/kg on all treatments, respectively.
**Based on three replications.
BLSD-Duncan Waller
* Significant (p=0.1)
** Highly significant (p=0.01)
NS Not significant

Table 8. Elemental analysis of silage at Staples in 1992.+

Compost	N rate LBS/A	Compost rate T/A	N %	Na	K	Ca	Mg	Fe	Mn	Cu	Zn	Mo	B	P
				mg/kg										
Control	0	0	0.9	28.8	11474	2021	1865	80.2	25.7	2.5	31.0	0.4	5.1	2878
Control	220	0	1.3	23.3	12002	2021	1488	72.3	28.7	3.6	23.0	0.3	4.9	1809
Truman	0	20	1.1	36.8	15897	2010	1705	100.0	26.2	3.6	40.5	0.7	7.7	3386
Truman	220	20	1.3	30.0	14655	1944	1435	73.3	26.6	4.0	36.4	0.7	7.8	2278
Truman	0	40	1.3	28.3	15374	2138	1656	85.3	29.9	3.4	36.6	0.7	8.1	3228
Truman	220	40	1.4	23.2	14940	2031	1526	69.3	28.7	4.2	43.9	0.8	8.6	2890
Truman	440	40	1.4	21.2	15624	2131	1503	72.7	30.2	4.9	38.7	0.8	8.7	2215
Truman	0	80	1.2	27.2	17175	2125	1811	89.1	27.2	3.7	46.8	0.8	8.6	3656
Truman	220	80	1.3	24.7	16168	2101	1541	81.7	28.0	4.7	45.8	1.0	10.1	2913
St Cloud	0	40	1.2	28.0	14311	1906	1572	81.1	24.2	3.6	37.5	1.3	7.8	3129
St Cloud	220	40	1.3	27.3	14758	1990	1409	78.9	27.5	4.1	32.4	0.8	7.4	2131
St Cloud	440	40	1.3	23.6	14778	2393	1505	76.0	33.3	4.8	33.4	1.0	8.4	2107
Significance			*	NS	**	NS	**	NS	NS	**	**	**	**	**
BLSD			0.3	-	2430	-	320	-	-	0.7	12.2	0.2	1.7	1109

+Pb and Cd were not significant with average values of <1.7 and <0.1 mg/kg on all treatments, respectively.
BLSD-Duncan Waller
* Significant (p=0.1)
** Highly significant (p=0.01)
NS Not significant

Table 9. NH_4OAC extractable cations, pH, and Bray-P of Hubbard loamy sand at 0-15 cm at the end of the 1992 growing season.

Compost	N rate LBS/A	Compost rate T/A	pH	Ca	Mg	Na	K	Mn	P
			mg/kg						
Control	0	0	6.3	475	85.8	3.1	48.9	3.4	16.5
Control	220	0	5.8	433	71.9	3.6	49.6	4.9	15.2
Control	440	0	5.7	447	76.3	3.3	45.1	6.3	18.8
Truman	0	20	6.1	514	85.2	4.4	54.8	3.9	17.3
Truman	220	20	5.8	470	73.1	3.8	52.6	5.6	16.8
Truman	0	40	6.4	549	85.5	3.9	57.0	3.2	21.5
Truman	220	40	6.1	554	80.9	6.5	59.6	4.6	22.5
Truman	440	40	5.7	464	72.0	4.1	45.8	6.1	20.5
Truman	0	80	6.3	557	79.4	5.0	56.7	3.5	17.0
Truman	220	80	6.3	590	73.8	9.4	59.7	4.0	18.3
Swift	0	40	6.2	606	94.8	19.5	112.7	4.0	21.8
Swift	220	40	5.9	541	79.4	14.0	103.7	6.1	24.7
Significance			**	NS	NS	**	**	**	NS
BLSD			0.4	-	-	9.3	25.3	1.6	-

BLSD-Duncan Waller
** Highly significant (p=0.01)
NS Not significant

Table 10. NH_4OAC extractable cations, pH, and Bray-P of Verndale sandy loam at 0-15 cm at the end of the 1992 growing season.

Compost type	N rate LBS/A	Compost rate T/A	pH	Ca	Mg	Na	K	Mn	P
			mg/kg						
Control	0	0	6.6	1214	165.9	7.6	145.0	7.4	27.3
Control	220	0	6.5	1193	162.8	7.7	135.2	8.5	28.8
Truman	0	20	7.0	1539	181.7	31.3	196.1	6.5	36.0
Truman	220	20	6.9	1637	188.4	25.0	196.0	7.0	32.3
Truman	0	40	7.2	1626	161.9	32.0	214.2	7.7	36.8
Truman	220	40	7.1	1661	153.3	25.3	193.2	6.8	35.8
Truman	440	40	7.1	1580	168.0	23.0	218.2	5.8	39.5
Truman	0	80	7.2	1620	164.9	35.4	229.9	7.4	42.0
Truman	220	80	7.1	1550	158.6	45.0	211.1	8.1	42.3
St Cloud	0	40	7.0	1897	219.1	24.0	289.8	7.1	57.0
St Cloud	220	40	7.0	1969	224.9	24.4	318.7	6.9	57.0
St Cloud	440	40	6.9	1477	168.6	11.8	231.9	6.7	45.5
Significance			**	**	**	**	**	NS	**
BLSD			0.5	332	29.1	19.5	43.2	-	8.6

BLSD-Duncan Waller
** Highly significant (p=0.01)
NS Not significant

Table 11. DTPA extractable trace metals of Hubbard loamy sand at 0-15 cm at the end of the 1992 growing season.

Compost	N rate LBS/A	Compost rate T/A	Fe	Mn	Zn	Cu	Pb	Ni	Cd
			mg/kg						
Control	0	0	16.8	6.9	0.7	0.2	0.6	0.3	0.03
Control	220	0	21.2	9.2	0.7	0.2	0.6	0.4	0.04
Control	440	0	20.8	10.2	0.6	0.2	0.4	0.3	0.04
Truman	0	20	20.0	7.1	1.2	0.4	0.5	0.4	0.05
Truman	220	20	24.6	10.5	1.4	0.4	0.6	0.4	0.05
Truman	0	40	17.6	6.3	2.7	0.9	0.5	0.3	0.05
Truman	220	40	22.4	9.1	3.9	1.4	0.8	0.4	0.05
Truman	440	40	22.2	10.4	2.4	0.8	0.6	0.4	0.05
Truman	0	80	18.8	6.5	3.4	1.3	0.6	0.3	0.05
Truman	220	80	21.9	7.9	5.4	1.6	0.8	0.4	0.06
Swift	0	40	24.3	8.5	3.5	0.9	0.8	0.4	0.06
Swift	220	40	25.8	11.4	3.5	0.6	0.9	0.4	0.06
Significance			*	**	**	**	NS	NS	NS
BLSD			7.4	4.3	2.6	0.9	-	-	-

BLSD-Duncan Waller
* Significant (p=0.1)
** Highly significant (p=0.01)
NS Not significant

Table 12. DTPA extractable trace metals of Verndale sandy loam sand at 0-15 cm at the end of the 1992 growing season.

Compost type	N rate	Compost rate	Fe	Mn	Zn	Cu	Pb	Ni	Cd
	LBS/A	T/A	mg/kg						
Control	0	0	36.8	19.8	2.9	0.6	0.6	0.7	0.1
Control	220	0	39.5	21.8	3.1	0.5	0.6	0.6	0.1
Truman	0	20	38.2	19.71	3.4	6.0	1.7	0.8	0.1
Truman	220	20	40.2	22.21	2.5	4.2	1.5	0.8	0.1
Truman	0	40	36.8	22.6	17.4	7.3	2.4	0.8	0.2
Truman	220	40	34.8	21.5	14.3	5.3	1.8	0.8	0.1
Truman	440	40	35.4	18.6	16.5	5.7	2.0	1.6	0.2
Truman	0	80	10.4	22.8	20.2	7.1	2.4	0.9	0.2
Truman	220	80	43.3	23.0	20.9	8.9	2.7	1.0	0.2
St Cloud	0	40	55.1	21.9	9.9	3.0	2.7	0.9	0.2
St Cloud	220	40	55.4	21.2	11.5	3.2	2.9	0.9	0.2
St Cloud	440	40	43.7	17.8	8.2	2.3	2.7	0.7	0.2
Significance			**	NS	**	**	**	NS	**
BLSD			12.1	-	3.7	2.0	0.8	-	0.03

BLSD-Duncan Waller
** Highly significant (p=0.01)
NS Not significant

Table 13. Total nitrogen of Hubbard loamy sand soil at two depths at the end of the 1992 growing season.

Compost type	N rate	Compost rate	Total %N	
	LBS/A	T/A	0-15 cm	15-30 cm
Control	0	0	0.26	0.23
Control	220	0	0.29	0.25
Control	490	0	0.29	0.26
Truman	0	20	0.28	0.32
Truman	220	20	0.30	0.30
Truman	0	40	0.29	0.28
Truman	220	40	0.30	0.31
Truman	440	40	0.28	0.29
Truman	0	80	0.32	0.32
Truman	220	80	0.32	0.32
Swift	0	40	0.38	0.37
Swift	220	40	0.36	0.40
Significance			NS	*
BLSD			-	0.14

BLSD-Duncan Waller
* Significant (p=0.1)
NS Not significant

Table 14. Total nitrogen of Verndale sandy loam soil at two depths at the end of the 1992 growing season.

Compost type	rate	Compost rate	Total %N	
	LBS/A	T/A	0-15 cm	15-30 cm
			mg/kg	
Control	0	0	0.55	0.47
Control	220	0	0.58	0.45
Truman	0	20	0.69	0.46
Truman	220	20	0.75	0.50
Truman	0	40	0.71	0.49
Truman	220	40	0.74	0.54
Truman	440	40	0.66	0.53
Truman	0	80	0.76	0.48
Truman	220	80	0.73	0.44
St Cloud	0	40	0.90	0.53
St Cloud	220	40	0.95	0.64
St Cloud	440	40	0.78	0.53
Significance			**	**
BLSD			0.07	0.07

BLSD-Duncan Waller
** Highly significant (p=0.01)
NS Not significant

1993:

Table 15. Effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population at the new field site in Becker, MN. 1993.

Compost type	N rate LBS/A	Compost T/A	Grain BU/A	Stover T/A	Plant/A x 1000
Control	0	0	83.2	1.82	33.3
Control	110	0	148.3	2.83	33.4
Control	220	0	158.6	2.94	32.8
Truman	0	40	136.6	2.52	31.9
Truman	110	40	157.6	3.13	33.4
Truman	220	40	157.1	3.39	33.0
Truman	0	1-0	133.9	2.45	29.5
Truman	110	120	136.5	2.61	29.5
Truman	220	120	142.3	2.74	28.7
Wright	0	40	138.1	2.71	32.3
Wright	110	40	152.6	3.16	33.5
Wright	220	40	158.0	3.15	31.9
Wright	0	120	153.4	3.04	31.4
Wright	110	120	151.5	3.10	33.4
Wright	220	120	149.7	2.93	32.2
STATISTICS					
Compost type			*	*	*
N rate			**	**	NS
Compost rate			**	**	**
Compost rate*N rate			**	**	NS
Compost type*Compost rate			*	NS	*
N rate* Compost type			NS	NS	NS
Compost type*Compost rate*N rate			NS	NS	NS

BLSD-Duncan Waller
* Significant (p=0.1)
** Highly significant (p=0.01)
NS Not significant

Table 16. Plant moisture stress measured on the 120 T/A compost rate at 220 lbs N/A during the 1993 growing season.

Compost Source	N rate LBS/A	Compost rate T/A	Leaf Tension in bar[1] Morning	Afternoon
Control	220	120	2.4aa	6.8ba
Truman	220	120	5.1ab	8.4aa
Swift	220	120	4.3ab	6.8aa

[1]Tukey's studentized mean comparison. Means with the same letter are not significantly different from each other (alpha=0.05).
Italicized letters compare means of morning and afternoon measurements across.
Bold letters compare means of compost sources.

Table 17. Residual effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population at Becker, MN., 1993

Compost type	N rate LBS/A	Compost T/A	Grain BU/A	Stover T/A	Plant/A x 1000
Control	0	0	52.4	1.41	24.6
Control	220	0	154.0	2.94	28.7
Control	440	0	155.0	3.10	28.9
Truman	0	20	113.6	2.25	30.5
Truman	220	20	144.7	3.55	26.2
Truman	0	40	104.3	2.20	29.6
Truman	220	40	156.7	3.24	29.3
Truman	440	40	158.7	3.15	28.5
Truman	0	80	105.1	2.64	25.3
Truman	220	80	138.8	3.20	25.8
Swift	0	40	133.2	2.53	29.9
Swift	220	40	160.7	3.23	30.8
Significance			**	**	NS
BLSD			29.2	0.48	---

BLSD-Duncan Waller
** Highly significant (p=0.01)
NS Not significant

Table 18. Residual effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population at Staples, MN. 1993.

Compost type	N rate LBS/A	Compost rate T/A	Grain BU/A	Stover T/A	Plant/A x 1000
Control	0	0	53.3	2.08	23.5
Control	220	0	114.8	1.34	24.7
Truman	0	20	72.2	1.77	22.0
Truman	220	20	119.1	1.56	23.8
Truman	0	40	94.7	1.47	22.9
Truman	220	40	123.8	1.85	24.1
Truman	440	40	112.1	1.71	23.5
Truman	0	80	98.9	1.73	23.3
Truman	220	80	123.5	1.85	24.8
St Cloud	0	40	80.1	1.61	23.3
St Cloud	220	40	122.4	1.72	24.9
St Cloud	440	40	113.3	1.41	23.2
Significance			**	NS	NS
BLSD			11.7	--	--

BLSD-Duncan Waller
** Highly significant (p=0.01)
NS Not significant

SUMMARY OF RESULTS

1992:

Initial soil: The Hubbard loamy sand was under continuous rye before initiation of our experiment. The pH of both Hubbard loamy sand and Verndale sandy loam were slightly acidic (Table 1). The Verndale loamy sand was high in O.M. content, nitrogen (both organic and inorganic) content (Table 2), and essential nutrients.

Municipal solid waste elemental composition: The inorganic nitrogen content of the composts was mainly present as NH_4 (Table 3). This may be a result of reduced (low oxygen) condition during the composting process. The O.M. matter content was high for all compost, being the highest in the Truman compost. The C:N was desirable for the Swift and St Cloud composts, but was very high for the Truman compost. The compost sources used qualified as Class I compost based on the relative concentration of trace metals (Table 4). All trace elements were elevated compared to what we find in natural soils.

Yield: Corn yield for Becker and Staples are presented in Tables 5 and 6. The Truman compost was relatively immature as indicated by the higher C:N ratio. Silage and grain yield was increased by the addition of fertilizer N for Truman compost. Grain and silage yield were much lower for the Truman when no N was applied. Swift and St Cloud compost with lower C:N ratio gave higher yield compared to Truman. Yield generally decreased with an increase in compost rate, regardless of N rate. The compost and N rate showed a significant interaction for the Becker location. The Swift compost at 40 T/A with and without N application had yield similar to the control at 220 lbs N/A.

Plant tissue metals: At Becker, compost and nitrogen treatments had significant effect on grain K, Ca, Fe, Mn, Cu, Zn, Mo, and B (Table 7). At Staples, compost and N treatments had significant effect on silage K, Ca, Fe, Mn, Cu, Zn, Mo, B, and P (Table 8). Neither grain nor silage produced in compost amended plots accumulated trace metals compared to the control.

NH_4OAC extractable cations, pH, and Bray extractable P: Becker- The pH of the soil was significantly affected by the treatments (Table 9). The soil pH was slightly acidic at the end of the growing season. The soil Ca, Mg, and P was not different due to treatment differences. Sodium and potassium was significant due to treatments. Soil K and Na were high in plots amended with Swift compost with or without N.
Staples- The soil pH was affected by treatments. Soil pH, Ca, Mg, Na, K, Mn, and P levels in soil were much higher at Staples than Becker. This may due to the initial conditions of the soil and the difference in compost incorporation between the two locations. All ammonium acetate extractable cations with the exception of MN were significant with treatments (Table 10). Bray extractable P was also significant with treatments.

Soil trace metals: Trace metals in soil were extracted in DTPA at the end of the growing season. Zinc was elevated in soils amended with Truman compost (Tables 11 and 12). The treatments had significant effect on Fe, Mn, Zn, and Cu, at Becker, and on Fe, Zn, Cu, Pb, and Cd at Staples. At Staples, the high compost rates of both Truman and St Cloud gave higher DTPA extractable Cd in soil compared to the control. Iron was elevated in soils amended with St Cloud compost compared to the control or the Truman compost at Staples. Iron was also elevated at Becker in soils amended with Swift compost.

Soil total N: The total N content of the Verndale sandy loam at two depths was much higher than the Hubbard soil (Tables 13 and 14). Generally, the percent N of the 0-15 cm depth was higher than the 15-30 cm depth at both locations. Plots that received St Cloud compost had the highest soil N at all rates. Compared to the controls at all N rates, plots with compost rates of 20, 40, and 80 T/A with no N application gave higher percent N at both depths.

Soil water: Becker- Soil water NO_3-N with no N application was high for the control compared to the Truman compost at all rates (Figs. 1 and 2). However, at the same rate, the Swift compost had much higher soil water NO_3-N compared to the control and Truman compost (Figs. 3 and 4). Truman compost had the least soil water with or without N application.
Staples- Similar to Becker, the soil water NO_3-N was high on the control plots throughout the growing seasons. Truman compost rates at 0 and 220 lbs N/A had lower soil water NO_3-N leaching (Figs. 5 and 6). However, an abrupt increase in soil water NO_3-N leaching was observed for all Truman compost rates at 220 lbs N/A toward the end of the growing season. This peak increase was especially abrupt for the 80 T/A Truman compost rate (Fig. 6). Soil water NO_3-N leaching was lower for the Truman and St Cloud composts throughout the season at both N rates (Figs. 7 and 8). There was an increase in soil water NO_3-N for the control, Truman, and Swift toward the end of the growing season.

The results suggest that compost with high C:N ratio has potential for N immobilization and may decrease yield unless fertilizer N is added. Compost with lower C:N ratio gave appreciable yield with or without N fertilizer application. Compost with a lower C:N ratio does not enhance NO_3-N leaching. Unlike the high C:N ratio compost, the lower C:N compost with no N fertilizer had high NO_3-N leaching due to the availability of mineralized N. Leaching was even enhanced upon the addition of fertilizer N on compost with low C:N ratio.

1993:
Yields were higher in 1993 compared to 1992 partly due to an earlier planting date in 1993. The Truman compost obtained in 1993 was relatively mature compared to the 1992 Truman compost.

New experiment yield: Grain and stover yields were relatively high for the new field (Table 15). Compared to the control, grain yield was high at both compost rates with no N application. Overall, the Wright county compost gave higher yield than the Truman compost.

Plant moisture stress: Plant water stress was measured using pressure bomb apparatus. Water stress was significantly lower in the morning than the afternoon for the control (Table 16). The morning and afternoon plant water stress for the composts were not significantly different. Plant water stress was high for all treatments in the afternoon, but were not significantly different.

Residual yield effect : Grain and stover yields were much higher for the all compost rates with no N application (Tables 17 and 18). The higher grain and stover yield of the compost with no N suggest residual compost effect. Grain yield was higher for the Swift compost compared to the control and the Truman compost.

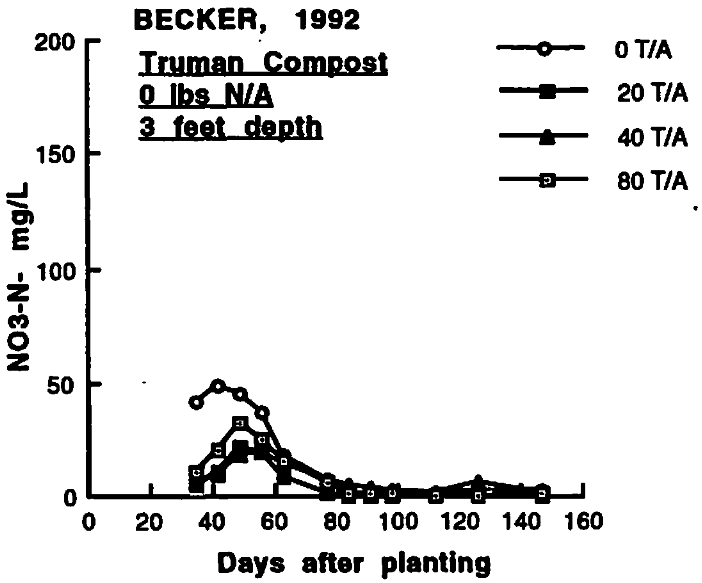

Fig. 1- Soil water NO3-N at Becker at four Truman compost rates.

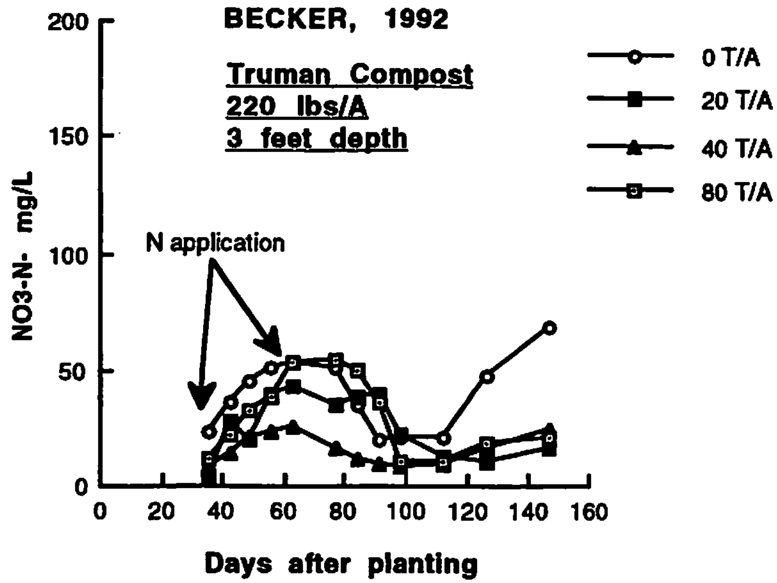

Fig. 2- Soil water NO3-N at Becker at four Truman compost rates.

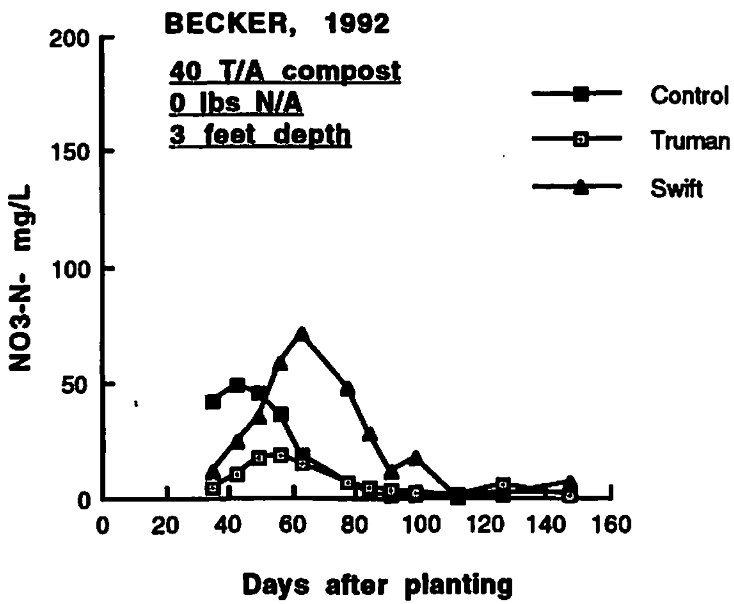

Fig. 3- Soil water NO3-N at Becker with two sources of compost.

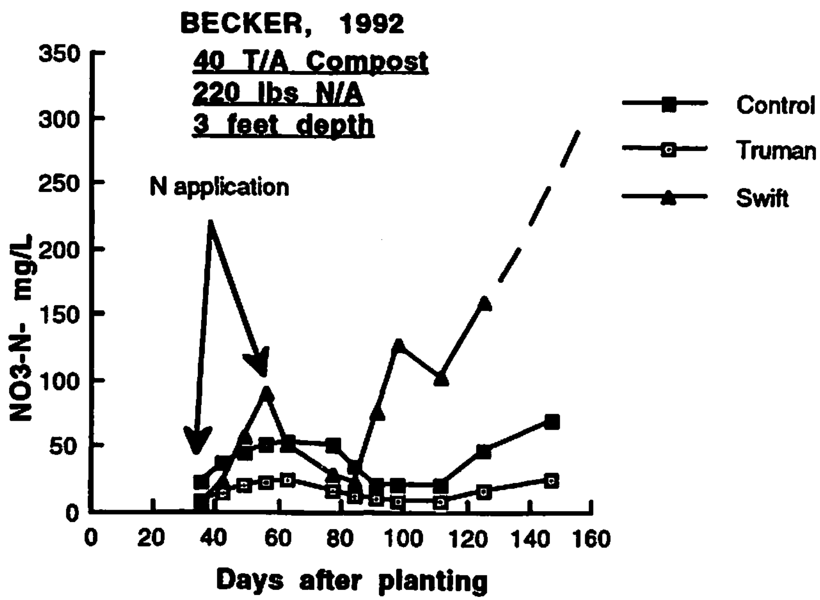

Fig. 4- Soil water NO3-N at Becker with two sources of compost.

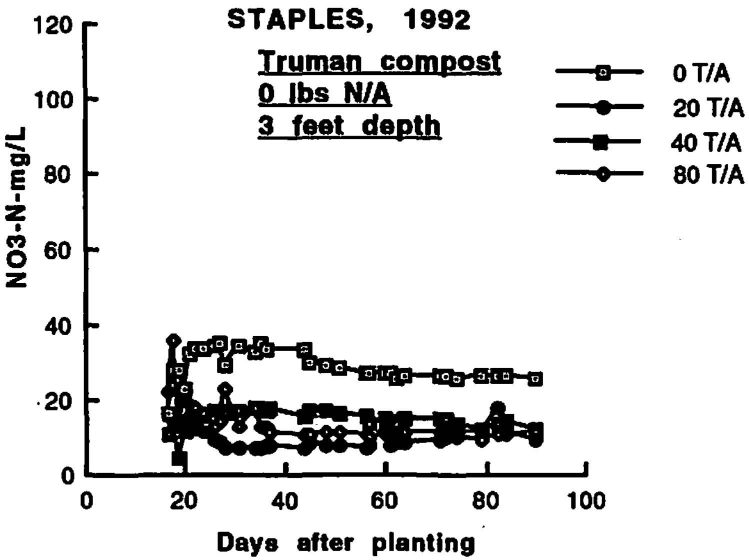

Figure 5- Soil water NO3-N at Staples at four Truman compost rates.

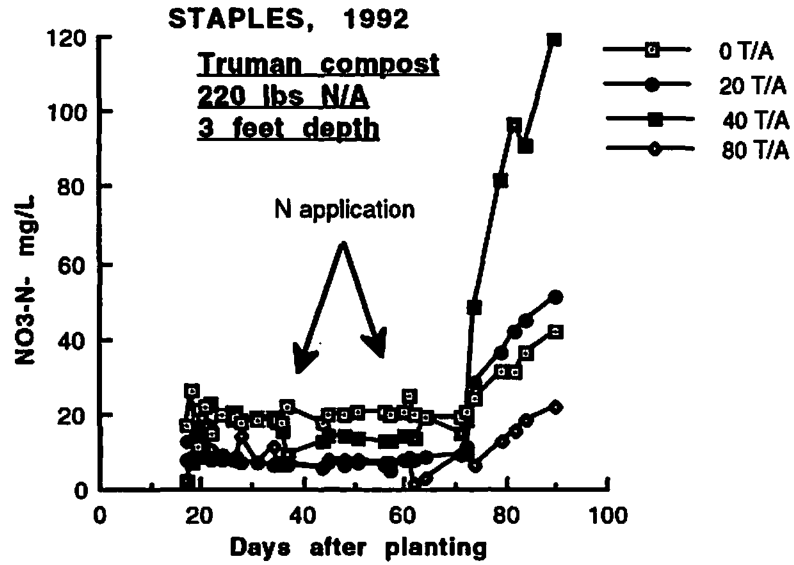

Figure 6- Soil water NO3-N at Staples at four Truman compost rates.

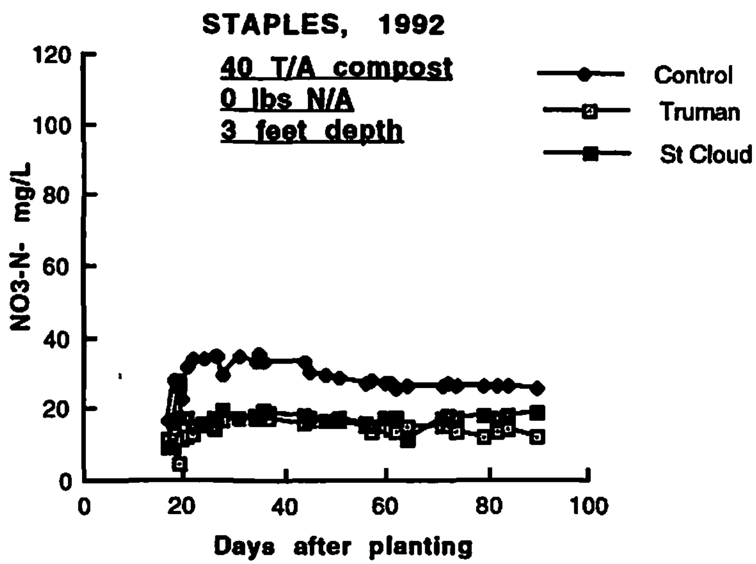

Figure 7- Soil water NO3-N at Staples with two sources of compost.

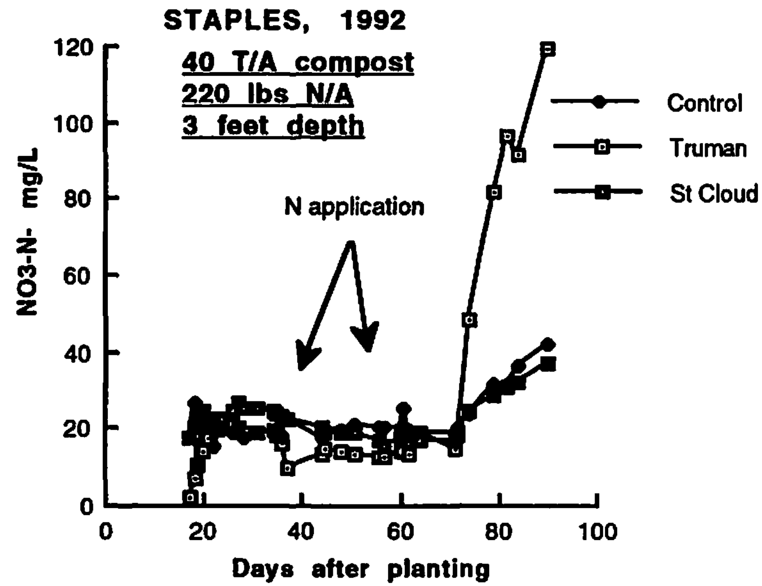

Figure 8- Soil water NO3-N at Staples with two sources of compost.

LAND SPREADING OF YARD WASTE

Matt McNearney, Carl Rosen, Thomas Halbach, David Birong, and Jennifer Weiszel

ABSTRACT: The second year of a field experiment at the Sand Plain Research Farm in Becker, Minn. was conducted to determine the residual effects of land applied yard waste, primarily tree leaves, on corn production and soil nitrate movement. Four yard waste treatments (0, 20, 40, and 80 dry T/A) were applied during the fall of 1991. In 1993, treatments included the four rates of yard waste that were applied in 1991 with 0, 100, and 200 lbs N/A applied during the growing season. During the first year of the study, 1992, yard waste application initially inhibited growth and depressed tissue nitrogen concentration in the corn plants. The inhibitory effect diminished by the middle of the 1992 growing season and final grain yields were similar to 0 T/A yard waste treatment (with 200 lb N/A) when 200 lb N/A was applied to the yard waste treatments. During the second year of the study, 1993, increases in growth and yield were greater with increasing yard waste application rates than with applied fertilizer N. Nitrate leaching tended to increase with increasing yard waste and N fertilizer application. These results suggest: 1) Soil N was initially immobilized during the first year after yard waste application; and 2) Yard waste decomposition increased available N during the second year after application, resulting in a reduced need for fertilizer N inputs. This study needs to be continued to determine nitrogen release rates from residual yard waste in subsequent years.

Until recently, yard wastes (tree leaves and grass clippings) accounted for 15-20% of the bulk in landfills. In 1990 (metro counties) and in 1992 (greater Minnesota), regulations were passed that prohibited dumping of yard wastes in landfills. Because of this legislation, alternatives to landfilling yard waste need immediate attention. Some options for using or recycling the yard waste include: 1) backyard composting and application of the compost to gardens; 2) municipal composting followed by land application of the compost; and 3) direct land application of noncomposted yard waste. While backyard composting is a desirable way to handle yard waste, not all homeowners desire to compost their own yard waste. Several problems with municipal yard waste composting include finding an acceptable site, controlling nutrient runoff, and controlling odors. Direct land application of noncomposted yard waste may be more efficient than composting and does not have the same problems associated with composting. Land application of yard waste may require an adjustment of nitrogen requirements, because of its high carbon to nitrogen ratio. The effects of nitrogen application on crop production also needs to be ascertained. Therefore, the objectives of this study were to: 1) Determine the residual effects of direct application and incorporation of noncomposted yard waste (primarily tree leaves), with and without fertilizer nitrogen, on the productivity of irrigated field corn, and 2) Characterize nitrogen release from the yard waste during the growing season in terms of availability for crop needs and movement through the soil profile.

PROCEDURES

The experiment was conducted at the Sand Plain Research Farm in Becker, MN on a Hubbard loamy sand soil. This was the second year of the study, to determine the residual effects of applied yard waste. The yard waste was collected and applied to 15' x 35' plots with a front end loader in October of 1991. The yard waste primarily consisted of tree leaves, although some garden plants and grass clippings were also present. Twelve treatments were tested: 0, 20, 40, and 80 dry tons/A yard waste with 0, 100, and 200 lbs N/A. The experimental design was a randomized complete block with 4 replications.

The field was plowed to a depth of 8-10 inches two days prior to planting. In addition, 220 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated prior to planting. Pioneer hybrid 3751 (100 day maturity) was planted on April 29, 1993 at a population of 32,000 seeds/A (2.5 ft. between rows). At planting, starter fertilizer was banded 2 inches to the side and 2 inches below the seed at a rate of 185 lbs/A 0-14-42. The nitrogen treated plots received split N applications with 50% rates applied on May 25 and June 15, 1993. Irrigation was used to supplement rainfall (Figure 1).

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[1]Funding for this project was provided by the Legislative Commission for Minnesota Resources
[2]Undergraduate Research Assistant, Extension Soil Scientist, Extension Waste Management Specialist, Assistant Scientist, and Senior Research Plot Technician respectively, Department of Soil Science.

Suction tubes with ceramic cups were installed at a depth of 4 feet in three replications of each treatment. Water samples were collected, after significant precipitation events, and analyzed for nitrate. Whole plant samples (4 per plot) were collected at the 8-12 leaf stage on June 23 after all fertilizer N was applied. Ear leaf samples were collected on August 2 at 50% silking. Two, 20 foot rows were harvested for grain and stover yield from each plot on October 6. Subsamples of stover and grain plus cob were taken for moisture determinations and nitrogen analyses. Plant tissue samples were dried and then ground through a 30 mesh screen. Dried samples were digested in concentrated sulfuric acid and Kjeldahl nitrogen was determined using conductimetric procedures.

After harvest, soil samples were collected from 0-6, 6-12, 12-24 and 24-36 inch depths. Soil nitrate was determined using 2 N KCl extracts.

RESULTS

Corn Growth and Yield: Initial corn growth increased with increasing rates of yard waste. The addition of nitrogen also increased initial growth (Table 1). At the 8 - 12 leaf stage, the greatest growth was found in treatments with the highest yard waste rates and highest nitrogen rates. The addition of yard waste also increased total yield indicating a significant release of nutrients during the second year after incorporation. Corn growth and yield displayed a greater response to yard waste application when nitrogen fertilizer was not applied. The diminishing response to yard waste when nitrogen fertilizer was applied suggests that a reduced rate of nitrogen fertilizer can be used the second year after yard waste application. Neither nitrogen application nor yard waste amendment affected the final stand count. Plant maturity, determined by kernel moisture at harvest, improved with the addition of yard waste and nitrogen. The application of nitrogen reduces kernel moisture response to the addition of yard waste.

Tissue Nitrogen Concentrations and Total Nitrogen Uptake: At the 8 - 12 leaf stage, yard waste application did not create a significant difference in tissue nitrogen concentration. The addition of fertilizer nitrogen did increase initial growth (Table 2). By the silking stage, yard waste amendment Nitrogen uptake increased with increased rates of yard waste. The addition of nitrogen further increased nitrogen uptake. Differences in tissue nitrogen concentration were observed at all growth stages with the application of fertilizer nitrogen.

Soil Nitrate-Nitrogen Content: Yard waste application increased nitrate-N in the soil (Table 4). The 80 T/A yard waste amendment, with or without fertilizer N, provided the greatest nitrogen content in the upper 12" of the soil. Yard waste amendment and fertilizer N application both increased nitrate-N content in the soil. Treatment 12 (80 T/A yard waste, 200 lbs. N/A) provided the greatest residual N in the top three feet of soil.

Soil Water Nitrate Concentrations: Concentrations of nitrate-N in soil water, as affected by treatments, are presented in figures 2 - 13. In all treatments, peak nitrate-N concentrations at the four foot depth occurred at about 11 - 12 weeks after planting. Yard waste application tended to increase nitrate-N concentrations in soil water at the four foot depth even when fertilizer N was not applied. Fertilizer N application further increased soil water nitrate concentrations. Variation in nitrate-N concentration, within treatments, became more pronounced as yard waste application rates increased. Nitrate-N concentrations were greatest in treatments with the highest yard waste and nitrogen applications. At the end of the season, the greatest N concentrations were found in the 80 T/A yard waste, 200 lbs N/A treatment. Application of 40 T/A yard waste with 100 lb N/A resulted in a greater yield, but similar nitrate concentrations at the four ft depth compared to the recommended N application of 200 lb N/A without yard waste application. Based on these observations, N fertilizer must be managed properly in order to minimize losses of nitrate following application of yard wastes.

Table 1. Effect of yard waste and nitrogen application on whole plant dry matter at the 8-12 leaf stage, final stand count, grain yield, and kernel moisture.

Yard waste rate	Nitrogen application	Whole plant dry matter (8-12 leaf)	Final stand count	Grain yield	Kernel moisture
-tons/A-	--lbs/A--	-grams/plant-	-plants/A-	-bu/A-	- % -
0	0	2.0	31581	42	47
20	0	6.5	31581	101	42
40	0	9.6	30274	148	41
80	0	9.2	30383	184	38
0	100	4.4	30274	103	45
20	100	8.3	30601	178	39
40	100	11.4	30928	197	39
80	100	11.5	31472	200	38
0	200	5.0	30274	153	42
20	200	10.3	30710	196	37
40	200	12.4	31254	205	38
80	200	12.6	30383	205	37
Significance		**	NS	**	**
BLSD (5%)		2.0	--	18	1
<u>Main effects</u>					
	<u>Yard Waste Rate</u>				
	0	3.8	30710	99	45
	20	8.4	30964	158	39
	40	11.1	30819	183	39
	80	11.1	30746	196	38
	Significance	**	NS	**	**
	BLSD (5%)	1.1	--	10	1
	Linear	**	NS	**	**
	Quadratic	**	NS	**	**
	<u>Nitrogen Application</u>				
	0	6.8	30955	119	42
	100	8.9	30819	169	40
	200	10.1	30655	190	38
	Significance	**	NS	**	**
	BLSD (5%)	1.0	--	9	1
<u>Interaction</u>					
	Yard Waste x Nitrogen	NS	NS	**	**

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

Table 2. Effect of yard waste and nitrogen application on nitrogen concentrations, dry matter accumulation, and nitrogen content.

Yard waste rate	Nitrogen application	Whole plant N 8-12 leaf stage	Ear leaf N silking stage	Nitrogen Concentration			Dry Mass				Nitrogen Content			
				Cob	Stover	Grain	Cob	Stover	Grain	Total	Cob	Stover	Grain	Total
-tons/A-	--lbs/A--	-------- % Nitrogen --------		--- % Nitrogen ---			--------- Ton/A ---------				-------- lb N/A ---------			
0	0	2.93	1.17	0.88	0.53	1.08	0.15	0.91	1.17	2.23	2.7	9.6	25.5	37.8
20	0	3.10	1.39	0.67	0.44	1.07	0.28	2.04	2.82	5.14	3.7	18.1	60.3	82.1
40	0	3.05	1.79	0.53	0.47	1.10	0.36	2.51	4.15	7.02	3.7	23.8	91.5	119.0
80	0	3.09	2.17	0.46	0.64	1.24	0.46	3.03	5.15	8.63	4.2	40.1	127.7	172.0
0	100	4.21	1.83	0.65	0.43	1.02	0.36	2.41	2.89	5.67	4.6	21.6	59.1	85.2
20	100	4.03	2.46	0.45	0.55	1.17	0.50	3.38	4.97	8.85	4.4	37.1	117.1	158.6
40	100	3.67	2.68	0.45	0.65	1.28	0.54	3.60	5.51	9.65	4.8	46.9	141.7	193.4
80	100	3.96	2.79	0.43	0.70	1.35	0.59	3.57	5.60	9.77	5.1	50.7	151.1	206.9
0	200	4.22	2.60	0.53	0.62	1.20	0.49	3.02	4.29	7.80	5.1	38.0	103.9	147.0
20	200	4.14	2.92	0.45	0.67	1.34	0.55	3.54	5.48	9.57	4.9	47.1	146.3	198.2
40	200	3.99	2.92	0.42	0.67	1.37	0.59	3.58	5.74	9.91	5.0	48.1	156.8	209.8
80	200	4.03	2.90	0.51	0.76	1.41	0.58	3.91	5.75	10.2	5.8	59.6	162.6	228.1
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.32	0.27	0.11	0.20	0.07	0.06	0.39	0.51	0.80	1.0	14.2	14.6	24.0
Main effects														
Yard Waste Rate														
0		3.79	2.35	0.69	0.52	1.10	0.33	2.12	2.78	5.23	4.1	23.1	62.8	90.0
20		3.76	2.47	0.52	0.55	1.19	0.44	2.99	4.42	7.85	4.3	34.1	107.8	146.3
40		3.57	2.56	0.47	0.60	1.25	0.49	3.23	5.13	8.86	4.5	39.6	130.0	174.1
80		3.69	2.76	0.47	0.70	1.33	0.54	3.50	5.50	9.55	5.0	50.1	147.2	202.3
Significance		NS	**	**	**	**	**	**	**	**	*	**	**	**
BLSD (5%)		--	0.16	0.06	0.11	0.04	0.04	0.22	0.29	0.46	0.6	8.0	8.4	13.7
Linear		NS	**	**	**	**	**	**	**	**	**	**	**	**
Quadratic		NS	**	**	NS	*	**	**	**	**	NS	NS	**	**
Nitrogen Application														
	0	3.04	1.92	0.63	0.52	1.12	0.31	2.12	3.32	5.76	3.6	22.9	76.3	102.7
	100	3.97	2.89	0.49	0.58	1.20	0.50	3.24	4.74	8.48	4.7	39.1	117.3	161.0
	200	4.09	2.84	0.48	0.68	1.33	0.55	3.51	5.31	9.38	5.2	48.2	142.4	195.8
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.16	0.13	0.05	0.09	0.03	0.03	0.19	0.25	0.40	0.5	6.8	7.3	11.9
Interaction														
Yard Waste x Nitrogen		NS	**	**	NS	**	**	**	**	**	NS	NS	**	*

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

Table 3. Effect of yard waste and nitrogen application on soil nitrate-N (lbs/A) in the top three feet at the end of the growing season.

Yard waste rate	Nitrogen application	Sample depth (inches) 0 - 6	6 - 12	12 - 24	24 - 36	Total
-tons/A-	--lbs/A--	lbs nitrate-N/A				
0	0	0.70	0.93	1.01	0.26	2.90
20	0	1.47	2.18	1.24	0.43	5.32
40	0	2.00	4.28	2.44	0.84	9.56
80	0	17.35	19.79	7.57	1.80	46.51
0	100	1.00	2.83	0.79	0.41	5.02
20	100	4.07	5.62	2.94	0.72	13.35
40	100	4.10	7.33	2.89	0.67	14.99
80	100	11.14	16.40	7.58	2.18	37.30
0	200	1.33	2.02	1.09	0.66	5.10
20	200	4.23	6.38	3.70	1.02	15.32
40	200	6.04	9.34	5.15	3.21	23.74
80	200	16.93	18.44	12.08	5.15	52.60
Significance		**	**	**	**	**
BLSD (5%)		8.83	8.22	4.32	1.60	18.14
Main effects						
Yard Waste Rate						
0		1.01	1.93	0.96	0.44	4.34
20		3.26	4.72	2.63	0.72	11.33
40		4.04	6.98	3.49	1.57	16.09
80		15.14	18.21	9.08	3.04	45.47
Significance		**	**	**	**	**
BLSD (5%)		4.52	4.34	2.29	0.88	9.81
Linear		**	**	**	**	**
Quadratic		++	NS	NS	NS	++
Nitrogen Application						
0		5.38	6.80	3.07	0.83	16.07
100		5.07	8.04	3.55	1.00	17.66
200		7.13	9.04	5.51	2.51	24.19
Significance		NS	NS	++	**	NS
BLSD (5%)		--	--	2.32	0.77	--
Interaction						
Yard Waste x Nitrogen		NS	NS	NS	++	NS

NS = nonsignificant, ++ = significant at 10%, * = significant at 5%, ** = significant at 1%.

Table 3. Effect of yard waste and nitrogen application on soil nitrate-N (lbs/A) in the top three feet at the end of the growing season.

Yard waste rate	Nitrogen application	Sample depth (inches) 0 - 6	6 - 12	12 - 24	24 - 36	Total
-tons/A-	--lbs/A--	lbs nitrate-N/A				
0	0	0.70	0.93	1.01	0.26	2.90
20	0	1.47	2.18	1.24	0.43	5.32
40	0	2.00	4.28	2.44	0.84	9.56
80	0	17.35	19.79	7.57	1.80	46.51
0	100	1.00	2.83	0.79	0.41	5.02
20	100	4.07	5.62	2.94	0.72	13.35
40	100	4.10	7.33	2.89	0.67	14.99
80	100	11.14	16.40	7.58	2.18	37.30
0	200	1.33	2.02	1.09	0.66	5.10
20	200	4.23	6.38	3.70	1.02	15.32
40	200	6.04	9.34	5.15	3.21	23.74
80	200	16.93	18.44	12.08	5.15	52.60
Significance		**	**	**	**	**
BLSD (5%)		8.83	8.22	4.32	1.60	18.14
Main effects						
Yard Waste Rate						
0		1.01	1.93	0.96	0.44	4.34
20		3.26	4.72	2.63	0.72	11.33
40		4.04	6.98	3.49	1.57	16.09
80		15.14	18.21	9.08	3.04	45.47
Significance		**	**	**	**	**
BLSD (5%)		4.52	4.34	2.29	0.88	9.81
Linear		**	**	**	**	**
Quadratic		++	NS	NS	NS	++
Nitrogen Application						
	0	5.38	6.80	3.07	0.83	16.07
	100	5.07	8.04	3.55	1.00	17.66
	200	7.13	9.04	5.51	2.51	24.19
Significance		NS	NS	++	**	NS
BLSD (5%)		--	--	2.32	0.77	--
Interaction						
Yard Waste x Nitrogen		NS	NS	NS	++	NS

NS = nonsignificant, ++ = significant at 10%, * = significant at 5%, ** = significant at 1%.

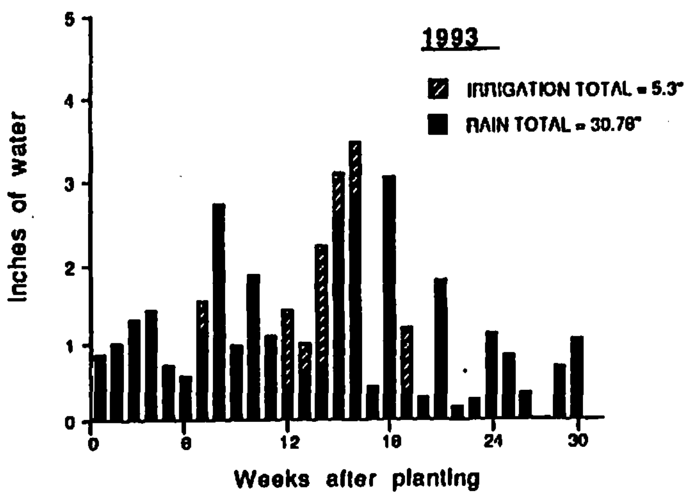

Figure 1. Rainfall and irrigation provided over the 1993 growing season.

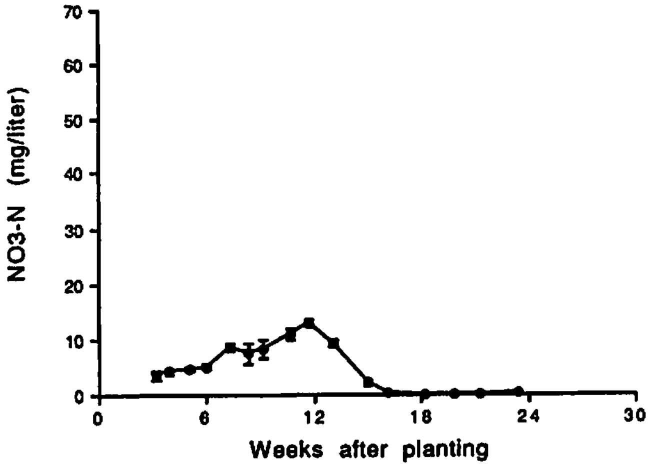

Figure 2. Nitrate-N concentration in soil water at the four foot depth over the 1993 growing season. Treatment 1: no leaves, no nitrogen applied. Error bars represent SE of the mean.

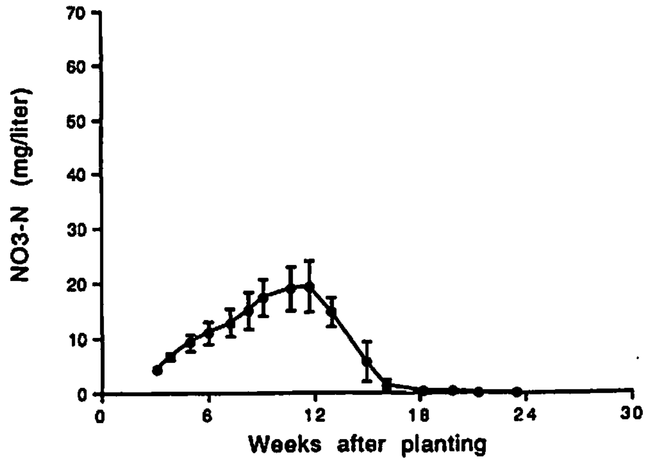

Figure 3. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 2: 20 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

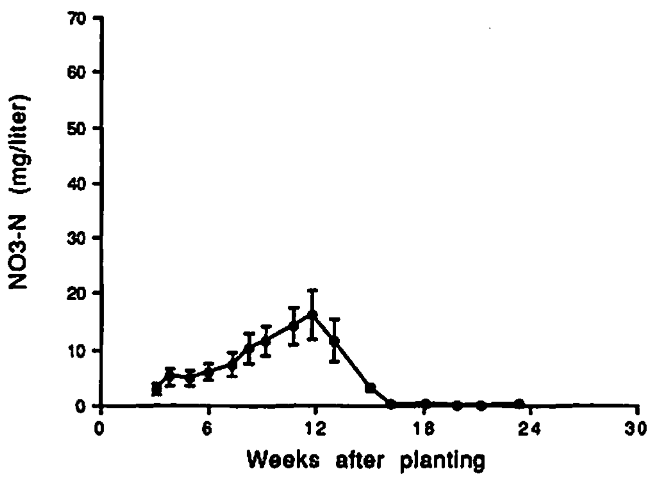

Figure 4. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 3: 40 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

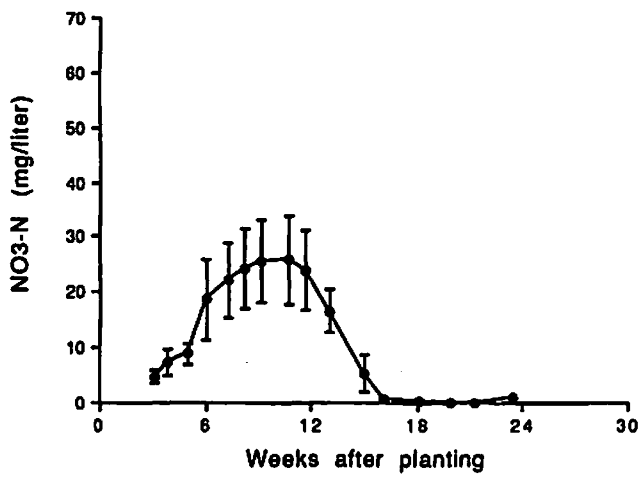

Figure 5. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 4: 80 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

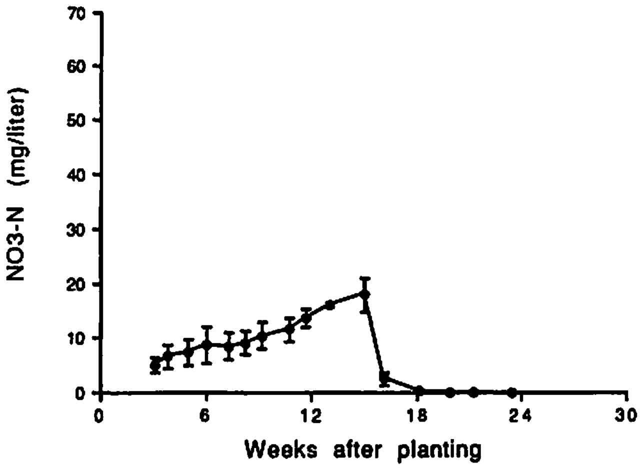

Figure 6. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 5: no leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

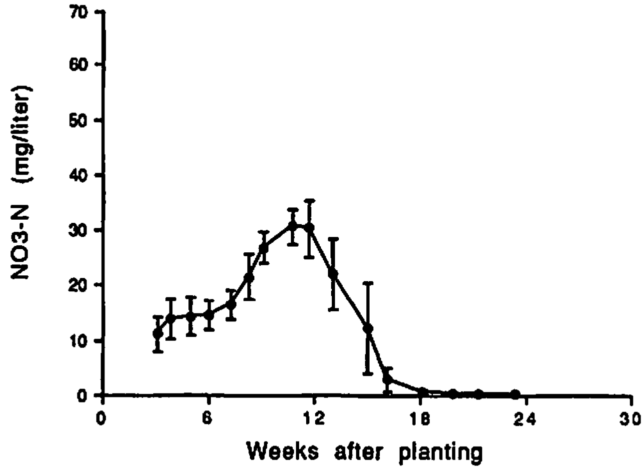

Figure 7. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 6: 20 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

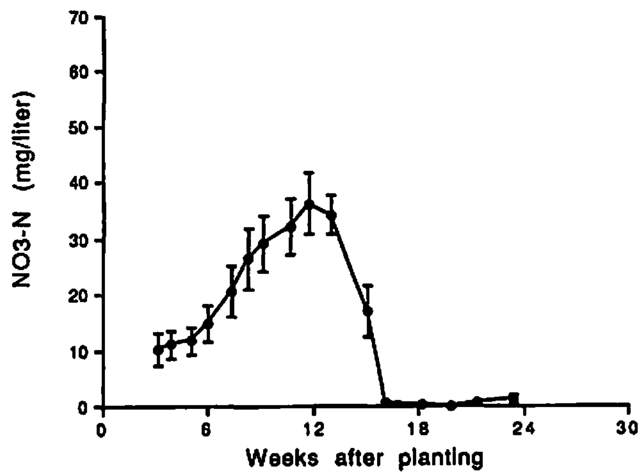

Figure 8. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 7: 40 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

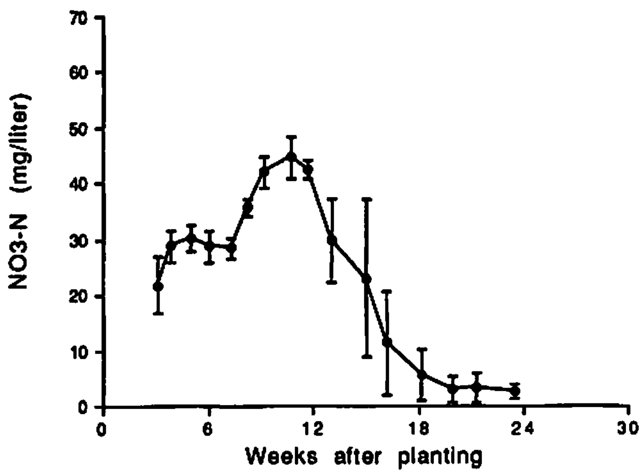

Figure 9. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 8: 80 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

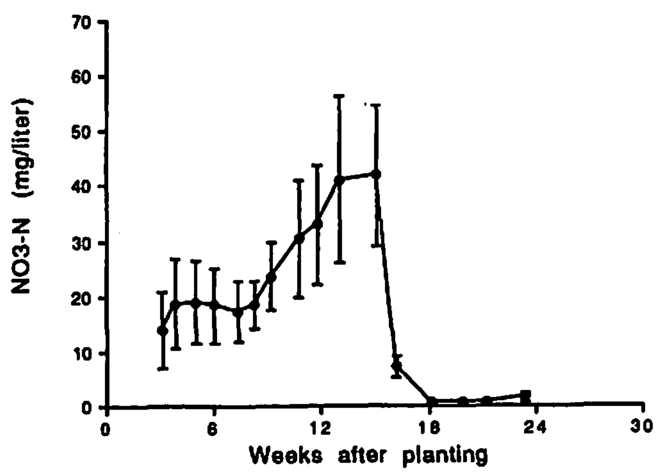

Figure 10. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 9: no leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

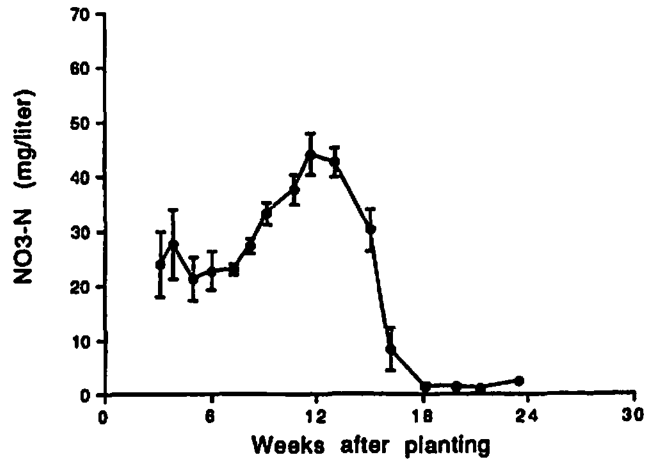

Figure 11. Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 10: 20 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

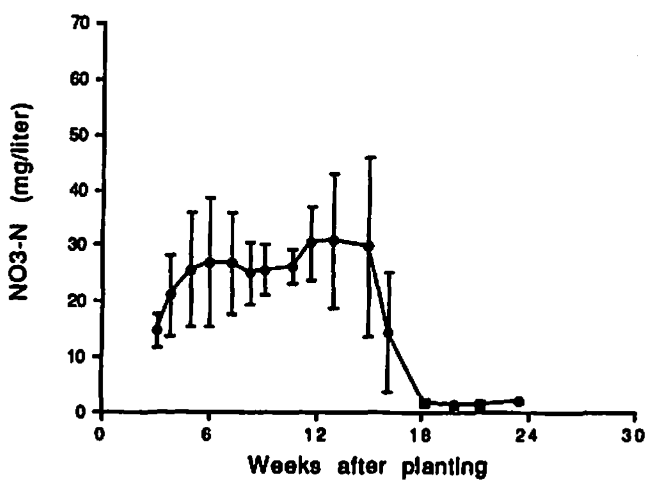

Figure 12: Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 11: 40 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

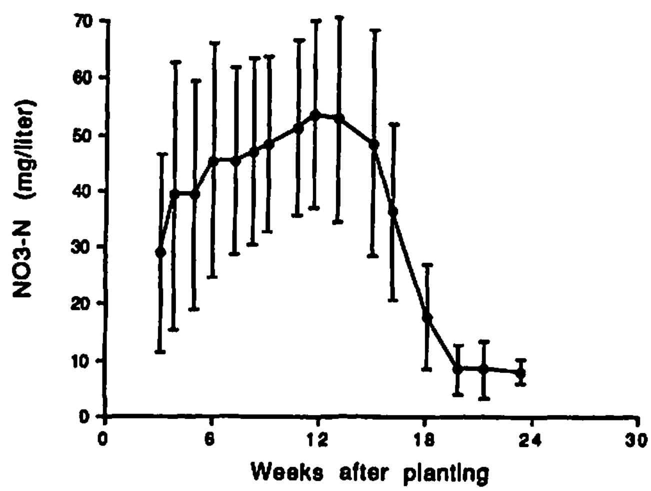

Figure 13: Nitrate-N concentration in soil water at the four ft. depth over the 1993 growing season. Treatment 12: 80 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

LAND TREATMENT OF SEWAGE SLUDGE INCINERATOR ASH - 1993[1]

Carl Rosen, Dave Birong, and Peter Bierman[2]

ABSTRACT: The seventh and final year of an experiment to evaluate the use of sewage sludge incinerator ash as a phosphorus source for corn production was conducted at the Rosholt Research Farm in Westport, MN. Ash was applied yearly from 1987 to 1991 and residual effects were determined in the following years. Treatments consisted of a control, three rates of phosphate fertilizer (0-46-0: 70, 140 and 280 lb P_2O_5/A) applied yearly until 1991 and three rates of sewage sludge incinerator ash. The cumulative rates of sewage sludge ash over the five years were 4.3, 8.6 and 17.2 dry tons. In addition, 6 tons/A lime were incorporated in half of each plot in 1991 and 4 tons/A in 1993. Results reported here are from the third year after the final application of ash and phosphate fertilizer. The crop grown was soybean. Early plant (flowering stage) dry weight and grain yield significantly increased with both ash and phosphate fertilizer amendments compared to the control. Lime application also increased grain yield. The Olsen P soil test seemed to predict response to the ash amended soils better than the Bray P1 or nitric acid extractants. Extractable levels of heavy metals increased in the 0-6 inch soil depth with increasing ash application. Lime increased soil pH by 0.9 units and decreased DTPA extractable Mn, Fe, Zn, Cu, Ni, and Cd. Tissue analysis revealed that both P sources increased P levels in the plant; however, at roughly equivalent phosphate rates, P concentrations were greater with the fertilizer source compared to the ash source. Tissue concentrations of Zn were higher with ash applications compared to fertilizer applications. Tissue levels of Mo increased substantially with ash applications. Heavy metals such as Cd, Pb, Ni, and Cr did not accumulate to levels that would be a health concern in grain tissue.

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, since 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. In the past, small amounts of ash were applied yearly to simulate phosphate fertilizer application. In 1991, greater amounts were applied to simulate a one time application. Results reported here are from the third year (residual effects) after the final application of ash in 1991.

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 initially collected from the Metropolitan Waste Water Treatment Plant in St. Paul in April 1987 and stored in 5 gallon covered plastic containers. Ash was collected a second time in April of 1991. The ash was analyzed for elemental content in a similar manner to that used in 1987. Particle size analysis both years revealed that 99% passed through a 60 mesh screen and 88% passed through a 100 mesh screen. Composition of the ash has been reported previously.

Treatments consisted of a control, three rates of phosphate fertilizer (0-46-0: 70, 140 and 280 lb P_2O_5/A) applied yearly and three rates of sewage sludge incinerator ash. The cumulative rates of sewage sludge ash over the five years (1987-91) were 4.3, 8.6 and 17.2 dry tons. Because of the increase in the amount of ash applied in 1991, the phosphate applied by ash was much greater than the amount of phosphate applied with the fertilizer. No additional ash or phosphate fertilizer was applied in 1992 or 1993. In addition to the ash and fertilizer treatments applied in 1991, each plot was split and half the plot received 6 tons/A of lime while the other half served as a control. An additional 4 T/A lime was applied to each limed plot in 1993.

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

[2] Ext. Soil Scientist, Assistant Scientist, Research Specialist, respectively, Soil Science Dept.

Soybeans (Pioneer 9062) were planted on May 18, 1993 at a population of 200,000 plants/A in 2.5 ft rows. As in previous years, a split plot treatment arrangement with four replications was used. Phosphate treatment was the main plot and lime was the subplot. Each plot consisted of four 15 ft rows. Irrigation supplemented rainfall to provide approximately 1" of water per week. On July 26 (flowering stage), 6 whole plants were sampled from each plot at the ends of the two middle rows. Diagnostic trifoliate leaves were sampled on August 23 at the initial pod filling stage. Samples were weighed dried, weighed and ground to pass through a 30 mesh screen. Plots were harvested for grain yield on October 4 (6 ft from the middle two rows). Samples were air-dried and shelled and then the grain was weighed. A subsample of grain was dried in an oven at 60C. Moisture content was determined and then samples were ground to pass through a 30 mesh screen. Multiple element analysis using ICP procedures were performed on ashed whole plant and grain samples dissolved in 1 N HCl. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

Soil samples were collected on October 4 at the 0-6" depth. 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, Olsen P, ammonium acetate, and DTPA. Soil pH and soluble salts were determined on a soil:water (1:1) mixture.

RESULTS

Soil Samples. As in previous years, extractable P increased with increasing ash and fertilizer rate in the 0-6" depth (Table 1). At roughly equivalent rates of applied P_2O_5, the Bray P1 extractant extracted more P from the soil amended with ash than with fertilizer. In contrast, Olsen P was greater in fertilizer amended plots compared to ash amended plots. DTPA extractable Zn, Cu, and Cd, increased and Mn decreased with increasing ash application. Ammonium acetate extractable Mg and Na also increased with increasing ash application. Soil pH linearly increased with ash application and slightly decreased with P fertilizer application. Soluble salts were not significantly affected by fertilizer or ash amendments. Lime application increased soil pH, soluble salts, extractable K and Ca and decreased DTPA extractable Mn, Fe, Cu, Ni, and Cd. Except for K, all nitric acid extractable elements increased with increasing ash application (Table 2). Phosphate fertilizer increased nitric acid extractable Al, As, Fe, Mo, P, and V. Lime application increased nitric acid extractable As, B, Ca, Co, K, Mg, S, Sr, and V.

Yield Data. Both residual triple superphosphate fertilizer and ash significantly increased early plant dry weight compared to plants growing in the check plot (Table 3). Residual effects from fertilizer were greater than those from the ash. This early plant response to P fertilizer is common in plants grown in low P soils, particularly under cool soil temperatures. Lime application also increased early plant growth. Grain yield increased linearly with phosphorus fertilizer and quadratically with ash amendments. Addition of lime also increased grain yields. These results clearly show an agronomic benefit to ash application and that the high rates of ash used had no detrimental effects on yield or plant establishment.

Tissue Analyses. Fertilizer and ash treatments increased tissue P concentrations in whole plant soybeans sampled at the flowering stage (Table 4). Even though rates of ash were higher in total P application than the fertilizer, availability of P, based on P concentrations in the plant tissue, was still greater from the fertilizer source than the ash source. Tissue concentrations of Mg, B, and Zn tended to increase with ash applications; however, these nutrients are essential for plant growth and the levels of B and Zn reported are well below those considered toxic to plants or animals. Tissue Mo increased with ash and at the highest ash rate the Mo levels may be of concern for chronic ingestion by ruminants. Availability of Mo increased with increasing pH and resulted in about a 1 ppm increase in tissue Mo. Although generally low, concentrations of Cd and Cr, a nonessential plant element increased with ash application. The other heavy metals, Pb and Ni were generally at background levels or not consistently affected by ash treatments. Tissue Mn decreased with increasing ash rate. Increasing phosphate fertilizer rate increased tissue Ca, B and Ni and decreased tissue Cu and Zn. Liming increase tissue N, K, Ca, Cu, and Mo decreased tissue Mg, B, Mn and Ni.

Diagnostic leaves sampled at initial pod fill increased in P with fertilizer and ash applications (Table 5). As in whole plant samples, the increase was greater in the 0-46-0 plots than in the ash plots on an equivalent P_2O_5 basis. Phosphate fertilizer increased tissue Ca, Mg, B, Mn, and Ni, but decreased K, Cu, and Zn concentrations. Ash application increased N, Ca, B, Cd, Mo, Ni, and Zn concentrations, and decreased Cu, Fe, and Mn levels. Liming increased tissue N, Ca, and Fe, but decreased tissue K, Mg, Al, B, Mn and Zn. Except for Mo in nonlimed control plots all levels of nutrients were in the satisfactory range for soybean growth.

Phosphorus concentrations in grain tissue increased with increasing fertilizer and ash amendments (Table 6). As with the other tissues, the fertilizer was a more effective P source based on tissue P concentrations. Concentrations of Na and Pb in grain tissue were either at background levels or below detection limits. Grain Cd levels slightly increased with ash in the nonlimed soil. Liming reduced Cd availability. Ash applications increased grain levels of K, B and Zn and decreased Cu, and Mn. Soybean grain accumulated substantial amounts of Mo in ash-amended plots, particularly when limed. Liming alone increased Mo levels in grain by about 5 ppm. Potassium, B, and Ni concentrations in the grain tissue increased with phosphate fertilizer application, while Ca, Al, Cu, Mn, and Zn concentrations decreased. Liming increased grain N, and Mo and decreased levels of B, Mn, and Ni.

GENERAL DISCUSSION

As in previous years, phosphate was not found to be as available from the ash source as from the fertilizer source. For some treatments, over twice as much P_2O_5 was applied with the ash compared to the fertilizer, yet P availability was the same or lower. 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 on 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. The high cumulative rate of ash applied to this site over the five years had no detrimental effects on yield and residual release of nutrients have resulted in increased yield over the plots not receiving any P amendments. Ash application did not increase accumulation of elements such as Cd, Cu, Pb, Cr, and Ni in grain tissue to levels where animal health would be of concern. The one element that needs to be monitored for legumes (especially for soybeans) is Mo. This element did accumulate to levels that would be cause for concern if chronically ingested at levels found in the higher ash amended plots. Whether high Mo in grain or plant tissue is a concern would depend on how much of the high Mo tissue is mixed with low Mo material. In most cases for soybeans, harvested product is mixed from many different sources, which would dilute any concentrated levels of Mo. Additionally if plant material elevated in Mo is fed to ruminants, Mo problems can be alleviated by supplementing the feed with Cu. It is important however that Mo levels in plant tissue be monitored, especially in legumes, so that rations can be adjusted properly.

Table 1. Effect of lime and residual effects of a five year cumulative application 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				Soluble	Bray	Olsen	NH_4OAc Extractable				DTPA Extractable							
Cumulative P_2O_5 (lb/A)	Source	Lime (T/A)	pH	Salts	P	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
				(mmhos/cm)	ppm													
0	Ctrl	0	5.7	0.10	15	9	93	1953	249	6.2	73	33	1.1	1.0	1.0	1.8	<0.03	0.14
350	Fert	0	5.6	0.15	39	25	108	1980	247	5.8	81	38	1.2	0.9	1.1	1.9	<0.03	0.14
700	Fert	0	5.6	0.10	74	47	106	1958	246	5.7	80	34	1.3	1.0	1.0	1.9	<0.03	0.14
1400	Fert	0	5.6	0.15	124	75	102	1987	241	6.0	77	29	1.3	1.0	1.0	2.0	<0.03	0.14
750	Ash	0	5.8	0.15	75	38	103	2065	279	7.3	71	25	2.2	2.7	1.2	2.0	<0.03	0.21
1500	Ash	0	6.0	0.13	121	53	93	2189	313	9.8	63	18	3.5	4.6	1.3	1.8	<0.03	0.29
3000	Ash	0	6.2	0.13	240	75	92	2190	335	11.8	62	16	4.9	7.5	1.6	1.9	0.04	0.38
0	Ctrl	10	6.5	0.38	16	9	109	2947	250	6.1	50	15	1.0	0.8	0.7	1.2	<0.03	0.12
350	Fert	10	6.5	0.35	27	16	101	2951	270	6.4	53	15	0.9	0.6	0.6	1.4	<0.03	0.10
700	Fert	10	6.3	0.43	71	45	130	2720	247	7.4	61	18	2.2	0.7	0.7	1.4	<0.03	0.11
1400	Fert	10	6.2	0.33	121	69	111	2722	253	6.4	62	16	1.2	0.8	0.7	1.5	<0.03	0.12
750	Ash	10	6.4	0.30	83	34	124	2763	265	6.7	58	16	2.1	2.6	1.8	1.4	<0.03	0.19
1500	Ash	10	6.6	0.35	142	54	118	3080	286	8.1	52	12	2.8	4.2	1.1	1.3	<0.03	0.26
3000	Ash	10	6.6	0.30	209	70	114	3009	316	9.5	54	12	3.8	6.0	1.2	1.5	<0.03	0.32
Significance			**	**	**	**	NS	**	**	**	**	**	**	**	NS	**	--	**
BLSD (0.05)			0.3	0.12	34	13	--	317	42	1.4	10	21	0.8	0.9	--	0.3	--	0.05
Main effects																		
Lime	-		5.8	0.13	98	46	99	2046	273	7.5	72	28	2.2	2.7	1.2	1.9	<0.03	0.20
	+		6.4	0.35	95	42	115	2885	269	7.2	56	15	2.0	2.2	1.0	1.4	<0.03	0.17
Significance			**	**	NS	NS	*	**	NS	NS	**	**	NS	*	NS	**	--	**
P Treatment																		
P_2O_5 (lb/A)	Source																	
0	Ctrl		6.1	0.24	15	10	101	2450	250	6.1	62	24	1.1	0.9	0.8	1.5	<0.03	0.13
350	Fert		6.0	0.25	33	20	104	2466	258	6.1	67	26	1.0	0.7	0.8	1.7	<0.03	0.12
700	Fert		6.0	0.26	73	46	118	2339	246	6.5	70	26	1.8	0.8	0.9	1.6	<0.03	0.12
1400	Fert		5.9	0.24	123	72	106	2355	248	6.2	69	23	1.2	0.9	0.9	1.7	<0.03	0.13
750	Ash		6.1	0.23	79	36	113	2414	272	7.0	64	20	2.2	2.7	1.5	1.7	<0.03	0.20
1500	Ash		6.3	0.24	131	53	105	2634	300	9.0	57	15	3.2	4.4	1.2	1.6	<0.03	0.27
3000	Ash		6.4	0.21	224	73	103	2600	326	10.6	58	14	4.3	6.7	1.4	1.7	<0.03	0.35
Significance			**	NS	**	**	NS	NS	**	**	**	**	**	**	*	NS	--	**
BLSD (0.05)			0.3	--	24	9	--	--	28	1.0	7	4	0.6	0.7	0.6	--	--	0.03
Contrasts																		
Ctrl vs Rest			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
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	--	**
Quad Ash			NS	NS	NS	**	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	--	*
Interactions																		
Lime by P			NS	NS	NS	NS	NS	NS	NS	**	NS	**	*	NS	NS	NS	--	NS

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

Table 2. Effect of lime and residual effects of a five year cumulative application of sludge ash and phosphate fertilizer on 1N nitric acid extractable elements.

Treatment			1 N Nitric Acid Extractable																								
Cum. P_2O_5	Source	Lime	Al	As	B	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	S	Si	Sr	Ti	V	Zn
(lb/A)		(T/A)	ppm																								
0	Ctrl	0	1592	1.5	1.3	88	2798	0.3	0.6	1.0	3.9	398	113	0.3	449	111	0.5	8	3.8	64	5.3	15.9	437	8.6	5.0	1.9	5.0
350	Fert	0	1594	1.5	1.3	90	2849	0.3	0.7	0.9	3.5	379	128	0.3	411	124	0.5	7	4.0	101	5.5	18.0	383	8.8	4.1	1.8	4.8
700	Fert	0	1647	1.5	1.3	89	2960	0.3	0.7	1.0	3.8	410	130	0.3	458	133	0.5	7	3.9	153	5.8	17.2	401	8.9	4.4	2.0	5.1
1400	Fert	0	1747	1.6	1.3	93	3005	0.3	0.7	1.1	4.4	448	126	0.3	436	129	0.5	7	4.3	229	6.1	17.8	422	9.5	5.0	2.1	5.5
750	Ash	0	1734	1.6	1.4	99	3132	0.5	0.7	1.6	9.7	445	127	0.3	475	128	0.5	10	4.3	218	6.8	17.9	454	9.7	5.4	2.1	7.9
1500	Ash	0	1934	1.8	1.6	102	3633	0.8	0.7	2.6	17.9	514	120	0.3	554	137	0.6	16	4.4	433	8.9	17.9	526	10.9	6.7	2.4	12.5
3000	Ash	0	2160	2.0	1.7	112	4145	1.3	0.7	4.1	31.1	619	127	0.4	630	154	0.7	23	5.0	789	11.6	19.1	607	12.5	8.9	2.7	18.9
0	Ctrl	10	1542	1.5	1.5	91	5042	0.3	0.8	1.0	4.0	330	138	<0.2	644	127	0.5	9	3.6	80	5.4	54.0	424	11.1	3.6	2.0	5.0
350	Fert	10	1582	1.5	1.4	93	4969	0.3	0.7	1.0	3.5	376	123	0.3	623	121	0.5	8	3.9	79	5.3	54.9	462	11.7	4.5	2.1	4.9
700	Fert	10	1604	1.6	1.6	90	4743	0.3	0.8	1.0	3.6	394	159	0.3	617	136	0.5	10	3.8	157	5.7	86.6	424	11.3	4.2	2.1	5.5
1400	Fert	10	1683	1.6	1.5	94	4797	0.3	0.8	1.2	4.0	428	140	0.2	591	136	0.5	9	3.9	255	5.8	49.6	421	11.4	4.5	2.2	5.4
750	Ash	10	1793	1.8	1.6	100	5870	0.6	0.8	1.9	13.7	431	162	<0.3	637	150	0.6	13	4.2	337	9.1	46.8	485	12.8	5.4	2.3	9.5
1500	Ash	10	1941	1.9	1.7	102	6613	0.9	0.8	2.9	21.9	500	156	0.3	810	161	0.6	17	4.2	559	9.52	48.6	540	14.1	6.7	2.5	13.0
3000	Ash	10	2178	2.2	1.9	116	6406	1.3	0.8	4.2	33.1	600	157	0.3	818	175	0.7	23	5.0	863	11.9	51.0	625	15.5	8.9	2.8	19.2
Significance			**	**	**	**	**	**	**	**	**	**	NS	--	**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (0.05)			147	0.2	0.3	10	812	0.2	0.1	0.6	5.2	75	--	--	129	25	0.1	3	0.6	144	1.6	28.2	101	1.5	1.4	0.3	2.4
Main effects																											
Lime		-	1772	1.6	1.4	96	3217	0.6	0.7	1.7	10.6	459	124	0.3	488	131	0.6	11	4.2	284	7.1	17.7	461	9.9	5.6	2.1	8.5
		+	1760	1.7	1.6	98	5491	0.6	0.8	1.9	12.0	437	148	<0.3	677	144	0.6	13	4.1	333	7.5	55.9	483	12.6	5.2	2.3	8.9
Significance			NS	**	**	NS	**	NS	**	NS	NS	NS	**	--	**	**	NS	**	NS	NS	NS	**	NS	**	NS	**	NS
P Treatment																											
P_2O_5 (lb/A)	Source																										
0	Ctrl		1567	1.5	1.4	89	3920	0.3	0.7	1.0	4.0	364	125	<0.3	547	119	0.5	8	3.7	72	5.3	35.0	431	9.9	4.3	1.9	5.0
350	Fert		1588	1.5	1.4	92	3909	0.3	0.7	0.9	3.5	378	125	0.3	517	122	0.5	8	4.0	89	5.4	36.4	423	10.3	4.3	2.0	4.9
700	Fert		1625	1.6	1.4	89	3851	0.3	0.8	1.0	3.7	402	145	0.3	537	134	0.5	9	3.8	155	5.7	51.9	413	10.1	4.3	2.1	5.3
1400	Fert		1715	1.6	1.4	93	3901	0.3	0.7	1.2	4.2	438	133	0.3	514	132	0.5	8	4.1	242	5.9	33.7	422	10.5	4.7	2.2	5.4
750	Ash		1763	1.7	1.5	99	4501	0.6	0.7	1.8	11.7	438	144	<0.3	556	139	0.6	12	4.2	277	8.0	32.3	470	11.2	5.2	2.2	8.7
1500	Ash		1938	1.9	1.6	102	5122	0.8	0.8	2.7	19.9	507	138	0.3	682	149	0.6	17	4.3	496	9.2	33.3	533	12.5	6.4	2.4	12.8
3000	Ash		2169	2.1	1.8	114	5275	1.3	0.8	4.2	32.1	609	142	0.3	724	165	0.7	23	5.0	826	11.8	35.1	616	14.0	8.5	2.7	19.0
Significance			**	**	**	**	**	**	NS	**	**	**	NS	--	**	**	**	**	**	**	**	NS	**	**	**	**	**
BLSD (0.05)			102	0.2	0.2	7	601	0.2	--	0.4	3.7	51	--	--	93	17	0.1	2	0.4	101	1.1	--	66	1.1	1.1	0.2	1.7
Contrasts																											
Ctrl vs Rest			**	**	**	**	*	**	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	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	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	NS	NS	NS
Interactions																											
Lime by P			NS	NS	NS	NS	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% and 1%, respectively.

Table 3. Effect of lime and residual effects of a five year cumulative application of sludge ash and phosphate fertilizer on whole plant dry weight (pre-flower stage) and grain yield.

Treatment: Cumulative P_2O_5 (lb/A)	Source	Lime (T/A)	Whole plant dry wt. pre-flower (g/plant)	Grain yield (bu/A)
0	Ctrl	0	2.8	32.0
350	Fert	0	3.1	34.5
700	Fert	0	2.9	34.5
1400	Fert	0	3.7	36.5
750	Ash	0	3.3	37.0
1500	Ash	0	3.8	40.0
3000	Ash	0	3.8	36.6
0	Ctrl	10	3.2	37.6
350	Fert	10	4.2	39.1
700	Fert	10	4.3	40.5
1400	Fert	10	5.0	39.0
750	Ash	10	4.3	39.9
1500	Ash	10	4.0	39.6
3000	Ash	10	3.8	38.6
Significance			**	**
BLSD (0.05)			1.3	3.5
Main effects				
Lime -			3.3	35.9
+			4.1	39.2
Significance			**	**
P Treatment: P_2O_5 (lb/A)	Source			
0	Ctrl		3.0	34.8
350	Fert		3.7	36.8
700	Fert		3.6	37.5
1400	Fert		4.3	37.8
750	Ash		3.8	38.5
1500	Ash		3.9	39.8
3000	Ash		3.8	37.6
Significance			*	**
BLSD (0.05)			0.9	2.6
Contrasts				
Ctrl vs Rest			**	**
Fert vs Ash			NS	NS
Linear Fert			**	*
Quad Fert			NS	NS
Linear Ash			NS	NS
Quad Ash			NS	**
Interactions				
Lime by P			NS	NS

NS = nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 4. Effect of lime and residual effects of a five year cumulative application of sludge ash and phosphate fertilizer on the elemental composition of whole plants at the pre-flower stage.

Treatment: Cumulative P_2O_5 (lb/A)	Source	Lime (T/A)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Al (ppm)	B (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Mo (ppm)	Na (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
0	Ctrl	0	3.75	0.32	2.62	1.70	0.70	293	37	0.3	1.0	10.5	252	87	0.4	16.1	3.4	2.4	37
350	Fert	0	3.83	0.37	2.57	1.65	0.67	272	38	0.3	1.0	8.7	244	88	0.4	21.0	3.4	2.4	35
700	Fert	0	3.91	0.39	2.39	1.74	0.70	293	40	0.3	1.1	6.8	255	91	0.4	16.1	3.4	2.5	33
1400	Fert	0	3.95	0.45	2.67	1.79	0.69	301	39	0.3	1.1	6.0	257	89	0.4	15.4	3.7	2.5	32
750	Ash	0	3.88	0.40	2.61	1.69	0.70	307	39	0.4	1.1	9.4	267	85	0.7	15.4	3.4	2.5	43
1500	Ash	0	3.98	0.42	2.55	1.70	0.73	304	41	0.4	1.2	9.5	263	81	1.9	17.0	3.3	2.6	48
3000	Ash	0	3.82	0.43	2.48	1.72	0.78	300	40	0.5	1.2	9.7	265	72	6.2	18.7	3.2	2.6	47
0	Ctrl	10	4.08	0.33	2.84	1.72	0.64	259	32	0.3	0.9	11.8	242	77	1.4	17.9	3.1	<2.2	38
350	Fert	10	3.89	0.38	2.81	1.76	0.67	291	33	0.2	1.0	9.2	270	83	1.3	15.3	3.1	<2.2	35
700	Fert	10	3.83	0.40	3.02	1.73	0.63	263	34	0.3	1.1	7.2	245	80	1.5	24.2	3.2	<2.6	34
1400	Fert	10	4.06	0.43	2.69	1.88	0.71	245	36	0.4	1.1	6.1	237	88	1.1	21.3	3.5	<2.6	33
750	Ash	10	4.40	0.39	2.85	1.76	0.65	280	33	0.3	1.0	11.6	260	84	2.7	19.1	3.3	<2.2	43
1500	Ash	10	3.97	0.41	2.87	1.76	0.67	285	35	0.4	1.2	11.7	261	79	6.2	22.5	3.0	<2.6	44
3000	Ash	10	4.11	0.40	2.80	1.77	0.68	258	36	0.4	1.1	11.0	244	75	7.3	16.8	2.9	<2.3	45
Significance			NS	**	**	**	*	NS	**	**	NS	**	NS	**	**	NS	NS	--	**
BLSD (0.05)			--	0.03	0.30	0.11	0.09	--	2	0.1	--	0.9	--	10	1.4	--	--	--	4
Main effects																			
Lime		-	3.87	0.40	2.55	1.71	0.71	296	39	0.3	1.1	8.6	258	84	1.5	17.1	3.4	2.5	39
		+	4.05	0.39	2.84	1.77	0.66	269	34	0.3	1.1	9.8	251	81	3.1	19.6	3.2	<2.4	39
Significance			*	NS	**	**	**	NS	**	NS	NS	**	NS	*	**	NS	*	--	NS
P Treatment: P_2O_5 (lb/A)	Source																		
0	Ctrl		3.91	0.33	2.73	1.71	0.67	276	34	0.3	1.0	11.1	247	82	0.9	17.0	3.2	<2.3	38
350	Fert		3.86	0.37	2.69	1.71	0.67	282	35	0.3	1.0	9.0	257	85	0.8	18.2	3.3	<2.3	35
700	Fert		3.87	0.39	2.70	1.73	0.67	278	37	0.3	1.1	7.0	250	85	1.0	20.1	3.3	<2.5	34
1400	Fert		4.00	0.44	2.68	1.83	0.70	273	38	0.3	1.1	6.0	247	88	0.8	18.3	3.6	<2.5	33
750	Ash		4.14	0.39	2.73	1.73	0.67	293	36	0.4	1.1	10.5	263	85	1.7	17.2	3.3	<2.4	43
1500	Ash		3.97	0.41	2.71	1.73	0.70	294	38	0.4	1.2	11.6	262	80	4.0	19.7	3.2	<2.6	46
3000	Ash		3.97	0.41	2.64	1.74	0.73	279	38	0.4	1.2	10.4	254	73	6.7	17.7	3.0	<2.5	46
Significance			NS	**	NS	**	NS	NS	**	**	*	**	NS	**	**	NS	NS	--	**
BLSD (0.05)			--	0.02	--	0.08	--	--	2	0.1	0.2	0.7	--	7	1.0	--	--	--	3
Contrasts																			
Ctrl vs Rest			NS	**	NS	NS	NS	NS	**	**	*	**	NS	NS	**	NS	NS	--	NS
Fert vs Ash			NS	NS	NS	NS	NS	NS	NS	**	*	**	NS	**	**	NS	*	--	**
Linear Fert			NS	**	NS	**	NS	NS	**	**	NS	**	NS	NS	NS	NS	*	--	**
Quad Fert			NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	--	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	--	**
Interactions																			
Lime by P			NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	*	NS	NS	--	NS

NS= nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 5. Effect of lime and residual effects of a five year cumulative application of sludge ash and phosphate fertilizer on the elemental composition of recently matured trifoliate leaves.

Treatment: Cumulative P_2O_5 (lb/A)	Source	Lime (T/A)	N	P	K	Ca	Mg	Al	B	Cd	Cr	Cu	Fe	Mn	Mo	Na	Ni	Pb	Zn
			%					ppm											
0	Ctrl	0	5.04	0.37	1.75	1.64	0.38	34.6	51	0.2	0.6	10.8	215	134	<0.2	<7.2	2.1	<1.9	39
350	Fert	0	5.00	0.41	1.71	1.77	0.40	36.8	57	0.2	0.6	10.4	212	157	<0.2	13.2	2.6	<1.9	41
700	Fert	0	4.91	0.42	1.69	1.81	0.43	30.8	58	0.2	0.6	9.3	195	144	<0.2	<7.8	2.8	2.0	41
1400	Fert	0	5.13	0.43	1.66	1.79	0.40	27.2	59	0.2	0.6	7.9	180	158	<0.2	<8.8	3.4	<2.0	39
750	Ash	0	5.39	0.41	1.64	1.69	0.37	32.1	56	0.3	0.6	10.0	198	142	0.3	<11.5	3.1	1.9	43
1500	Ash	0	5.36	0.42	1.54	1.74	0.39	27.5	56	0.3	0.6	9.4	183	124	0.9	<6.5	2.9	<1.8	45
3000	Ash	0	5.53	0.43	1.66	1.71	0.39	31.1	58	0.3	0.6	9.0	184	117	4.6	<11.9	2.9	<1.9	48
0	Ctrl	10	5.24	0.37	1.69	1.66	0.31	33.6	41	0.2	0.6	11.3	219	127	0.8	<7.3	2.3	2.1	38
350	Fert	10	5.31	0.40	1.59	1.77	0.34	35.6	41	0.2	0.6	10.1	224	131	0.9	10.9	2.4	<2.1	36
700	Fert	10	5.22	0.42	1.63	1.89	0.36	26.0	49	0.2	0.6	8.7	202	146	0.8	<6.9	2.8	<2.0	38
1400	Fert	10	5.30	0.43	1.62	1.83	0.36	25.8	51	0.2	0.6	7.4	190	142	0.9	<6.6	3.2	<1.9	36
750	Ash	10	5.35	0.40	1.56	1.82	0.36	22.5	46	0.2	0.6	10.7	199	134	2.1	<11.2	2.8	2.0	42
1500	Ash	10	5.36	0.42	1.66	1.81	0.34	21.5	50	0.2	0.6	10.6	198	131	7.1	10.8	2.5	<2.1	44
3000	Ash	10	5.42	0.42	1.64	1.77	0.35	25.4	53	0.3	0.7	10.3	197	122	9.4	<7.3	2.9	2.2	46
Significance			**	**	**	*	**	NS	**	**	NS	**	**	**	--	--	**	--	**
BLSD (0.05)			0.37	0.02	0.10	0.15	0.04	--	4	0.1	--	1.1	19	16	--	--	0.6	--	4
Main effects																			
Lime	-		5.19	0.42	1.67	1.74	0.39	31.4	56	0.2	0.6	9.5	195	139	<1.0	<9.5	2.8	<1.9	42
	+		5.31	0.41	1.63	1.79	0.35	27.2	47	0.2	0.6	9.9	204	133	3.2	<8.7	2.7	<2.1	40
Significance			*	NS	*	*	**	*	**	NS	NS	NS	*	*	--	--	NS	--	**
P Treatment: P_2O_5 (lb/A)	Source																		
0	Ctrl		5.14	0.37	1.72	1.65	0.35	34.1	46	0.2	0.6	11.0	217	130	<0.5	<7.3	2.2	<2.0	39
350	Fert		5.15	0.41	1.65	1.77	0.37	36.2	49	0.2	0.6	10.2	218	144	<0.6	12.1	2.5	<2.0	38
700	Fert		5.06	0.42	1.66	1.85	0.39	28.4	53	0.2	0.6	9.0	199	145	<0.5	<7.4	2.8	<2.0	40
1400	Fert		5.22	0.43	1.64	1.81	0.38	26.5	55	0.2	0.6	7.6	185	150	<0.6	<7.7	3.3	<2.0	38
750	Ash		5.37	0.41	1.60	1.76	0.36	27.3	51	0.2	0.6	10.4	198	138	1.2	<11.4	2.9	1.9	42
1500	Ash		5.36	0.42	1.60	1.78	0.37	24.5	53	0.3	0.6	10.0	190	128	4.0	<8.5	2.7	<1.9	45
3000	Ash		5.47	0.43	1.65	1.74	0.37	28.3	55	0.3	0.6	9.7	190	120	7.0	<9.6	2.9	<2.0	47
Significance			**	**	**	**	*	*	**	**	NS	**	**	**	--	--	**	--	**
BLSD (0.05)			0.24	0.02	0.07	0.10	0.03	8.2	3	0.1	--	0.8	13	11	--	--	0.4	--	3
Contrasts																			
Ctrl vs Rest			NS	**	**	**	*	*	**	**	NS	**	**	NS	--	--	**	--	**
Fert vs Ash			**	NS	NS	*	NS	NS	NS	**	NS	**	*	**	--	--	NS	--	**
Linear Fert			NS	**	*	**	*	*	**	**	NS	**	**	**	--	--	**	--	NS
Quad Fert			NS	**	NS	**	**	NS	*	NS	NS	NS	NS	NS	--	--	NS	--	NS
Linear Ash			**	**	NS	NS	NS	NS	**	**	*	**	**	**	--	--	**	--	**
Quad Ash			NS	**	**	*	NS	*	*	*	NS	NS	**	NS	--	--	*	--	NS
Interactions																			
Lime by P			NS	NS	*	NS	NS	NS	**	**	NS	NS	NS	*	--	--	NS	--	NS

NS = Nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 6. Effect of lime and residual effects of a five year cumulative application of sludge ash and phosphate fertilizer on the elemental composition of grain at harvest.

Treatment: Cumulative P_2O_5 (lb/A)	Source	Lime (T/A)	N	P	K	Mg	Ca	Al	B	Cd	Cr	Cu	Fe	Mn	Mo	Na	Ni	Pb	Zn
			%					ppm											
0	Ctrl	0	6.18	0.61	1.73	0.28	0.32	18.8	29	<0.1	0.5	15.0	103	40	0.4	<3.7	7.2	<1.7	48
350	Fert	0	6.03	0.72	1.84	0.29	0.32	15.7	30	<0.1	0.5	13.9	103	41	0.3	<3.6	8.5	<1.7	50
700	Fert	0	6.09	0.72	1.83	0.29	0.30	12.6	30	<0.1	0.4	11.1	92	39	0.4	<3.6	8.7	<1.7	49
1400	Fert	0	6.08	0.74	1.84	0.28	0.30	11.2	30	0.1	0.5	9.0	88	40	0.5	<3.6	9.5	<1.7	48
750	Ash	0	6.31	0.67	1.83	0.28	0.29	12.2	29	0.2	0.4	11.9	87	38	1.2	<4.1	7.5	<1.7	50
1500	Ash	0	6.38	0.69	1.85	0.28	0.29	12.3	29	0.2	0.4	11.2	85	35	4.0	<3.6	7.1	<1.7	52
3000	Ash	0	6.36	0.71	1.85	0.27	0.29	11.6	29	0.3	0.5	10.6	82	34	12.4	<3.6	7.1	<1.7	53
0	Ctrl	10	6.42	0.61	1.76	0.28	0.31	13.0	25	<0.1	0.4	15.7	91	35	5.2	<5.2	5.7	<1.7	49
350	Fert	10	6.46	0.67	1.81	0.28	0.30	12.7	25	<0.1	0.4	11.7	93	35	4.9	<3.6	6.9	<1.7	47
700	Fert	10	6.34	0.70	1.86	0.28	0.29	10.2	27	<0.1	0.4	9.6	86	36	4.7	<3.6	7.6	<1.7	48
1400	Fert	10	6.40	0.71	1.85	0.28	0.30	9.8	28	<0.1	0.4	7.7	86	36	5.2	<3.6	8.5	<1.7	47
750	Ash	10	6.44	0.68	1.86	0.28	0.28	8.6	26	<0.1	0.4	14.0	86	33	8.5	<3.6	6.8	<1.7	51
1500	Ash	10	6.35	0.68	1.86	0.28	0.29	13.0	26	<0.1	0.5	14.0	97	33	16.0	<4.2	6.2	<1.7	52
3000	Ash	10	6.35	0.70	1.85	0.28	0.29	13.1	27	0.2	0.4	12.9	89	33	22.0	<3.6	6.7	<1.7	53
Significance			**	**	**	**	**	NS	**	--	NS	**	NS	**	**	--	**	--	**
BLSD (0.05)			0.17	0.03	0.07	0.01	0.02	--	2	--	--	0.9	--	2	3.1	--	1.3	--	3
Main effects																			
Lime		-	6.20	0.69	1.82	0.28	0.30	13.5	30	<0.2	0.5	11.8	92	38	2.7	<3.7	7.9	<1.7	50
		+	6.39	0.68	1.83	0.28	0.29	11.5	26	<0.1	0.4	12.1	90	34	9.5	<3.9	6.9	<1.7	49
Significance			**	*	NS	*	*	NS	**	--	NS	NS	NS	**	**	--	**	--	NS
P Treatment: P_2O_5 (lb/A)	Source																		
0	Ctrl		6.30	0.61	1.75	0.28	0.31	15.9	27	<0.1	0.5	15.3	97	38	2.8	<4.4	6.4	<1.7	48
350	Fert		6.24	0.69	1.82	0.29	0.31	14.2	28	<0.1	0.5	12.8	98	38	2.6	<3.6	7.7	<1.7	49
700	Fert		6.21	0.71	1.84	0.28	0.30	11.4	28	<0.1	0.4	10.3	89	38	2.6	<3.6	8.2	<1.7	49
1400	Fert		6.24	0.73	1.84	0.28	0.30	10.5	29	<0.1	0.4	8.3	87	38	2.9	<3.6	9.0	<1.7	48
750	Ash		6.37	0.68	1.84	0.28	0.28	10.4	28	<0.1	0.4	12.9	86	36	4.9	<3.8	7.1	<1.7	50
1500	Ash		6.37	0.69	1.85	0.28	0.29	12.6	28	<0.2	0.5	12.4	91	34	10.0	<3.9	6.7	<1.7	52
3000	Ash		6.36	0.70	1.85	0.28	0.29	12.4	28	0.2	0.5	11.8	86	33	17.2	<3.6	6.9	<1.7	53
Significance			*	**	**	**	**	NS	**	--	NS	**	NS	**	**	--	**	--	**
BLSD (0.05)			0.14	0.03	0.04	0.01	0.02	--	1	--	--	0.7	--	2	2.2	--	0.9	--	2
Contrasts																			
Ctrl vs Rest			NS	**	**	NS	**	*	**	--	NS	**	NS	**	**	--	**	--	*
Fert vs Ash			**	**	NS	**	NS	NS	*	--	NS	**	NS	**	**	--	**	--	**
Linear Fert			NS	**	**	NS	**	*	**	--	NS	**	*	NS	NS	--	**	--	NS
Quad Fert			NS	**	**	NS	NS	NS	NS	--	NS	**	NS	NS	NS	--	NS	--	NS
Linear Ash			NS	**	**	NS	NS	NS	*	--	NS	**	NS	**	**	--	NS	--	**
Quad Ash			NS	**	**	NS	*	NS	NS	--	NS	**	NS	*	NS	--	NS	--	NS
Interactions																			
Lime by P			**	NS	NS	NS	NS	NS	*	--	*	**	NS	**	**	--	NS	--	NS

NS = nonsignificant; *, ** = significant at 5% and 1%, respectively.

AGRICULTURAL UTILIZATION OF NUTRALIME: ON FARM DEMONSTRATION PLOTS - 1993[1]

Carl Rosen, Dave Birong, Peter Bierman, and Jennifer Weiszel[2]

ABSTRACT: The third year of NutraLime demonstrations were conducted in Dakota, Isanti, and Washington counties. NutraLime (spent lime and sewage sludge incinerator ash) was applied in 1991 at all three locations. Residual effects were monitored in 1993 on seed corn (Dakota county), field corn (Washington County) and alfalfa (Isanti County). For alfalfa at the Isanti county site, spent lime without ash was applied on half the control plot to determine effects of raising pH without the elements in the ash. Alfalfa yields increased substantially with NutraLime application and to a lesser extent with spent lime application. Elevated Mo tissue alfalfa tissue concentrations were associated with NutraLime application. The Mo levels accumulated in alfalfa tissue were above those considered safe for ruminants. Higher Mo was also found in alfalfa grown on limed plots, but levels were not in a range considered to be and animal health problem. Field corn yields significantly increased with NutraLime application and was associated with an increase in soil pH from 5.3 in the control plots to above 7.0 in the amended plots. In contrast, seed corn yield decreased with NutraLime application. Causes for this yield decrease are unclear, but may be due to pH induced Mn deficiency. Seed corn has a limited root system and most roots were probably confined to the high pH region where NutraLime was applied. Application of NutraLime increased soil water sulfur concentrations at the 2.5 ft depth. Trace metals were generally below detection limits at the 2.5 ft depth. In cases where NutraLime increased trace elements in soil water (Zn for example), the levels detected were all well below limits set for drinking water. Soil pH and plant available P increased with increasing NutraLime application. DTPA extractable Cd and Cu increased with NutraLime in the top 6 inches, whereas DTPA extractable Ni and Mn decreased. NutraLime had no effect on DTPA extractable Pb, Zn, or Cr. Nitric acid extractable elements increased in the top 6 inches and to a lesser extent in the 6-12 inch depth. Except for S, NutraLime did not consistently affect nitric acid extractable elements in the 12-24 inch depth.

NutraLime is a product made from two waste materials: sewage sludge incinerator ash from the Metropolitan Waste Control Commission in St. Paul and spent lime from municipal water treatment plants. Land application of these waste products has been studied individually in previous research. The sewage sludge ash was found to supply phosphorus and micronutrients for crop production. At realistic application rates, heavy metals were not found to be taken up by corn plants nor did the metals move significantly in the soil. Spent lime was found to an effective liming amendment. By combining these two waste products, both nutrients and lime could be recycled onto cropland, alleviating the need to rely on landfills for disposal. The objectives of these demonstration plots were to inform growers and the public about NutraLime, monitor crop growth at various rates of applied NutraLime, monitor plant uptake of elements supplied by NutraLime, and follow movement of elements supplied by NutraLime in soil. All results reported here are based on residual effects of NutraLime following a one time application in 1991.

PROCEDURES

Three field sites, all used for commercial crop production, were selected for the demonstration plots. The sites were located in Dakota Co. (Wadena loam), Isanti Co. (Hayden silt loam), and Washington Co. (Antigo silt loam). Selected soil characteristics of each site were presented previously. The same basic procedure was followed at each site. Treatments were applied in 1991 and consisted of a control and three rates (0.5X, 1.0X, 2.0X) of NutraLime, replicated three times in strips. The strips were 25-30 feet wide and 300 feet in length. Prior to NutraLime application, 14" suction tubes were buried so that the ceramic tip was about 2.5' deep. These suction tubes were intended to be used for the duration of the demonstration without having to reinstall them each year. Plastic line from the suction tubes was laid along a 5' trench, so that soil above the suction tube would not be disturbed when water samples were collected, and the line was buried to allow for tillage operations. The NutraLime was applied as a slurry using a terragator set at the 0.5X rate. To obtain the 1X and 2X rate, the terragator travelled 2 and 4 times, respectively, over the plots at the same speed. Preweighed plastic trays (3ft x 2ft) were placed in the middle of each 0.5X strip to catch the applied material. The trays were weighed again after application and a subsample was collected in plastic bottles for moisture determination and elemental content. The actual rates applied varied with each site and are presented in Table 1. Elemental content of the NutraLime at each site was determined on concentrated nitric acid/perchloric acid digests and presented previously.

[1]Funding for this project was provided by the Metropolitan Waste Control Commission.
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At the Dakota Co. site in 1993, the crop tested for response to NutraLime was seed corn, Jacques Y001XJ46 (female inbred). The seed corn was planted May 16 at a rate of 26,500 seeds/A (2.5' between rows). Anhydrous ammonia was applied preplant at the rate of 140 lb N/A. Irrigation was used to supplement rainfall when needed. At the Isanti Co. site, the crop tested for response to NutraLime was Alfalfa (Agate). In addition to the NutraLime applied in 1991, spent lime (without the ash) was applied on half of the control plots at a rate of 20 dry tons/A on April 24, 1993. Potassium was applied as KCl at the rate of 600 lb K_2O/A. The lime and potassium were disked in to a depth of 6" and the alfalfa was planted on April 25. The site was nonirrigated. At the Washington Co. site, the crop tested for response to NutraLime was Jacques 6770 field corn planted on April 29. The plant population was 28,000 seeds/A (2.5' between rows). Anhydrous ammonia was applied preplant at the rate of 150 lb N/A and 150 lb K_2O/ was broadcast and incorporated in the spring. Starter fertilizer was applied at a rate of 13 lb N/A, 34 lb P_2O_5/A, and 15 lb K_2O/A. Irrigation was used to supplement rainfall when needed.

Soil water samples were collected 2-3 times during the growing season at each site. Multiple elements were determined in water samples using ICP procedures. In Isanti Co., alfalfa was harvested twice: July 12 and August 26. Harvested area included 5 sq. ft. per replication. Samples were dried, weighed and then ground. At the Dakota Co. site, whole plant seed corn at the 8-12 leaf stage was sampled on July 20. Ear leaves were sampled at silking on August 6 and the plot was harvested on September 1 (two 25 ft rows per replication). At the Washington Co. site, field corn whole plants (8-12 leaf) were sampled on July 7. Ear leaves were sampled at silking on August 6 and the plot was harvested on October 12 (two 25 ft rows per replication). For both corn plots, samples of stover and ears (grain and cob) were collected. Samples were dried at 60 C, moisture content was determined and then the samples were ground to pass through a 30 mesh screen. Samples were ashed, dissolved in 1 N HCl and then analyzed for elemental content using ICP procedures. Tissue nitrogen concentrations were determined following Kjeldahl digestion using conductimetric procedures. Soil samples were collected after harvest. Within each replication, eight subsamples were combined at one foot intervals down to a depth of three feet. Samples were air dried and then ground. Multiple elements were determined on 1 N nitric acid extracts. Other analyses included soil pH and soluble salts (1:1 soil:water), ammonium acetate extractable cations, and DTPA extractable metals.

RESULTS

Plant Growth and Yield. NutraLime had a negative effect on seed corn grain yield at the Dakota Co. site (Table 2). Causes for this negative response are not known, but may be due to delayed maturity due to NutraLime. Grain moisture was significantly higher with increasing NutraLime application. Early plant growth, final stand count and stover yield were not affected by NutraLime application. In contrast to the negative effects on seed corn NutraLime significantly increased grain yield in field corn at the Washington Co. site (Table 3). Associated with this increase was an increase in early plant growth due to NutraLime application. No effects due to NutraLime application were found for grain moisture, final stand count, or stover yield.

Effects of NutraLime on alfalfa growth in Isanti Co. are presented in Tables 4. For both cuttings, NutraLime increase alfalfa yield substantially compared to the nonlimed control. Yield with NutraLime also tended to be greater than yield with the limed control. This comparison is somewhat biased toward the NutraLime treatment since the lime application was recently applied and only disked in prior to planting. Except for the seed corn results from this year, the yield data from 1993 indicate that when applied at realistic rates, NutraLime can have a beneficial effect on plant growth. Causes for the negative effects on seed corn in 1993 need to be investigated further.

Elemental Concentrations in Soil Water. Elemental concentrations in water collected from suction tubes at the 2.5' depth are presented in Tables 5 - 7. At the Dakota Co. site Al, Cd, Cr, Cu, Fe, K, Mg, Mo, Na, Ni, Pb, and P were all at background levels or below detection limits (Table 7). S and Zn concentrations increased slightly with NutraLime application on some sampling dates. None of the elements detected were at levels above drinking water standards. Slight trends in increasing B, Mg, and Ca concentrations with increasing NutraLime were also detected.

At the Isanti Co. site Al, B, Cd, Cr, Cu, Fe, K, Mo, Ni, P, and Pb concentrations were generally below detection limits (Table 6). Ca, Mg, Mn, and Zn slightly increased with NutraLime application. Concentrations of S increased with increasing NutraLime at the both sampling date. Concentrations of Na were not consistently affected by NutraLime.

At the Washington county site, concentrations of all elements were at background levels or below detection limits except for Ca, Mg, and S (Table 7). These elements tended to increase with NutraLime application.

Elemental Concentrations in Soil. Soluble salts, soil pH, Bray and Olsen P, ammonium acetate extractable cations and DTPA extractable metals are presented in Tables 8-10. Soil pH was still substantially higher (1.3-1.7 units) in the top 6 inches with the 0.5X NutraLime rate compared to the control. With higher

NutraLime rates, soil pH increased by an additional 0.1-0.6 units. At the 6-12 inch depth, soil pH was 0.3-1.3 units higher in the 2X rate compared to the control. Soil pH was not affected by NutraLime treatment at the 12-24 inch depth at any site. Lime applied at the Isanti site resulted in similar pH changes as the 2X NutraLime rate at all depths. Soluble salts in the top 6 inches generally increased with NutraLime application rate; however, none of the soluble salt levels were in a range considered to be high enough to cause salt toxicity. Lime application at the Isanti site resulted in higher salt levels than the 2X NutraLime rate. In the 6-12 inch and 12-24 inch depths, soluble salts tended to increase with NutraLime application, although the increase was not always statistically significant. Bray and Olsen P increased with NutraLime application in the top 6 inches at all sites. In the 6-12 and 12-24 inch depths, soil P tended to increase with NutraLime application at all sites. As with soil pH, this increase was not always statistically significant. Lime application resulted in similar extractable P levels as the control. Extractable K was not consistently affected by NutraLime application. In Isanti Co. extractable K decreased with NutraLime application rate, while in Dakota and Washington Counties, no trend with NutraLime was apparent. Extractable Na increased with NutraLime rate at the Washington Co. site in the top 24 inches. Slight trends Na levels were also found at the Dakota and Isanti sites at the 6-12" depth. Extractable Ca and Mg increased with NutraLime application in the top 6 inches at all sites. At the 6-12 inch depth, Ca and Mg increased with NutraLime rate at the Washington and Isanti Co. sites. In the 12-24 inch depth, Ca and Mg were not significantly affected by NutraLime treatment. DTPA extractable Fe, Mn, and Ni decreased with NutraLime application in the top 6 inches and were unaffected or continued to decrease with NutraLime rate in the lower depths. DTPA extractable Cu increased in the top 6 inches at all sites and generally increased in the 6-12 inch depth. DTPA extractable Zn in the top 6" increased slightly with NutraLime rate at the Isanti Co. site, but was not affected at the other sites. Extractable Pb either was not affected or decreased with NutraLime rate. DTPA extractable Cd tended to increase with NutraLime rate in the top 6 inches. In the 6-12 inch depth, DTPA Cd was not consistently affected by NutraLime rate and in the 12-24 inch depth, DTPA Cd was generally below detection limits. DTPA extractable Cr was not affected by NutraLime application, with most concentrations below detection limits of the spectrophotometer. In general, DTPA extractable trace elements were not affected by NutraLime in the 12-24" depth. Lime treatment at the Isanti Co. site generally decreased availability of Mn, Pb, Ni, and Cd in the top 6" with not difference in trace element levels at lower depths compared to the control.

Nitric acid extractable soil elements are presented in Tables 11-13. All elements tested, except Be, Co, K, and Li increased with NutraLime application in the top 6 inches at all sites. Li was frequently below detection limits, K increased with NutraLime application at two of the three sites, and Co increased at two of the three sites. Sulfur generally increased with NutraLime application in all depths at the Isanti and Washington Co. sites, indicating that S was moving through the soil profile. The results substantiate the increases in S with NutraLime treatment in soil water. At Dakota County, As, Cu, and Na increased with NutraLime application in the 6-12 inch depth. At the Isanti Co. site, Ca, Cr, Cu Na, and Si increased with increasing NutraLime treatment. At Washington County, As, Ca, Co, Pb, Mg, Mo, Si, Na, Ti, and V tended to increase with NutraLime application rate. It is likely that most of the increases in elements with NutraLime treatment at the 6-12 inch depth are due to tillage operations. Tillage operations at the Dakota County site would be expected to have had the most influence on mixing of NutraLime to lower depths since deeper tillage was used. Significant increases in elements with NutraLime application at the 12-24 inch depth were not detected at the Dakota Co. or Isanti Co. sites. At Washington County, Al, As, Cu, Mo, P, Na slightly increased at the 12-24" depth. Background concentrations of most elements at this lower depth indicate that minimal movement had occurred three years after NutraLime application. Lime treatment at Isanti Co. resulted in higher levels nitric acid extractable As, Ca, Mg, Mn, Si, and S in the 0-6" depth relative to the nonlimed treatment. At lower depths the limed treatment resulted in similar concentrations of nitric acid extractable elements compared to the nonlimed treatment.

Elemental Concentrations in Plant Tissue. Elemental concentrations in seed corn whole plant at the 8-12 leaf stage, ear leaf at silking, stover, cob, and kernels are presented in Tables 14-18. Whole plant samples increased in Mo concentrations with NutraLime application. Ear leaf (diagnostic leaf) concentrations of Mo and Cu increased and Fe decreased with increasing NutraLime application. All other elements were not significantly affected by NutraLime application and except for Zn, were within sufficiency ranges expected for healthy plants. Even though Fe concentrations decreased with NutraLime application, they were still well above a range where any deficiency would be expected to occur. The decrease in yield with NutraLime application at this site does not appear to be caused by nutritional imbalances. The only element that appeared to be in the deficiency range was Zn, but the control was also low. Concentrations of Mn were on the low side for the NutraLime treatments, but still considered adequate for optimum corn growth. Perhaps seed corn with its more limited root system requires higher levels of nutrients compared to field corn. Concentrations of Mo increased and Mn decreased with increasing NutraLime application in seed corn stover. It is possible that the higher pH induced a Mn deficiency causing the yield decrease. Further research would have to be conducted to substantiate this possibility. Concentrations of Mo, B, Zn, Cu, Fe, Mg, Ca, and K tended to increase in cobs with NutraLime application. Concentrations of Mo, N, and Zn increased in kernel samples with increasing NutraLime application. Levels of Cd, Ni, Pb, and Cr were either below detection limits or not significantly affected by NutraLime application.

Elemental concentrations in field corn whole plants at the 8-12 leaf stage, ear leaf at silking, stover, cob and kernels are presented in Tables 19-23. In whole plant samples, concentrations of Mo, Mg, and Ca increased and concentrations of N, Fe, Mn and Zn decreased with increasing NutraLime application. Ear leaf (diagnostic leaf) concentrations of Mo, Cr, Al, Ca, and P increased with increasing NutraLime application. All other elements were not significantly affected by NutraLime application and were within sufficiency ranges expected for healthy plants. The increase in yield with NutraLime application at this site is difficult to explain on a nutritional basis from nutrient levels in the diagnostic leaf. Concentrations of Mo, B, Cu, and Cd increased with increasing NutraLime application in seed corn stover. It is possible that the low Mo in plants growing in the control plots were deficient, resulting in a lower yield compared to plants in the NutraLime amended plots. Even though Cd levels increased in stover, they were well below the level of 0.5 ppm required to cause problems in animals. Concentrations of Mo increased and Zn and Mn decreased in cobs with NutraLime application. Concentrations of Mo increased in kernel samples with increasing NutraLime application. Levels of Cd, Ni, Pb, and Cr in kernels were below detection limits in all treatments.

Elemental concentrations in alfalfa tissue at the two harvests are presented in Tables 24 and 25. In the first harvest concentrations of N, P, K, Na, and Mo increased and Al, Mn, Zn, B, and Ni decreased with increasing NutraLime. Spent lime applications increased N, P, K, Mg, Na, Mo, Mn, Zn, B, and Ni compared to the nonlimed treatment. Alfalfa tissue concentrations of Mo in NutraLime amended plots, were at a level where molybdenosis could be a problem. As discussed in previous years when soybean was grown, legumes have a high demand for Mo and seem to accumulate this element in foliage and grain. Implications for using NutraLime for alfalfa are that it needs to be monitored for Mo content so that rations can be supplemented with copper or mixed with forage that is much lower in Mo. Although the lime treatment also increased Mo concentrations, the level was below that considered a problem for ruminants. At the second harvest, concentrations of Mo increased and N, Mg, Fe, Mn, Cu, B, and Ni decreased with increasing NutraLime application. Concentrations of Mo were lower in the second harvest compared to the first harvest due to the fact that the root system had begun to explore lower depths where the pH was lower resulting in lower Mo availability. The limed treatment resulted in higher Mo concentrations and lower Ca, Mn, Zn, Cu, B, and Ni compared to the nonlimed treatment. For both harvests, Cd, Cr, and Pb were either not affected by NutraLime treatment or were below detection limits.

GENERAL SUMMARY

NutraLime application increased field corn yield and alfalfa yield, but decreased yield of seed corn. For alfalfa, yield increases were substantial with increasing NutraLime, but tissue levels of Mo increased to levels where molybdenosis could be a problem if the forage was chronically ingested. Improved P and Mo nutrition appeared to be involved with increases in alfalfa yield. Reasons for the decrease in seed corn yield with NutraLime application are unclear, but may be related to a pH induced Mn deficiency. The increase in field corn yield was related to an increase in soil pH from 5.3 in the control to above 7 in NutraLime amended plots. The main nutrient associated with the yield increase was Mo. Concentrations of Cd, Cr, Ni and Pb in plant tissues were below the levels where animal health problems would be a concern. In general, trace metals applied with NutraLime were confined to the top 12 inches of soil. NutraLime effectively increased soil pH and plant available P. Trace elements detected in soil water at the 2.5 foot depth were below limits set for drinking water.

Table 1. NutraLime treatments applied at each site prior to planting in 1991.

Demonstration sites					
Dakota Co.		Isanti Co.		Washington Co.	
NutraLime applied					
Wet tons/A	Dry tons/A	Wet tons/A	Dry tons/A	Wet tons/A	Dry tons/A
0.0	0.0	0.0	0.0	0.0	0.0
9.8	4.3	13.1	5.1	18.6	7.8
19.6	8.6	26.2	10.2	37.2	15.6
39.2	17.2	52.3	20.4	74.4	31.2

Table 2. Effect of NutraLime on whole plant dry matter at the 10-14 leaf stage, final stand count, grain and stover yield, and grain moisture - seed corn, Dakota County.

NutraLime Treatment	Whole plant dry matter (10-14 leaf)	Final stand count	Grain yield	Dry stover	Grain moisture
	-grams/plant-	-plants/A-	-bu/A-	-tons/A-	- % -
0	209	22796	51.3	3.61	19
0.5x	213	24394	42.1	3.67	26
1.0x	201	25264	42.6	4.07	29
2.0x	207	23522	37.8	4.14	28
Significance	NS	NS	NS	NS	NS
BLSD (5%)	--	--	--	--	--
Linear	NS	NS	*	NS	*
Quadratic	NS	NS	NS	NS	NS

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

Table 3. Effect of NutraLime on whole plant dry matter at the 8-12 leaf stage, final stand count, grain and stover yield, and grain moisture - field corn, Washington County.

NutraLime Treatment	Whole plant dry matter (8-12 leaf)	Final stand count	Grain yield	Dry stover	Grain moisture
	-grams/plant-	-plants/A-	-bu/A-	-tons/A-	- % -
0	71	28750	125.4	2.12	45
0.5x	92	29040	145.3	2.05	44
1.0x	88	27298	140.2	2.22	45
2.0x	97	28750	140.7	2.37	46
Significance	*	NS	*	NS	NS
BLSD (5%)	17	--	13.6	--	--
Linear	*	NS	NS	NS	NS
Quadratic	NS	NS	*	NS	NS

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

Table 4. Effect of NutraLime on alfalfa whole plant dry weight at the 1 to 10 percent bloom stage - Isanti County.

NutraLime Treatment	Plant dry weight first cutting	Plant dry weight second cutting
	-tons/A-	-tons/A-
0	0.74	0.79
Lime	1.07	1.68
0.5x	1.45	1.70
1.0x	1.55	2.16
2.0x	1.62	2.11
Significance	**	**
BLSD (5%)	0.39	0.38
Linear	**	**
Quadratic	**	**
Lime vs 2.0x	*	*

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

Table 5. Effect of NutraLime on elemental composition of soil water collected from suction tubes - Dakota County.

Date	Trmt	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn
July 6, 1993										ppm								
	0	<0.18	<0.02	63	<0.006	<0.01	<0.03	<0.02	<1.7	16	<0.01	<0.01	7	<0.02	<0.04	<0.08	12	0.06
	0.5x	<0.18	<0.02	62	<0.006	<0.01	<0.03	<0.03	4.0	17	0.03	<0.03	12	<0.02	<0.05	<0.08	21	0.19
	1.0x	<0.21	<0.02	70	<0.006	<0.01	<0.03	<0.02	1.1	15	<0.02	<0.01	12	<0.02	<0.04	<0.08	22	0.18
	2.0x	<0.18	0.04	67	<0.006	<0.01	<0.03	<0.02	<1.4	16	<0.01	<0.01	6	<0.02	<0.04	<0.08	12	0.10
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
August 6, 1993																		
	0	<0.19	<0.03	86	<0.006	<0.01	<0.03	<0.02	1.9	21	<0.01	<0.01	10	<0.02	<0.05	<0.08	13	0.08
	0.5x	<0.22	<0.03	53	<0.006	<0.01	<0.03	<0.02	4.0	14	<0.04	<0.01	11	<0.02	<0.04	<0.08	20	0.14
	1.0x	<0.25	<0.03	102	<0.006	<0.01	<0.03	<0.03	2.0	25	0.04	<0.01	16	<0.03	<0.04	<0.08	27	0.21
	2.0x	<0.20	0.06	133	<0.006	<0.01	<0.03	<0.02	2.8	35	<0.02	<0.01	10	<0.02	<0.04	<0.08	14	0.13
Significance		--	--	NS	--	--	--	--	NS	NS	--	--	NS	--	--	--	*	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	NS	NS	--	--	NS	--	--	--	NS	NS
Quadratic		--	--	NS	--	--	--	--	NS	NS	--	--	NS	--	--	--	**	NS
September 1, 1993																		
	0	<0.18	<0.03	69	<0.006	<0.01	<0.03	<0.02	1.7	17	<0.01	<0.01	7	<0.02	<0.05	<0.08	12	0.05
	0.5x	<0.22	<0.02	50	<0.006	<0.01	<0.03	<0.02	3.3	13	<0.04	<0.01	11	<0.02	<0.06	<0.08	20	0.12
	1.0x	<0.28	0.03	99	<0.006	<0.01	<0.03	<0.02	1.9	24	0.05	<0.01	15	<0.03	<0.04	<0.08	30	0.20
	2.0x	<0.20	0.05	94	<0.006	<0.01	<0.03	<0.02	2.6	24	<0.02	<0.01	8	<0.02	<0.04	<0.08	13	0.07
Significance		--	--	NS	--	--	--	--	NS	NS	--	--	NS	--	--	--	*	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	NS	NS	--	--	NS	--	--	--	NS	NS
Quadratic		--	--	NS	--	--	--	--	NS	NS	--	--	NS	--	--	--	**	*

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

Table 6. Effect of NutraLime on elemental composition of soil water collected from suction tubes - Isanti County.

Date	Trmt	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn
June 22, 1993										ppm								
	0	<0.18	<0.02	25	<0.006	<0.01	<0.03	<0.02	<0.7	9	<0.02	<0.01	9	<0.03	<0.04	<0.08	9	0.06
	0.5x	<0.18	<0.02	50	<0.006	<0.01	<0.03	<0.02	<0.7	17	0.05	<0.02	12	<0.03	<0.04	<0.08	20	0.07
	1.0x	<0.18	<0.02	41	<0.007	<0.01	<0.03	<0.02	<0.8	14	0.05	<0.01	9	<0.03	<0.04	<0.08	24	0.15
	2.0x	<0.18	<0.03	49	<0.006	<0.01	<0.03	<0.03	<0.9	17	0.06	<0.01	9	<0.04	<0.05	<0.08	32	0.10
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
August 3, 1993																		
	0	<0.18	<0.02	23	<0.006	<0.01	<0.04	<0.02	<0.7	8	0.02	<0.01	8	<0.03	<0.04	<0.08	9	0.07
	0.5x	<0.18	<0.02	46	<0.006	<0.01	<0.03	<0.02	<0.7	16	0.05	<0.01	12	<0.03	<0.04	<0.08	20	0.06
	1.0x	<0.18	<0.02	38	<0.006	<0.01	<0.03	<0.02	0.9	14	0.05	<0.01	10	<0.03	<0.10	<0.08	24	0.10
	2.0x	<0.22	<0.02	45	<0.006	<0.01	<0.04	<0.02	<1.0	16	0.07	<0.01	9	<0.03	<0.06	<0.08	30	0.12
Significance		--	--	NS	--	--	--	--	--	NS	NS	--	NS	--	--	--	**	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	NS	--	NS	--	--	--	**	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	NS	--	NS	--	--	--	NS	NS

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

Table 7. Effect of NutraLime on elemental composition of soil water collected from suction tubes - Washington County.

Date	Trmt	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn
		ppm																
June 8, 1993																		
	0	<0.18	<0.03	35	<0.006	<0.01	<0.03	<0.02	3.2	10	0.01	<0.01	4	<0.02	0.06	<0.08	16	0.07
	0.5x	<0.18	<0.03	27	<0.006	<0.01	<0.03	<0.02	<0.8	8	0.02	<0.01	21	<0.02	<0.04	<0.08	21	0.07
	1.0x	<0.18	<0.03	46	<0.006	<0.01	<0.03	<0.02	<3.6	13	0.01	<0.01	14	<0.02	<0.09	<0.08	20	0.06
	2.0x	<0.18	<0.02	46	<0.006	<0.01	<0.03	<0.02	<0.8	12	<0.01	<0.01	12	<0.02	<0.31	<0.08	16	0.06
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
July 6, 1993																		
	0	<0.18	<0.03	34	<0.006	<0.01	<0.03	<0.02	4.3	10	<0.02	<0.01	4	<0.02	<0.04	<0.08	7	0.06
	0.5x	<0.18	0.04	42	<0.006	<0.01	<0.03	<0.02	<0.9	11	0.02	<0.01	25	<0.02	<0.04	<0.08	12	0.08
	1.0x	<0.18	<0.03	51	<0.006	<0.01	<0.03	<0.02	<4.3	15	<0.01	<0.01	14	<0.02	<0.04	<0.08	16	0.06
	2.0x	<0.18	<0.03	51	<0.006	<0.01	<0.03	<0.02	<0.9	13	<0.01	<0.01	11	<0.02	<0.23	<0.08	13	0.05
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
August 23, 1993																		
	0	<0.18	<0.02	21	<0.006	<0.01	<0.03	<0.02	1.5	6	<0.01	<0.01	4	<0.02	0.04	<0.08	7	0.05
	0.5x	<0.18	0.04	36	<0.006	<0.01	<0.03	<0.02	<0.7	10	<0.02	<0.01	23	<0.02	<0.04	<0.08	10	0.05
	1.0x	<0.18	0.04	55	<0.006	<0.01	<0.03	<0.02	<1.8	15	<0.01	<0.01	14	<0.02	<0.05	<0.08	15	0.05
	2.0x	<0.18	<0.04	86	<0.006	<0.01	<0.03	<0.02	1.1	24	<0.01	<0.01	13	<0.02	<0.20	<0.08	20	0.09
Significance		--	--	*	--	--	--	--	--	*	--	--	NS	--	--	--	NS	NS
BLSD (5%)		--	--	36	--	--	--	--	--	12	--	--	--	--	--	--	--	--
Contrasts																		
Linear		--	--	**	--	--	--	--	--	**	--	--	NS	--	--	--	*	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS

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

Table 8. Effect of NutraLime on soil pH, soluble salts, Bray P, Olsen P, ammonium acetate extractable cations and DTPA extractable metals - Dakota County.

						NH_4OAc Extractable				DTPA Extractable							
Depth	Trmt	pH	Soluble Salts	Bray P	Olsen P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			mmhos/cm	ppm													
0-6"	0	6.1	0.10	104	59	213	2239	508	6.0	81	16.1	1.7	1.0	1.5	1.0	0.08	<0.03
	0.5x	7.4	0.20	231	107	194	2978	415	6.1	41	5.3	1.7	3.6	1.5	0.6	0.13	0.03
	1.0x	7.6	0.23	299	130	190	4124	437	9.2	43	4.9	1.9	5.5	1.8	0.6	0.15	0.04
	2.0x	7.7	0.20	315	134	209	4324	452	8.5	42	4.7	2.0	6.2	2.5	0.6	0.16	0.04
Significance		**	**	**	**	NS	**	NS	NS	**	**	NS	**	NS	**	**	--
BLSD	(5%)	0.3	0.06	57	24	--	771	--	--	16	3.0	--	0.7	--	0.2	0.02	--
Contrasts																	
Linear		**	**	**	**	NS	**	NS	NS	**	**	NS	**	NS	**	**	--
Quadratic		**	**	**	**	NS	*	NS	NS	**	**	NS	**	NS	**	**	--
6-12"	0	5.9	0.10	30	18	69	1601	355	6.8	67	8.8	0.6	0.6	0.9	0.8	0.04	<0.03
	0.5x	6.2	0.13	52	27	74	1727	381	8.5	71	8.4	0.9	0.7	1.1	0.8	0.06	0.03
	1.0x	5.9	0.17	57	32	68	1680	357	10.8	81	10.0	0.8	0.7	1.1	0.9	0.05	0.03
	2.0x	6.2	0.17	45	23	76	1701	370	9.8	72	7.6	0.7	0.8	1.8	0.8	0.05	0.03
Significance		NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS	NS	NS	--
BLSD	(5%)	--	--	--	--	--	--	10	2.0	--	--	--	--	--	--	--	--
Contrasts																	
Linear		NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	*	NS	NS	NS	--
Quadratic		NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	--
12-24"	0	6.2	0.10	7	4	27	708	136	4.3	22	1.1	0.1	0.4	<0.2	<0.1	<0.01	<0.03
	0.5x	6.2	0.17	8	6	33	875	181	5.8	23	0.9	0.1	0.5	0.2	0.1	<0.01	<0.03
	1.0x	6.2	0.10	7	5	31	881	177	6.2	25	0.9	0.1	0.5	0.2	0.1	<0.01	<0.03
	2.0x	6.2	0.17	8	5	31	888	167	6.3	24	1.0	0.1	0.4	<0.2	0.1	<0.01	<0.03
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--	--	--
BLSD	(5%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Contrasts																	
Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--	--	--
Quadratic		NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	--	--	--	--

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

Table 9. Effect of NutraLime on soil pH, soluble salts, Bray P1, Olsen P, ammonium acetate extractable cations, and DTPA extractable metals - Isanti County.

						NH_4OAc Extractable				DTPA Extractable							
Depth	Trmt	pH	Soluble Salts	Bray P	Olsen P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			mmhos/cm	ppm													
0 - 6"	0	5.8	0.20	36	15	259	930	81	4.6	83	24.9	1.4	0.6	0.9	0.8	0.07	<0.03
	Lime	7.5	0.43	30	16	188	3981	252	5.3	44	9.5	1.0	0.6	0.6	0.5	0.06	<0.03
	0.5x	7.6	0.27	114	31	213	2010	118	4.6	30	6.2	1.1	2.4	0.7	0.4	0.09	<0.03
	1.0x	7.7	0.27	134	36	185	2610	138	5.1	28	5.7	1.1	2.9	0.8	0.4	0.10	<0.03
	2.0x	7.6	0.23	150	40	194	2976	167	6.6	30	5.1	1.2	3.3	0.8	0.4	0.11	<0.03
Significance		**	*	**	**	NS	**	**	NS	**	**	NS	**	**	**	**	--
BLSD (5%)		0.4	0.12	24	5	--	713	60	--	19	4.4	--	0.6	0.1	0.2	0.02	--
Contrasts																	
Linear		**	NS	**	**	NS	**	**	**	**	**	NS	**	NS	**	**	--
Quadratic		**	NS	**	**	NS	*	NS	NS	**	**	NS	**	**	**	NS	--
Lime vs 2.0x		NS	**	**	**	NS	**	**	NS	NS	NS	NS	**	**	NS	**	--
6 - 12"	0	5.5	0.27	19	11	113	896	119	5.7	60	11.7	0.6	0.4	0.5	0.5	0.03	<0.03
	Lime	6.1	0.20	27	13	102	927	100	4.6	60	10.5	0.7	0.4	0.5	0.5	0.04	<0.03
	0.5x	6.9	0.30	50	16	107	1449	151	6.9	47	6.9	0.6	0.9	0.6	0.4	0.04	<0.03
	1.0x	6.8	0.30	54	16	96	1432	128	6.3	42	7.2	0.6	0.9	0.5	0.4	0.05	<0.03
	2.0x	6.7	0.33	49	14	86	1302	137	7.5	49	6.4	0.7	0.8	0.5	0.5	0.05	<0.03
Significance		**	NS	NS	*	NS	NS	NS	*	NS	NS	NS	*	NS	NS	NS	--
BLSD (5%)		0.4	--	--	5	--	--	--	1.7	--	--	--	0.4	--	--	--	--
Contrasts																	
Linear		**	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--
Quadratic		**	NS	*	*	NS	*	NS	NS	NS	NS	NS	*	NS	NS	NS	--
Lime vs 2.0x		**	NS	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	NS	NS	--
12 - 24"	0	5.6	0.10	23	23	128	1460	314	13.8	77	5.6	0.2	0.7	0.5	0.6	<0.01	0.04
	Lime	5.7	0.10	23	20	94	1423	283	10.6	80	5.1	0.2	0.7	0.4	0.5	<0.01	<0.04
	0.5x	5.8	0.13	23	20	96	1498	329	16.5	62	6.0	0.3	0.7	0.5	0.6	<0.01	<0.04
	1.0x	5.7	0.17	22	17	86	1357	260	12.0	58	4.0	0.2	0.5	0.5	0.4	<0.01	0.03
	2.0x	5.7	0.17	20	17	81	1411	271	13.4	68	4.5	0.2	0.6	0.5	0.5	<0.01	0.03
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Contrasts																	
Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--
Quadratic		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--
Lime vs 2.0x		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--

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

Table 10. Effect of NutraLime on soil pH, soluble salts, Bray P1, Olsen P, ammonium acetate extractable cations and DTPA extractable metals - Washington County.

						NH_4OAc Extractable				DTPA Extractable							
Depth	Trmt	pH	Soluble Salts	Bray P	Olsen P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			mmhos/cm	ppm													
0 - 6"	0	5.3	0.20	67	43	236	1766	250	5.7	125	32.3	2.1	1.0	1.9	2.1	0.12	<0.03
	0.5x	7.0	0.47	133	77	258	3575	342	7.4	65	8.9	2.7	2.9	1.4	1.4	0.18	<0.03
	1.0x	7.4	0.43	151	91	243	4874	379	8.6	48	5.6	2.3	4.4	1.4	1.0	0.21	<0.03
	2.0x	7.6	0.33	209	105	293	5477	467	10.4	44	4.3	3.0	6.9	1.7	0.9	0.24	0.04
Significance		**	*	**	**	NS	**	**	**	**	**	*	**	NS	**	**	--
BLSD (5%)		0.5	0.14	26	31	--	647	61	1.2	35	9.0	0.6	0.9	--	0.5	0.02	--
Contrasts																	
Linear		**	NS	**	**	NS	**	**	**	**	**	*	**	NS	**	**	--
Quadratic		**	**	NS	NS	NS	**	NS	NS	*	**	NS	NS	*	*	**	--
6 - 12"	0	5.3	0.20	43	30	153	1966	285	6.7	111	24.0	1.5	0.9	1.5	2.0	0.09	<0.03
	0.5x	6.2	0.37	64	40	158	2690	341	8.5	87	13.3	1.9	1.5	1.3	1.8	0.11	<0.03
	1.0x	6.8	0.57	84	37	154	3437	372	9.7	73	8.2	1.5	2.1	1.1	1.5	0.11	0.03
	2.0x	6.6	0.30	90	45	172	3079	399	11.0	81	10.7	2.0	2.0	1.2	1.4	0.11	0.04
Significance		**	*	NS	NS	NS	*	NS	**	NS	*	NS	NS	NS	NS	NS	--
BLSD (5%)		0.7	0.22	--	--	--	1066	--	1.0	--	10.2	--	--	--	--	--	--
Contrasts																	
Linear		**	NS	NS	*	NS	*	*	**	NS	*	NS	NS	NS	*	NS	--
Quadratic		*	**	NS	NS	NS	*	NS	*	NS	*	NS	NS	NS	NS	NS	--
12 - 24"	0	5.8	0.20	10	8	99	2133	399	8.9	49	4.3	0.4	1.0	0.6	0.9	<0.02	0.04
	0.5x	6.0	0.20	10	8	90	2180	383	9.8	51	3.0	0.3	0.8	0.6	1.1	0.02	0.04
	1.0x	6.0	0.20	8	7	86	2154	379	10.9	46	2.9	0.2	0.7	0.6	1.0	0.02	0.04
	2.0x	6.1	0.23	16	12	109	2347	422	12.1	59	4.1	0.5	1.0	0.6	1.0	<0.03	0.04
Significance		NS	NS	*	NS	*	NS	NS	**	NS	NS	NS	NS	NS	NS	--	NS
BLSD (5%)		--	--	5	--	16	--	--	1.1	--	--	--	--	--	--	--	--
Contrasts																	
Linear		NS	NS	*	*	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	--	NS
Quadratic		NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	NS

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

Table 11. Effect of NutraLime on nitric acid extractable elements - Dakota County.

DEPTH	Treatment	Al	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	P	K	Si	Na	Sr	S	Ti	V	Zn
		1 N Nitric Acid Extractable																									
		ppm																									
0 - 6 inches	0	1403	1.5	107	0.4	1.1	0.3	2696	1.1	0.8	4	593	9	<0.20	629	111	0.44	2.9	198	235	333	8	10	12	8	2.6	5
	0.5x	1904	2.0	122	0.4	1.6	0.8	5456	3.4	1.1	30	862	15	<0.20	899	191	0.67	3.2	921	263	610	22	14	20	13	3.8	12
	1.0x	2367	2.6	139	0.4	2.1	1.2	7694	5.4	1.2	55	1078	21	0.26	898	259	0.90	3.8	1639	284	797	41	18	29	17	4.4	19
	2.0x	2491	2.7	142	0.3	2.2	1.4	8767	6.2	1.3	65	1132	24	0.28	962	284	0.97	4.0	1916	312	847	45	20	31	19	4.5	22
Significance		**	**	**	NS	**	**	**	**	**	**	**	**	--	NS	**	**	NS	**	NS	**	**	**	**	**	**	**
BLSD (5%)		217	0.2	11	--	0.2	0.1	774	0.6	0.1	6	137	3	--	--	27	0.08	--	191	--	81	7	2	3	2	0.4	2
Contrasts																											
Linear		**	**	**	NS	**	**	**	**	**	**	**	**	--	*	**	**	*	**	*	**	**	**	**	**	**	**
Quadratic		**	**	*	NS	**	**	**	**	**	**	**	**	--	NS	**	**	NS	**	NS	**	**	**	**	**	**	**
6 - 12 inches	0	1447	1.4	98	0.3	0.8	0.2	1984	1.1	0.4	2	545	6	<0.21	502	47	0.43	2.0	49	82	375	9	11	12	10	2.3	4
	0.5x	1467	1.4	101	0.4	0.9	0.2	2280	1.1	0.5	4	566	10	<0.20	529	60	0.45	2.0	94	92	370	11	11	15	9	2.4	4
	1.0x	1511	1.5	105	0.4	0.9	0.2	2122	1.2	0.4	3	613	7	<0.22	511	55	0.46	2.1	95	82	389	13	11	19	11	2.5	4
	2.0x	1474	1.4	99	0.3	0.9	0.2	2235	1.2	0.4	4	557	8	<0.21	528	55	0.45	2.0	93	94	372	13	11	18	9	2.4	4
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	**	NS	*	NS	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	2	--	4	--	--	--
Contrasts																											
Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	**	NS	**	NS	NS	NS
Quadratic		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
12 - 24 inches	0	702	0.8	40	0.1	<0.3	<0.1	1028	0.6	<0.1	2	389	2	<0.20	232	15	0.22	0.7	100	36	237	7	6	6	10	1.3	2
	0.5x	822	0.9	47	0.1	0.4	0.1	1174	0.7	<0.1	2	412	3	<0.20	282	15	0.25	0.6	84	42	250	9	7	8	11	1.6	2
	1.0x	790	0.9	47	0.1	0.3	0.1	1149	0.7	<0.1	2	426	3	<0.20	271	14	0.24	0.5	95	39	257	9	7	12	12	1.6	2
	2.0x	800	0.9	44	0.1	<0.4	0.1	1178	0.7	<0.1	2	416	3	<0.20	268	15	0.25	0.6	93	39	259	9	7	10	11	1.5	2
Significance		NS	NS	NS	NS	--	--	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Contrasts																											
Linear		NS	NS	NS	NS	--	--	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quadratic		NS	NS	NS	NS	--	--	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 12. Effect of NutraLime on nitric acid extractable elements - Isanti County.

		1 N Nitric Acid Extractable																									
DEPTH	Treatment	Al	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	P	K	Si	Na	Sr	S	Ti	V	Zn
		ppm																									
0 - 6 inches	0	743	1.1	43	0.1	0.6	0.3	1178	0.7	<0.4	2	813	5	<0.20	124	133	0.26	2.1	97	337	155	8	4	10	12	2.6	4
	Lime	833	1.5	45	0.2	0.8	0.3	6332	0.9	0.5	3	947	6	<0.20	391	174	0.27	1.8	119	262	243	10	7	19	14	3.3	5
	0.5x	976	1.5	51	0.1	0.9	0.7	3235	2.2	0.6	20	951	9	<0.20	259	198	0.36	2.2	504	312	330	17	6	14	18	3.2	10
	1.0x	1133	1.8	56	0.1	1.1	0.9	4327	3.0	0.6	28	1031	11	<0.20	334	218	0.43	2.5	704	282	392	21	8	17	20	3.4	13
	2.0x	1244	2.0	61	0.2	1.2	1.0	4935	3.3	0.5	32	1186	12	<0.21	389	231	0.49	2.7	800	289	435	25	9	19	22	3.9	15
Significance		**	**	NS	NS	**	**	**	**	--	**	NS	**	--	**	**	**	*	**	NS	**	**	**	**	**	NS	**
BLSD (5%)		126	0.4	--	--	0.2	0.2	1440	0.5	--	7	--	1	--	88	29	0.06	0.5	149	--	50	4	2	4	2	--	2
Contrasts																											
Linear		**	**	*	NS	**	**	**	**	--	**	NS	**	--	**	**	**	**	**	NS	**	**	**	**	**	*	**
Quadratic		*	NS	NS	NS	*	**	*	**	--	**	NS	**	--	*	**	*	NS	**	NS	**	*	*	NS	**	NS	**
Lime vs 2.0x		**	*	*	NS	**	**	NS	**	--	**	NS	**	--	NS	**	**	**	**	NS	**	**	**	NS	**	NS	**
6 - 12 inches	0	753	1.0	31	0.1	0.4	0.2	1082	1.0	<0.2	1	802	4	<0.23	218	60	0.25	1.2	56	153	234	10	4	6	16	2.8	3
	Lime	760	1.1	33	0.1	0.5	0.2	1156	1.0	<0.2	2	1023	4	<0.20	179	85	0.26	1.5	96	149	209	9	4	7	17	3.3	3
	0.5x	880	1.2	37	0.1	0.6	0.4	1891	1.4	<0.3	7	901	6	<0.23	280	94	0.31	1.6	183	157	300	14	5	9	18	3.2	5
	1.0x	827	1.2	38	0.1	0.6	0.4	1985	1.4	<0.2	8	841	6	<0.21	249	100	0.33	1.7	210	146	263	14	5	9	17	2.9	5
	2.0x	811	1.2	38	0.1	0.6	0.3	1727	1.2	<0.2	6	876	5	<0.20	239	87	0.28	1.6	154	129	242	14	5	10	17	3.0	5
Significance		NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--
Contrasts																											
Linear		NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	*	NS	*	NS	NS	NS
Quadratic		NS	NS	NS	NS	NS	NS	*	*	--	*	NS	NS	--	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Lime vs 2.0x		NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
12 - 24 inches	0	1201	1.5	36	0.2	0.5	0.2	1728	1.8	<0.1	2	1264	4	0.49	577	25	0.39	1.8	115	149	552	18	6	7	27	4.3	4
	Lime	1161	1.5	34	0.2	0.5	0.3	1819	2.0	<0.1	2	1415	4	0.49	557	28	0.39	1.9	144	116	547	15	6	6	25	4.8	4
	0.5x	1233	1.5	34	0.2	0.6	0.2	1829	1.9	<0.1	3	1264	4	0.58	647	32	0.41	2.0	128	113	630	21	6	9	28	4.3	5
	1.0x	1081	1.3	32	0.2	0.5	0.2	1601	1.6	<0.1	2	988	4	0.42	495	26	0.36	1.7	90	106	463	16	6	10	25	3.6	3
	2.0x	1121	1.3	33	0.2	0.5	0.2	1691	1.7	<0.1	2	1144	4	<0.43	526	23	0.37	1.5	86	104	488	18	6	11	26	4.1	4
Significance		NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--
Contrasts																											
Linear		NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
Quadratic		NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lime vs 2.0x		NS	NS	NS	NS	NS	NS	NS	*	--	NS	NS	NS	--	NS	NS	NS	NS	*	NS	NS	NS	NS	**	NS	NS	NS

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

Table 13. Effect of NutraLime on nitric acid extractable elements - Washington County.

DEPTH	Treatment	1 N Nitric Acid Extractable																								
		Al	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	P	K	Si	Na	Sr	S	Ti	V	Zn
		ppm																								
0 - 6 inches	0	1343	1.3	105	0.39	1.1	0.3	2357	0.8	0.6	4	506	8	<0.20	331	92	0.43	3.8	109	257	264	6	12	10	6	2.2	6
	0.5x	1523	1.7	123	0.39	1.7	0.8	5503	2.4	0.8	21	614	12	<0.20	518	154	0.52	4.4	566	298	492	14	17	14	8	3.3	13
	1.0x	1869	2.2	127	0.39	1.9	1.3	8271	4.3	1.1	39	765	15	<0.21	709	195	0.67	4.7	967	294	668	24	19	19	10	3.8	18
	2.0x	2368	2.8	141	0.39	2.5	2.0	11601	6.4	1.3	70	999	22	0.29	957	250	0.89	5.5	1740	379	886	42	24	27	14	4.6	29
Significance		**	**	**	NS	**	**	**	**	**	**	**	**	--	**	**	**	**	**	*	**	**	**	**	**	**	**
BLSD (5%)		164	0.2	16	--	0.2	0.2	1480	0.6	0.1	7	59	1	--	105	15	0.06	0.6	192	78	79	3	3	6	2	0.4	2
Contrasts																											
Linear		**	**	**	NS	**	**	**	**	**	**	**	**	--	**	**	**	**	**	**	**	**	**	**	**	**	**
Quadratic		NS	NS	NS	NS	*	NS	*	*	*	NS	NS	NS	--	NS	**	NS	NS	NS	NS	*	NS	NS	NS	NS	**	NS
6 - 12 inches	0	1418	1.4	107	0.40	1.0	0.3	2526	0.9	0.4	4	534	7	<0.21	408	69	0.45	3.8	73	168	343	7	13	9	8	2.3	5
	0.5x	1390	1.4	115	0.40	1.2	0.4	3658	1.3	0.5	9	536	8	<0.21	486	82	0.46	4.2	191	175	397	11	15	11	8	2.7	8
	1.0x	1591	1.7	116	0.40	1.3	0.6	4908	2.1	0.5	17	614	9	<0.24	609	96	0.53	4.1	375	177	495	16	16	16	10	3.0	10
	2.0x	1601	1.7	114	0.39	1.4	0.6	4508	1.9	0.6	16	624	10	<0.22	587	100	0.55	3.8	378	201	470	18	16	16	10	3.0	10
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	*	*	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8	--	--	2	0.5	--
Contrasts																											
Linear		NS	*	NS	NS	NS	NS	*	NS	*	NS	NS	*	--	*	NS	*	NS	NS	NS	*	*	NS	*	*	*	NS
Quadratic		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12 - 24 inches	0	1515	1.4	91	0.34	0.7	0.2	2434	1.1	<0.2	3	676	6	0.34	628	26	0.48	2.1	24	104	528	10	15	5	16	2.9	5
	0.5x	1391	1.3	95	0.35	0.8	0.2	2520	1.1	0.2	3	605	5	0.30	588	24	0.45	2.6	19	92	483	11	15	6	16	2.7	5
	1.0x	1403	1.3	95	0.34	0.8	0.2	2515	1.1	0.2	4	677	5	0.34	619	24	0.46	2.4	24	89	529	12	15	8	18	2.9	5
	2.0x	1557	1.5	99	0.34	0.9	0.2	2961	1.2	0.2	5	649	6	0.31	639	34	0.50	2.5	72	117	501	14	16	12	14	2.9	5
Significance		*	*	NS	NS	NS	NS	NS	NS	--	*	NS	NS	NS	NS	NS	NS	NS	*	*	NS	*	NS	*	NS	NS	NS
BLSD (5%)		109	0.1	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	29	19	--	1	--	4	--	--	--
Contrasts																											
Linear		NS	*	NS	NS	NS	*	NS	NS	--	**	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	**	NS	**	NS	NS	NS
Quadratic		**	**	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	*	NS	*	*	NS	NS	NS	NS	NS	NS	NS

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

Table 14. Effect of NutraLime on the elemental composition of seed corn whole plant samples, July 20, 1993 - Dakota Co.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	2.90	0.36	2.85	0.41	0.46	60	104	11	38	22.6	5.8	6.5	2.17	1.23	1.39	0.25	0.67
0.5x	2.82	0.37	2.36	0.47	0.48	76	125	11	45	22.1	6.6	6.7	2.10	1.52	1.86	0.25	3.50
1.0x	2.84	0.35	2.45	0.48	0.52	78	122	13	32	22.5	6.9	6.2	2.15	1.44	1.76	0.27	4.35
2.0x	3.14	0.39	2.86	0.44	0.44	67	124	12	37	24.8	7.1	6.6	2.04	1.19	1.45	0.25	4.58
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
BLSD (5%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.43
Contrasts																	
Linear	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
Quadratic	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**

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

Table 15. Effect of NutraLime on the elemental composition of seed corn ear leaf samples, August 6, 1993 - Dakota Co.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.19	0.38	1.53	0.65	0.50	38	134	<4	40	18.6	5.4	7.8	<1.68	0.64	0.82	<0.13	0.90
0.5x	3.07	0.39	1.40	0.73	0.59	38	140	<4	32	17.1	6.6	7.1	<1.68	0.66	0.83	0.13	4.82
1.0x	3.17	0.39	1.44	0.73	0.57	29	128	<4	27	18.7	7.0	7.8	<1.68	0.63	0.78	0.13	6.13
2.0x	3.28	0.39	1.52	0.69	0.53	32	122	<6	35	19.0	7.5	7.9	<1.68	0.63	0.80	0.15	7.83
Significance	NS	NS	NS	NS	NS	NS	*	--	NS	NS	NS	NS	--	NS	NS	--	**
BLSD (5%)	--	--	--	--	--	--	10	--	--	--	--	--	--	--	--	--	1.73
Contrasts																	
Linear	NS	NS	NS	NS	NS	NS	**	--	NS	NS	*	NS	--	NS	NS	--	**
Quadratic	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	--	NS	NS	--	*

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

Table 16. Effect of NutraLime on the elemental composition of seed corn stover samples, September 1, 1993 - Dakota Co.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	1.67	0.27	1.19	0.35	0.39	68	139	6	37	16.0	4.3	6.4	<1.68	0.66	0.83	0.14	0.58
0.5x	1.46	0.23	0.93	0.35	0.42	54	98	<7	26	13.2	3.9	6.0	<1.68	0.65	0.82	<0.13	1.90
1.0x	1.73	0.26	1.06	0.41	0.44	77	122	<6	26	15.1	4.3	6.9	<1.68	0.73	0.92	0.14	3.55
2.0x	1.65	0.26	1.04	0.32	0.37	72	126	6	23	15.4	4.5	6.9	<1.68	0.73	0.92	<0.16	3.35
Significance	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	--	NS	NS	--	**
BLSD (5%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.56
Contrasts																	
Linear	NS	NS	NS	NS	NS	NS	NS	--	*	NS	NS	NS	--	NS	NS	--	**
Quadratic	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	--	NS	NS	--	**

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

Table 17. Effect of NutraLime on the elemental composition of seed corn cob samples, September 1, 1993 - Dakota Co.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	0.84	0.16	0.87	0.02	0.11	<4	23	<5	12	25.5	3.5	3.9	<1.68	0.93	0.87	<0.12	0.29
0.5x	1.12	0.22	1.08	0.03	0.14	5	25	<4	13	30.0	4.4	4.8	<1.68	0.80	0.78	<0.12	0.66
1.0x	1.09	0.22	1.03	0.03	0.14	5	29	<4	13	31.1	4.4	4.8	<1.68	0.98	0.90	<0.12	0.80
2.0x	0.96	0.20	0.91	0.02	0.12	<4	23	<4	10	28.6	3.9	4.0	<1.68	0.89	0.82	<0.12	0.77
Significance	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	NS	--	**
BLSD (5%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.24
Contrasts																	
Linear	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	NS	--	**
Quadratic	NS	NS	*	*	*	--	*	--	NS	NS	*	*	--	NS	NS	--	**

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

Table 18. Effect of NutraLime on the elemental composition of seed corn kernel samples, September 1, 1993 - Dakota Co.

Treatment	N	P	K	Mg	Ca	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%				ppm												
0	1.93	0.64	0.80	0.25	78	<4	39	<4	13	30.7	1.5	4.5	<1.68	0.69	0.54	<0.12	0.31
0.5x	1.92	0.61	0.76	0.24	77	<4	37	<4	12	29.9	1.7	4.4	<1.68	0.60	0.53	<0.12	0.69
1.0x	2.02	0.55	0.75	0.22	82	<4	34	<4	11	27.5	1.6	4.1	<1.68	0.70	0.54	<0.12	0.70
2.0x	2.04	0.77	0.94	0.32	93	<4	46	<4	16	39.1	1.8	5.3	<1.68	0.56	0.53	<0.12	0.81
Significance	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	NS	--	**
BLSD (5%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.22
Contrasts																	
Linear	*	NS	NS	NS	NS	--	NS	--	NS	*	NS	NS	--	NS	NS	--	**
Quadratic	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	NS	--	*

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

Table 19. Effect of NutraLime on the elemental composition of corn whole plant samples, July 6, 1993 - Washington county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	3.61	0.41	4.98	5339	2464	113	152	14	77	48.0	7.1	6.3	<1.84	1.78	1.86	0.33	0.58
0.5x	3.51	0.43	4.72	6604	2872	87	131	13	70	44.3	7.6	6.5	<1.97	1.41	1.49	0.36	3.83
1.0x	3.36	0.43	4.75	6422	3032	77	125	10	57	34.8	7.6	6.5	<1.81	1.78	1.94	0.37	5.78
2.0x	3.28	0.45	4.91	6011	2842	76	119	10	50	36.0	7.4	6.5	<1.86	1.46	1.52	0.36	8.65
Significance	*	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	--	NS	NS	NS	**
BLSD (5%)	0.22	--	--	--	--	--	--	--	20	--	--	--	--	--	--	--	3.45
Contrasts																	
Linear	**	NS	NS	NS	NS	NS	*	NS	**	*	NS	NS	--	NS	NS	NS	**
Quadratic	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS

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

Table 20. Effect of NutraLime on the elemental composition of corn ear leaf samples, August 6, 1993 - Washington county.

Treatment	N	P	K	Ca	Mg	S	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%						ppm											
0	2.93	0.34	2.73	0.60	0.22	0.27	19	98	12	74	31.1	6.2	4.6	<1.68	0.48	0.62	<0.14	0.47
0.5x	3.06	0.35	3.11	0.71	0.24	0.27	23	95	20	51	28.2	7.4	5.0	<1.68	<0.46	0.63	0.16	4.35
1.0x	2.84	0.35	2.93	0.74	0.23	0.26	24	96	13	54	28.2	7.8	5.0	<1.68	0.52	0.70	0.19	5.99
2.0x	3.06	0.37	3.08	0.69	0.22	0.28	26	101	18	48	25.9	7.7	5.2	<1.68	0.55	0.75	0.17	9.17
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--	*	--	**
BLSD (5%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.08	--	3.31
Contrasts																		
Linear	NS	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	--	--	**	--	**
Quadratic	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--	NS	--	NS

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

Table 21. Effect of NutraLime on the elemental composition of corn stover samples, October 12, 1993 - Washington county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	0.85	0.07	1.86	0.37	0.17	128	129	10	55	10.8	3.6	3.9	<1.86	0.67	0.79	0.17	<0.33
0.5x	0.95	0.11	2.27	0.48	0.18	231	212	21	40	9.8	4.5	4.5	<1.98	0.90	1.06	0.19	2.64
1.0x	1.00	0.09	2.04	0.52	0.20	133	137	11	46	9.9	4.5	4.4	2.02	0.79	0.85	0.22	3.35
2.0x	1.06	0.10	2.14	0.51	0.20	226	210	17	38	9.6	5.1	4.9	<2.14	1.07	1.32	0.24	5.06
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	--	NS	NS	NS	**
BLSD (5%)	--	--	--	--	--	--	--	--	--	--	0.7	0.5	--	--	--	--	1.80
Contrasts																	
Linear	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	--	NS	NS	*	**
Quadratic	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 22. Effect of NutraLime on the elemental composition of corn cob samples, October 12, 1993 - Washington county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	0.49	0.04	1.22	0.02	0.02	<4	14	<4	11	15.9	2.5	2.1	<1.68	1.13	1.26	<0.12	<0.23
0.5x	0.49	0.04	1.18	0.02	0.01	<4	15	<4	7	10.9	2.3	2.0	<1.68	1.14	1.29	<0.12	0.38
1.0x	0.48	0.04	1.04	0.02	0.01	<4	14	<4	9	11.0	2.6	2.0	<1.68	1.07	1.21	<0.12	0.39
2.0x	0.45	0.05	1.22	0.02	0.01	<4	14	<4	7	8.6	2.3	1.9	<1.68	1.28	1.53	<0.12	0.56
Significance	NS	NS	NS	NS	NS	--	NS	--	*	**	NS	NS	--	NS	NS	--	**
BLSD (5%).	--	--	--	--	--	--	--	--	3	2.9	--	--	--	--	--	--	0.14
Contrasts																	
Linear	NS	NS	NS	NS	NS	--	NS	--	*	**	NS	NS	--	NS	NS	--	**
Quadratic	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	NS	--	NS

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

Table 23. Effect of NutraLime on the elemental composition of corn kernel samples, October 12, 1993 - Washington county.

Treatment	N	P	K	Mg	Ca	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%				ppm												
0	1.35	0.28	0.44	0.12	56	<4	21	<4	8	22.0	1.5	1.7	<1.68	<0.55	<0.31	<0.12	<0.24
0.5x	1.42	0.29	0.42	0.12	50	<4	19	<4	6	18.0	1.3	1.4	<1.68	<0.50	<0.29	<0.12	0.39
1.0x	1.38	0.31	0.45	0.12	55	<4	19	<4	6	18.2	1.4	1.5	<1.68	<0.53	<0.52	<0.12	0.56
2.0x	1.41	0.31	0.45	0.12	56	<4	19	<4	6	18.2	1.7	1.6	<1.78	<0.53	<0.31	<0.12	0.55
Significance	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	--	--	*
BLSD (5%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.19
Contrasts																	
Linear	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	--	--	**
Quadratic	NS	NS	NS	NS	NS	--	NS	--	NS	NS	NS	NS	--	NS	--	--	NS

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

Table 24. Effect of NutraLime on the elemental composition of alfalfa samples, July 12, 1993 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	1.92	0.28	2.47	1.29	0.17	40	63	38	62	31.1	8.2	32.4	<1.79	1.99	0.63	<0.22	<0.57
Lime	2.99	0.33	3.28	0.99	0.23	29	65	53	41	24.8	8.9	19.5	<1.69	1.05	0.62	<0.13	3.23
0.5x	3.25	0.34	3.05	1.27	0.17	24	63	54	34	22.4	8.3	25.0	<1.76	1.19	0.57	<0.14	9.66
1.0x	3.20	0.34	3.06	1.33	0.17	21	62	54	35	22.0	8.6	26.8	<1.68	1.07	0.55	<0.12	13.80
2.0x	2.98	0.32	2.89	1.17	0.15	19	54	60	28	19.6	7.9	24.0	<1.68	0.79	0.49	<0.12	14.05
Significance	**	*	**	NS	*	NS	NS	NS	*	*	NS	*	--	NS	NS	--	**
BLSD (5%)	0.44	0.04	0.26	--	0.04	--	--	--	20	6.5	--	6.0	--	--	--	--	2.67
Contrasts																	
Linear	**	NS	*	NS	NS	*	NS	*	**	**	NS	*	--	*	NS	--	**
Quadratic	**	**	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	--	**
Lime vs 2.0x	NS	NS	**	NS	**	NS	NS	NS	NS	NS	*	NS	--	NS	NS	--	**

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

Table 25. Effect of NutraLime on the elemental composition of alfalfa samples, August 26, 1993 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.62	0.34	3.24	1.17	0.19	41	102	68	76	37.7	10.3	29.0	<1.68	3.74	<0.35	<0.17	0.39
Lime	3.42	0.32	3.54	0.94	0.17	23	74	58	45	27.5	9.1	17.9	<1.68	1.58	<0.30	<0.12	1.59
0.5x	3.37	0.33	3.32	1.19	0.16	19	74	81	43	20.7	8.4	20.6	<1.68	2.17	<0.28	<0.12	4.90
1.0x	3.13	0.32	3.33	1.11	0.14	21	68	70	30	19.5	8.1	23.1	<1.68	1.60	<0.31	<0.12	7.49
2.0x	3.26	0.33	3.36	1.20	0.15	22	76	87	31	19.8	8.4	25.0	<1.68	1.80	<0.33	<0.12	9.01
Significance	**	NS	NS	**	NS	NS	NS	NS	*	**	**	*	--	*	--	--	**
BLSD (5%)	0.21	--	--	0.13	--	--	--	--	31	7.0	0.9	5.5	--	1.53	--	--	2.90
Contrasts																	
Linear	**	NS	NS	NS	*	NS	NS	NS	**	**	**	NS	--	*	--	--	**
Quadratic	**	NS	NS	NS	*	NS	*	NS	*	**	**	*	--	*	--	--	*
Lime vs 2.0x	NS	NS	NS	**	NS	NS	NS	**	NS	*	NS	*	--	NS	--	--	**

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

EFFECTS OF TILLAGE AND LIQUID DAIRY MANURE ON NITROGEN AVAILABILITY TO CORN AND INFILTRATION[1]

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Abstract: The study to determine the influence of tillage and manure application on corn production at the Dale Flueger farm in Goodhue county, MN was continued in 1993. Results from 1993 showed reduced yields and higher moisture contents than the long term average at this site. Annually applied manure produced the greatest yields (83 bu/A) and anhydrous ammonia applied at 180 lb N/A produced 59 bu/A. Biennially applied manure produced 74 bu/A of grain in the year of application and 64 bu/A of grain in the year following application. Triennially applied manure produced 88 bu/A the year of application, 71 bu/A the year after application, and 54 bu/A two years after application. The amount of surface residue left by the various tillage and N treatments and the corn population was similar to previous years. An unusually wet, cool summer, and the late planting date may have been responsible for the low yields.

Introduction

This study is being conducted to determine the long term impacts of tillage and frequency of manure application on corn yield and soil N levels. The Dale Flueger farm is located near Red Wing in Goodhue County, Minnesota. The research plots are on a Seaton silt loam soil. This study began in 1982.

The experimental design is a randomized complete block with tillage main plots (chisel plow and no till) with N source (commercial fertilizer and manure) and N frequency (annual, biennial, and triennially applied manure) subplots. Liquid dairy manure is injected each spring into the chisel plow and no till annual manure plots, and into the biennial manure plots that did not receive manure the previous year. Triennially applied manure plots only receive chisel plowing, and liquid dairy manure is injected at the same time into the plots that did not receive manure over the previous two years. Commercial fertilizer (anhydrous ammonia) was applied about two months after the manure injection. Zero N check treatments are also included in this study. Refer to table 1 for details on N treatments and other cultural practices.

From 1982 to 1986 the manure treatments were split with 0 and 200 lbs/A K_2O treatments, and the commercial fertilizer treatments were split with 0, 200, and 400 lbs/A K_2O treatments. These potassium additions were stopped in 1987, but some data in this report is split by K_2O treatment to check for residual effects of the added potassium.

Results and Discussion

Residue Cover and Corn Population. Residue and population counts were both taken on June 24, 1993. Residue was measured in duplicate in and between the rows for all plots. Population counts were made in duplicate for all plots. A table of significance of treatment effects on residue cover and population is provided in table 3. Residue cover between the row in the no till system resulted in about 62.4% residue cover (Table 2). Residue cover was reduced to 38% between the row in the no till system with the injection of liquid dairy manure. Chisel plowing reduced residue cover to around 20% between the rows for all plots. Plant population was at or near planting rate for all treatments. The row area is defined as the three inches on both sides of the corn plant, between the row is the remaining thirty-two inches.

Grain yields, Moisture, percent N, and N uptake: Biennial study.
The effects of the various annual and biennial treatments on corn grain yields, grain moisture, and grain percent N, can be found in Table 4. Grain yields were dramatically lower than in previous years. The trend of yields were as follows: annual manure>biennial manure in year of application>biennial manure in the year following application>commercial fertilizer. Grain moisture was about 33% lower in 1993 compared to 1992, most likely due to the delayed date of harvesting. Grain percent N was generally around 1.55%, except for biennial manure the year of application which contained only 1.17% N. Grain N uptake can also be found in Table 4, and was similar to grain percent N.

Grain yields, Moisture, and percent N: triennial study.
The effects of the various triennial treatments on corn grain yields, grain moisture, and grain percent N can be found in Table 5. Grain yields, as expected, decreased with each year after N was applied. Triennially applied manure in the year of application produced similar yields and held grain moisture to about the same level as annually applied manure.

[1] Support for this project in part was provided by a USDA-CSRS, LCMR, and the Soil Conservation Service. Their support is greatly appreciated.

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Rainfall Simulation.

Rainfall simulations were run on several plots from 7/6/93 to 8/3/93. The rainfall simulator consisted of a water tank, pump, and panels with hypodermic needles. The water was pumped into the panels at the rate of 100 mm/hour. The runoff and Sediment was collected from a bordered 152 x 90 cm plot into a large cylinder where runoff volume was measured and sediment samples were taken. The infiltration rate, sediment load, and time that runoff began can be found in table 6. Infiltration rate was significantly higher and sediment load was significantly lower for no till than chisel plow. Infiltration rate was also significantly higher for the annual manure treatment than for the annual fertilizer and the check plots. The time to the beginning of runoff showed no significant differences.

Infiltration rates, Organic carbon, and Bulk Density.

Saturated infiltration reading were taken using double ring infiltrometers from 9/23-10/9. Tension infiltrometers were used to take one dimensional tension infiltration readings at -3.5 cm and -7.0 cm tension during this same time period. Unlike the rainfall simulation, chisel plow and annual manure plots had significantly higher saturated infiltration rates than no till and annual fertilizer plots respectively. The difference is believed to be due to the increased formation of a surface crust on the chisel plow plots during rainfall simulation due to the lack of residue cover. Tension infiltrometer readings were not significantly different. Organic carbon samples were taken on 6/24/93 at 0-3 inches and 3-6 inches, and they showed no significant differences between treatments. Bulk density measurements were taken on 8/6/93 at 1-3 inches, 5-7 inches, and 9-11 inches, and they showed chisel plow and annual manure treatments were significantly lower than no till and annual fertilizer treatments respectively. These results can be seen in table 7.

Table 1. 1993 cultural practices at the Flueger farm in Goodhue County, MN.

Soil: Seaton silt loam (mixed, mesic, fine silty Typic hapludalf), well drained, 2 to 12% slope.

Cropping History:

1981-1988	Corn	Pioneer	3906
1989	Corn	Pioneer	3737
1990	Corn	Pioneer	3751
1991	Corn	NK	3624
1992-1993	Corn	Pioneer	3751

Manure Application and Analysis: Liquid dairy manure injected on May 20, 1993.

	1993 rate Mean
Manure (gal/A)	7675
Total N (lbs/A)	300
NH_4 N (lbs/A)	130
Solids (%)	9.0

Fertilizer:

Material	Tillage	N (lbs/A)	Date Applied	Application
82-0-0	Both	180	July 24,1993	Injected
5-14-42	Both	6	June 4,1993	As a starter

Planting and Harvest Information: A four row John Deere Maxi-Emerge planter with two inch fluted coulters was used to plant on June 4, 1993. Corn was harvested on Nov 27, 1993.

Insect control: 5.2 lbs/A Thimet 20G applied June 4, 1993.

Weed Control: .75 lbs/A Prowl and 1.2 lbs/A Bladex 90 DF applied on June 18, 1993.

Table 2. Surface residue cover and population as affected by tillage, N source, and row position at the Flueger farm in Goodhue Co., MN, measured on 6/24/93.

N source AND FREQUENCY	**Row POSITION**	**RESIDUE (%) NO TILL**	**CHISEL**	**Pop. (1000 plants/A) NO TILL**	**CHISEL**
Annual Manure	In	38.0	11.0	27.0	28.4
	Between	62.2	24.3		
Anhydrous Ammonia	In	67.4	12.1	27.9	28.1
	Between	84.2	22.5		
Biennial Manure (yr. of application)	In	29.0	15.7	26.1	28.0
	Between	26.3	18.0		
Biennial Manure (yr after application)	In	59.0	11.7	26.6	27.2
	Between	77.0	21.3		
			Average	**26.9**	**27.9**

Table 3. Significance table for surface residue cover and population at the Flueger Farm in Goodhue Co., MN.

	Till(T)	N treatment(N)	T*N	Row(R)	T*R	N*R	T*N*R
Residue	.000	.000	1.00	.000	.023	.065	1.00
Population	.255	.753	.814	----	----	----	----

Table 4. Grain yield, grain moisture, and grain N percentage as influenced by tillage, N source and frequency and potassium rates at the Flueger farm in Goodhue Co., MN.

N source & freq.	**K_2O lbs/A**	**Grain Yield NoTill**	**Chsl**	**Mean**	**Grain Moisture NoTill**	**Chsl**	**Mean**	**Grain N NoTill**	**Chsl**	**Mean**	**Grain N uptake No Till**	**Chisel**	**Mean**
		------bu/A------			--------%-------			-------%--------			--------lbs/A--------		
Annual	0	67	90	**79**	29.7	25.0	**27.4**	1.40	1.47	**1.44**	44.6	63.0	**53.8**
Manure	200	85	104	**95**	25.2	23.3	**24.3**	1.58	1.52	**1.55**	62.8	74.4	**68.6**
	Mean	**76**	**97**	**87**	**28.5**	**24.1**	**26.3**	**1.49**	**1.50**	**1.50**	**53.7**	**69.7**	**61.2**
Biennial	0	77	80	**79**	27.5	26.1	**26.8**	1.30	1.22	**1.26**	46.0	47.2	**46.6**
Manure	200	51	88	**70**	29.7	21.5	**25.6**	1.14	1.02	**1.08**	27.3	43.0	**35.2**
(yr of)	**Mean**	**64**	**84**	**74**	**28.6**	**23.8**	**26.2**	**1.22**	**1.12**	**1.17**	**36.7**	**45.1**	**40.9**
Biennial	0	57	78	**68**	33.2	26.1	**29.7**	1.54	1.53	**1.54**	41.6	56.7	**49.2**
Manure	200	54	72	**63**	31.7	21.5	**26.6**	1.62	1.38	**1.50**	41.6	47.0	**44.3**
(yr after)	**Mean**	**56**	**75**	**66**	**32.5**	**24.2**	**28.3**	**1.58**	**1.46**	**1.52**	**41.6**	**51.9**	**46.7**
Anhydrous	0	41	72	**57**	33.2	22.6	27.9	1.55	1.57	**1.56**	30.9	53.6	**42.3**
Ammonia	200	51	67	**59**	28.8	25.3	**27.1**	1.61	1.63	**1.62**	38.9	51.4	**45.2**
	400	51	75	**63**	29.7	21.9	**25.8**	1.63	1.60	**1.62**	38.7	56.7	**47.7**
	Mean	**48**	**71**	**60**	**30.6**	**23.3**	**27.0**	**1.60**	**1.60**	**1.60**	**36.2**	**53.9**	**45.1**
Overall Mean		**61**	**82**	**72**	**30.1**	**23.9**	**27.0**	**1.47**	**1.42**	**1.45**	**42.1**	**55.2**	**48.6**
Check (0 N)[1]		37	55	**46**	31.5	27.3	**29.4**	1.21	1.21	**1.21**	20.8	31.2	**26.0**

	Till(T)	N source(N)	T*N	K rate(K)	K*T	K*N	K*N*T
Grain Yield	.076	.001	.900	.687	.851	.375	.333
Grain Moisture	.122	.385	.757	.357	.860	.880	.299
Grain N %	.492	.000	.469	.727	.250	.017	.609
N uptake	.167	.000	.339	.703	.986	.129	.670

[1] Check plots not included in the statistical analysis.

Table 5. Grain yields, percent moisture, and N percentage at harvest for triennially applied manure with chisel plowing system at the Flueger farm in Goodhue Co., MN.

Year of manure Application	**K_2O** lbs/A	**Grain Yield** ---bu/A----	**Grain Moisture** ------%-----	**Grain N** ---%---	**N Uptake** --lbs/a--
First Year	0	88	24.8	1.09	45.4
	200	88	22.8	1.09	45.4
	Mean	**88**	**23.8**	**1.09**	**45.4**
Second Year	0	73	24.7	1.43	49.4
	200	69	23.6	1.35	44.1
	Mean	**71**	**24.2**	**1.39**	**46.7**
Third Year	0	60	27.7	1.28	36.3
	200	49	28.0	1.15	26.7
	Mean	**55**	**27.9**	**1.22**	**31.8**

Table 6. Infiltration rates, sediments, and time to beginning of runoff for rainfall simulation at the Flueger farm in Goodhue, Co., MN, measured 7/6/93 through 8/3/93.

Nsource	**Inf. rate**			**Sediments**			**Time to runoff**		
	Notill	Chisel	Mean	Notill	Chisel	Mean	Notill	Chisel	Mean
	--------mm/hr-----			-------T/ha-------			--------min-------		
Annual manure	58.0	20.3	**39.2**	2.6	15.4	**9.0**	16.2	11.2	**13.7**
Fertilizer	33.9	11.3	**22.6**	.8	11.2	**6.0**	12.5	5.8	**9.2**
Check	20.3	19.9	**20.1**	5.9	6.8	**6.4**	9.0	6.2	**7.6**
Mean	**37.4**	**17.2**	**27.3**	**3.1**	**11.1**	**7.1**	**12.6**	**7.7**	**10.2**

	Till(T)	Nsource(N)	T*N
Inf. Rate	.031	.073	.337
Sediments	.035	.672	.267
Time to Runoff	.132	.176	.267

Table 7. Infiltration rates (taken 9/23 through 10/9), organic carbon (taken 6/24), and bulk density measurements (taken 8/6) at the Flueger farm in Goodhue Co., MN.

Nsource & freq.	Inf. Rate									Organic Carbon					
	SAT			-3.5			-7.0			0-3 in			3-6 in		
	Notil	Chsl	Mean	Notil	Chsl	Mean	Notil	Chsl	Mean	Notil	Chsl	Mean	Notil	Chsl	Mean
	mm/hr									%					
Annual manure	293	587	**440**	61	137	**99**	31	12	**22**	1.47	1.67	**1.57**	1.20	1.33	**1.27**
Fertilizer	139	293	**216**	25	84	**55**	8	18	**13**	1.57	1.57	**1.57**	1.43	1.30	**1.37**
Check	180	392	**286**	49	28	**39**	6	19	**13**	1.37	1.27	**1.32**	1.00	1.17	**1.09**
Mean	**204**	**424**	**314**	**45**	**83**	**64**	**15**	**16**	**16**	**1.47**	**1.50**	**1.49**	**1.21**	**1.27**	**1.24**

	Bulk Density											
	1-3 in			5-7 in			9-11 in			1-11 in		
	Notil	Chsl	Mean	Notil	Chsl	Mean	Notil	Chsl	Mean	Notil	Chsl	Mean
	Mg/m^3											
Annual manure	1.32	1.41	**1.37**	1.44	1.32	**1.38**	1.53	1.46	**1.50**	1.43	1.39	**1.41**
Fertilizer	1.59	1.28	**1.44**	1.49	1.40	**1.45**	1.57	1.50	**1.54**	1.55	1.39	**1.47**
Check	1.47	1.41	**1.44**	1.46	1.33	**1.40**	1.54	1.51	**1.53**	1.49	1.42	**1.46**
Mean	**1.46**	**1.37**	**1.42**	**1.46**	**1.35**	**1.41**	**1.55**	**1.49**	**1.52**	**1.49**	**1.40**	**1.45**

	Till(T)	Nsource(N)	T*N	Depth(D)	D*T	D*N	D*T*N
Saturated	.057	.042	.652	----	---	---	----
-3.5 cm	.305	.144	.241	----	---	---	----
-7.0 cm	.794	.500	.171	----	---	---	----
Organic C.	.661	.108	.621	.002	.864	.811	.415
Bulk Density	.039	.053	.001	.000	.449	.756	.009

TILLAGE COMPARISON AT ROSEMOUNT, 1993[1]

T.L Hansmeyer, D.R. Linden, K.L. Walters,
R.H. Dowdy, R.R. Allmaras and C.E. Clapp[2]

ABSTRACT: A long term tillage system study was initiated at Rosemount in 1991. Four tillage systems including Conventional Tillage, Conservation Tillage, Ridge Tillage, and Minimum Tillage are used in a continuous corn and corn/soybean rotation. Nitrogen inputs remained constant across all plots planted to corn with no nitrogen applied to plots in soybeans. The objectives of the study are to determine the long term effects of various cropping systems on herbicide movement, earthworm activity, grain yield, nutrient availability and nutrient uptake. Though it is too early in the study to examine the differences in many of the objectives, grain yields and surface residue have proven to be significantly different in various tillage and rotation comparisons.

Site An 18 acre site at the Rosemount Agricultural Experiment Station was chosen for study. The dominant soil type is a Waukegon silt loam (Typic Hapludoll) which has 20 to 32 inches of silt loam overlying calcareous sand and gravel with a slope of less than 2%. The site was grid sampled for elevations and depth to gravel prior to plot layout.

Experimental Procedure The site was separated into 36 plots of 0.4 acre each. A continuous corn (CC),corn/soybean (CS) [corn 1993], and soybean/corn (SC) [soybean 1993] rotations were planted into four tillage systems in a randomized complete block design with three replications. The four tillage systems are described as follows:

CONVENTIONAL (T1):
Fall moldboard plow following corn and fall chisel plow following soybeans. Disk or field cultivate to prepare seedbed. One or two cultivations after planting as needed.

CONSERVATION (T2):
Fall chisel plow following corn with no fall tillage following soybeans. Disk and/or field cultivate to prepare seedbed for soybean. Corn is no-tilled into soybean stubble. One or two cultivations after planting as needed.

RIDGE-TILL (T3):
No fall tillage following corn or soybeans (stalks chopped in the fall following corn harvest). Planting done in ridges formed by previous cultivation. Two cultivations following planting to control weeds and reestablish ridges.

MINIMIZED (TACTICAL) TILLAGE (T4):
Generally, no primary or secondary tillage is prescheduled. Tillage will be performed only when soil or weed conditions require attention. Cultivation performed only when determined necessary.

Prepared seedbed by discing all Conventional and the CC and SC rotations of Conservation tillage plots. Corn (Pioneer 3751) was planted in the CC and CS plots across all tillage systems on May 14. The seeds were planted at a population of 26,000 seeds/acre. Force insecticide was banded over the row at a rate of 9 oz./1000 ft of row. Corn and soybean emergence was counted from two 20' sections of row of each plot periodically throughout the first 5 weeks after planting. Alachlor (Lasso) was broadcast at a rate of 2 qt product/acre on all CC and CS plots May 16. Soybeans (Hodgsen 78) were planted into the SC plots on June 4. All soybeans were planted at the rate of 60 lbs/acre. Alachlor (Lasso) was broadcast at the rate of 2 qt product/ac on all SC plots June 11. A photo slide of the surface residue was taken directly after planting. The developed slide is then projected onto a grid. Residue intersecting the grid lines are counted toward the percent residue coverage. Rotary hoed all T1 and T3 corn plots and the CC rotation of T2 tillage plots on June 12. Applied 2 pt product/acre of bentazon (Basagran) to all corn plots June 15. All soybean plots received 4 oz. product/acre of imazethapyr (Pursuit). A 28% solution of Nitrogen at 150 lbs N/acre was applied during the first cultivation on all CC and CS plots June 25. All CC and CS plots were cultivated and ridged in the T4 tillage treatment July 15. Cultivated all SC plots in the T4 tillage system July 15. Cultivated all soybean plots including T4 on July 27. Created ridges in all ridge-till (T3) plots planted to soybeans on August 2. Observed and recorded stands during the season and recorded final plant populations in all plots on Oct. 8.

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[1]This project was supported by the University of Minnesota Agricultural Experiment Station at Rosemount and the USDA-ARS Soil and Water Unit in St. Paul.

[2] T.L. Hansmeyer, D.R. Linden, R.H. Dowdy, R.R. Allmaras and C.E. Clapp are Ag. Research Technician, Soil Scientist, Soil Scientist, Soil Scientist and Research Chemist of the USDA-ARS, St. Paul MN. K.L. Walters is Director of the Agriculture Experiment Station at Rosemount.

Harvested (by combine) 8 center rows in all soybean plots Oct. 13. Harvested (by combine) 12 center rows in all corn plots Nov. 3. Corn stalks chopped and fall tillage performed Nov. 13-16.

RESULTS

Yield Grain yields and moistures from all tillages and rotations are given in figures 1-3 and table 1.

Within the continuous corn system, grain yields from the conventional till plots out-yielded all other tillages followed by ridge-till, conservation and minimum-till in that order. Statistically, the yields were not significantly different between any of the tillages (fig. 1). The two year average yields under the continuous corn rotation are also presented in table 1. The two year average yield puts ridge-till ahead of all other tillage systems followed by Conventional, Conservation and Minimum-till, respectively.

As with the yields under continuous corn, the corn/soybean rotation created the same yield rank when comparing the 4 tillage systems in 1993 and the two year average. Conventional tillage yielded the highest followed by Ridge-till, Conservation and then Minimum-till. Corn grain yields under these tillage systems for the Soybean/Corn rotation were not significantly different (Fig 2). The 1993 soybean yields in the corn/soybean rotation created a different yield rank with Conventional having the highest yield followed by Conservation, Ridge-till and Minimum-till, respectively (Fig 3). For soybeans, as with the previous cropping systems, no significant yield difference exists between tillages. The two year average shows the same yield rank as 1993.

The mean yield (which includes both crops) for each tillage indicates that Conventional tillage produced the highest yield followed by ridge-till, conservation and minimum-till, respectively. The grain yields from both ridge and conventional tillage systems are significantly higher than the yields from minimum-till (fig. 5). Also, the mean corn grain yields in 1993 indicate that the corn/soybean rotation with a mean yield of 110 bu/ac had a higher yield than continuous corn (CC) at 100 bu/ac (fig. 4).

Residue Residue cover after planting is shown in fig. 5. As expected, both Conservation and Minimum-till provide sufficient corn and soybean residue to qualify for the requirements for erosion control, where residue must provide at least 30% coverage after planting. It must be noted that in the conservation tillage plots, corn is no-tilled into the previous years soybean stubble, leaving the soybean stubble on the surface. Ridge-till provided sufficient residue to qualify under the continuous corn rotation, but only produced 28% residue cover under the corn/soybean rotation. Ridge-till buried a majority of the soybean stubble under the soybean/corn rotation leaving only 21% surface residue. A conventional tillage system did not provide enough surface residue to qualify for the residue requirements. Since the soybean plots in conventional tillage are chisel plowed in the fall, one might expect at least 30% residue cover. However, the fall chisel plowed soybean plots only produced 12% residue cover at planting.

Emergence Corn seed emergence varied in the cropping systems presumably due to spring soil moisture and temperatures. Figure 6 depicts three types of corn emergence trends. Conventional (CC), Conventional (CS) and Ridge-till (CS) cropping systems favored quick emergence of the corn seedlings with 50% of the total number of seeds emerging within 14 days (Type 1 Fig. 6). Conservation (CC), Conservation (CS), Ridge-till (CC) and Minimum-till (CS) cropping systems had 10 to 20% of the corn seeds emerged at day 14 (Type 2 Fig. 6). The third trend, represented by Minimum-till had the slowest emergence. After 14 days only 5% of the seeds had emerged. After 18 days and 70% emergence all trends begin to merge except for Minimum-till (CC) which lagged behind at 15% emergence.

The large difference in emergence found for corn does not exist under the soybean cropping systems (Fig. 7). Conventional and Conservation tillages have similar soybean seed emergence of 67-69% after 10 days. Seed emergence in Minimum-till equaled 60% after 10 days. The emergence under ridge-till was the lowest at 45% at 10 days. All soybean emergence trends begin to merge at day 14.

Weeds Weed populations in all corn plots except those planted no-till were compared between rotary hoeing and no rotary hoe (Fig. 8). The plots were randomly split with half receiving one pass with a rotary hoe and the other half receiving no rotary hoe. Rotary hoeing was most successful under Conventional (CC) Conventional (CS) and Conservation (CC) tillage treatments reducing the total weed population by 35ft^2, 23ft^2, and 74ft^2 respectively.

Fig. 1

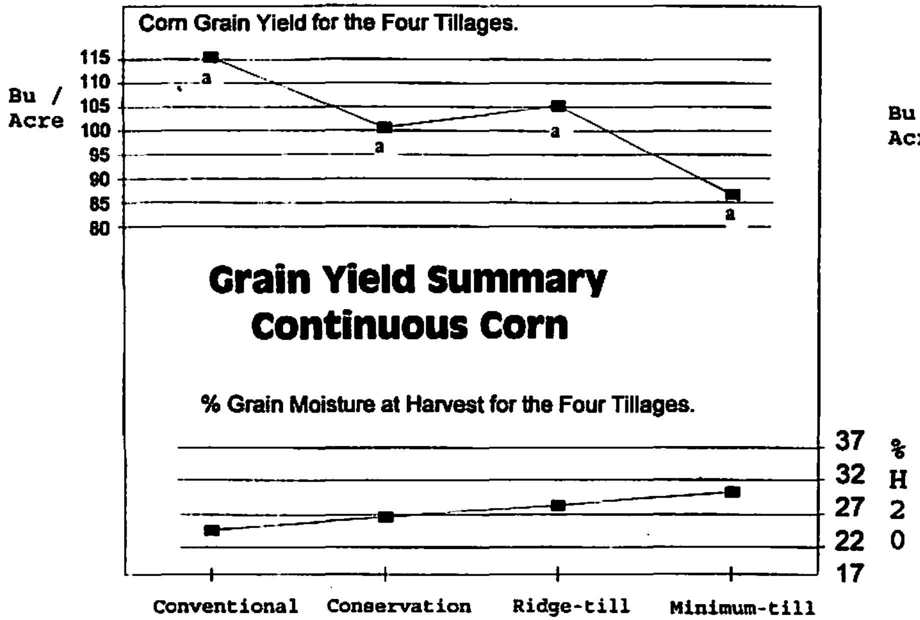


Fig. 2

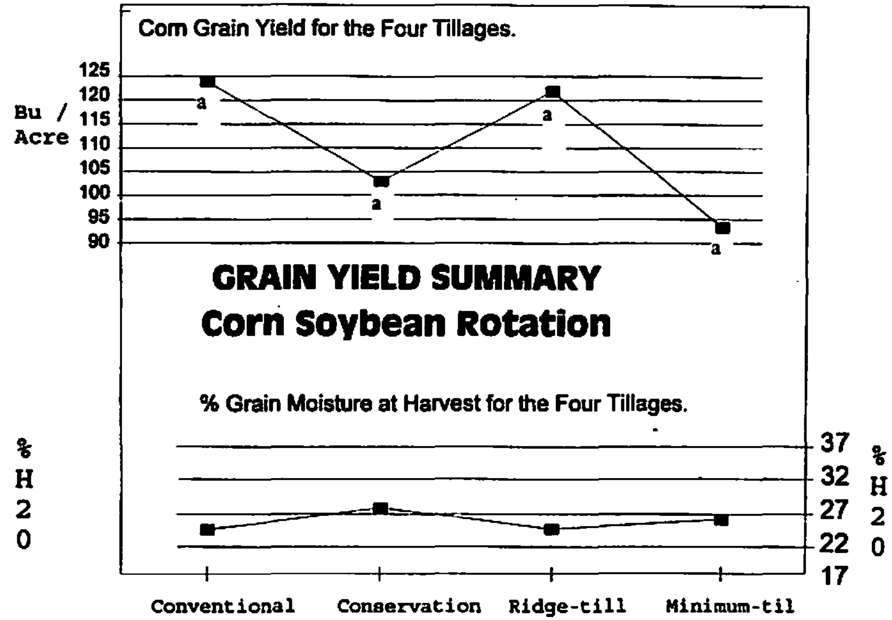
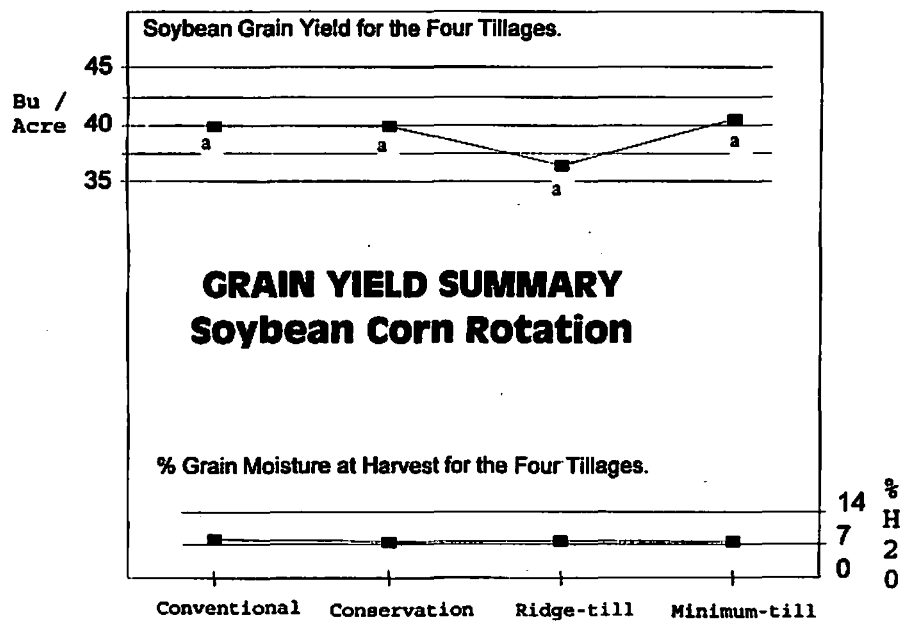
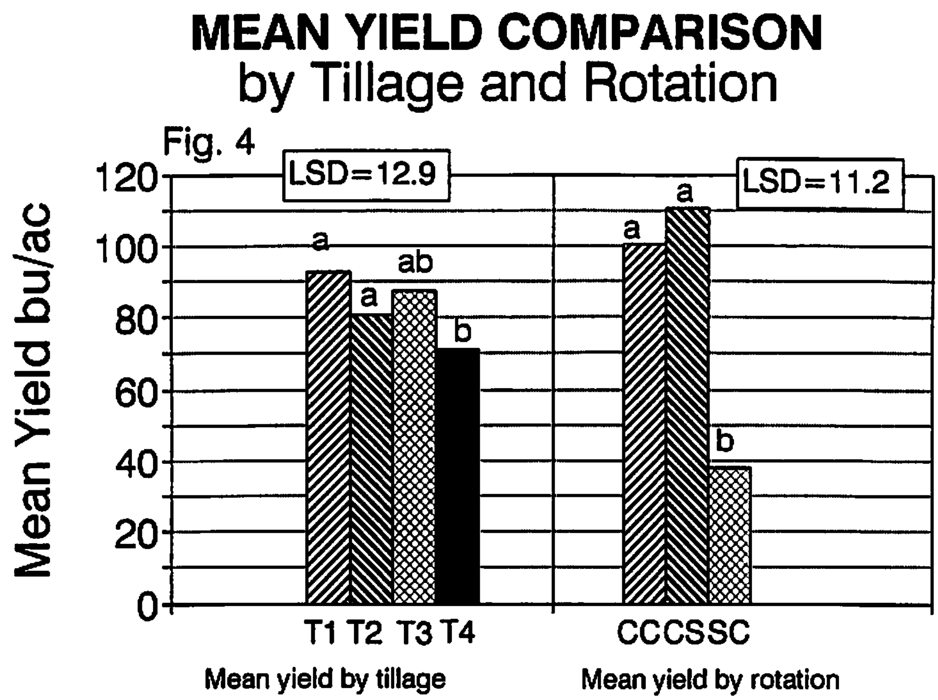
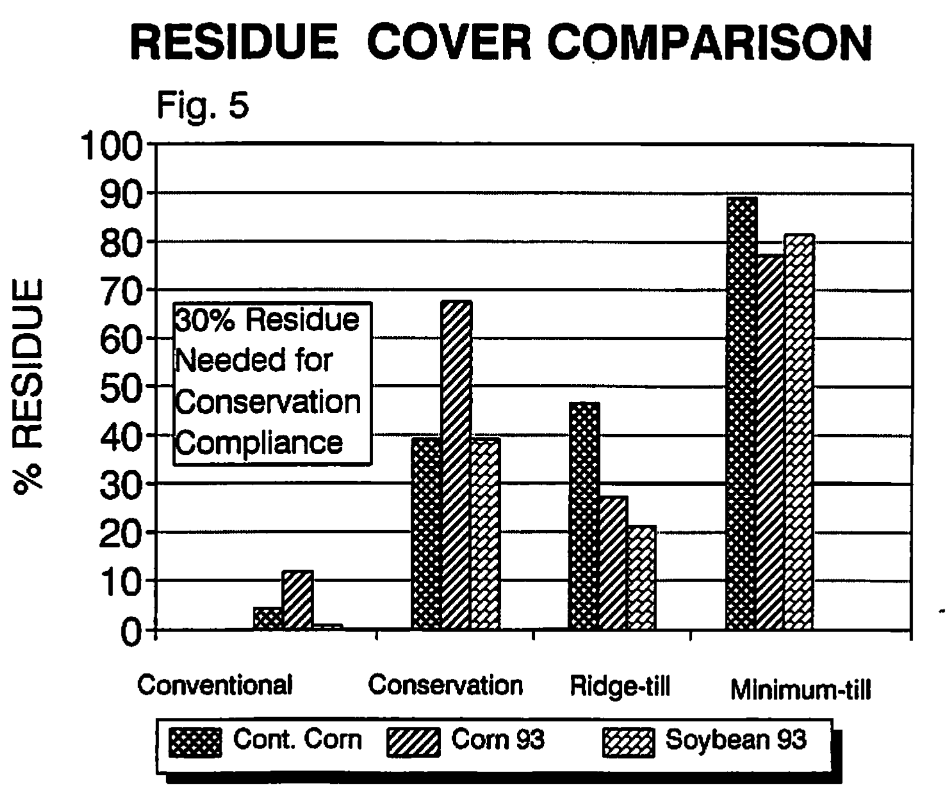


Fig. 3




MEAN YIELD COMPARISON
by Tillage and Rotation
Fig. 4
LSD=12.9
LSD=11.2
Mean Yield bu/ac
120
100
80
60
40
20
0
a
a
ab
b
a
a
b
T1 T2 T3 T4
CCCSSC
Mean yield by tillage
Mean yield by rotation


RESIDUE COVER COMPARISON
Fig. 5
% RESIDUE
100
90
80
70
60
50
40
30
20
10
0
30% Residue Needed for Conservation Compliance
Conventional
Conservation
Ridge-till
Minimum-till
Cont. Corn
Corn 93
Soybean 93

1993 Corn Emergence
Tillage and Rotation Comparison

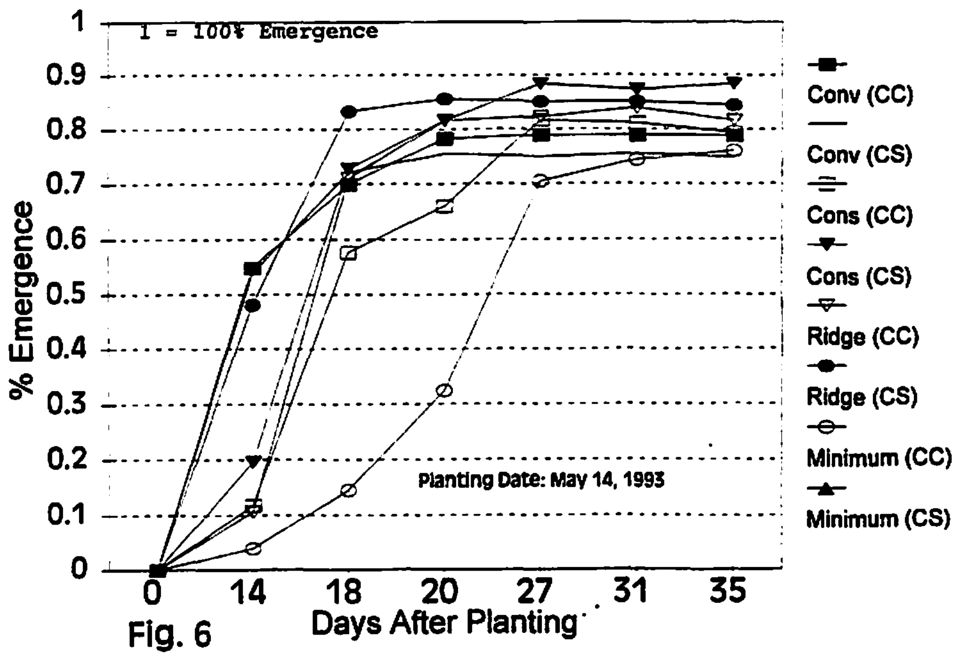


Fig. 6

1993 Soybean Emergence
Tillage and Rotation Comparison

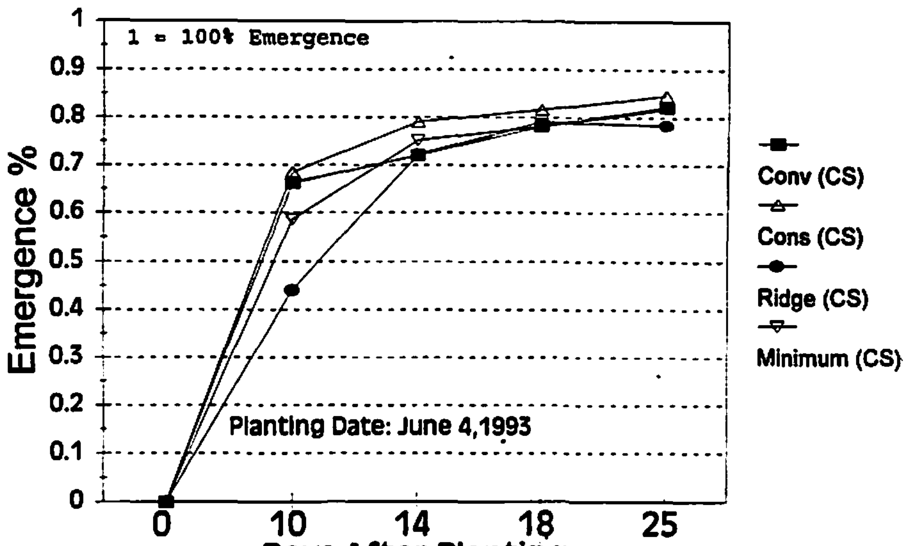


Fig. 7

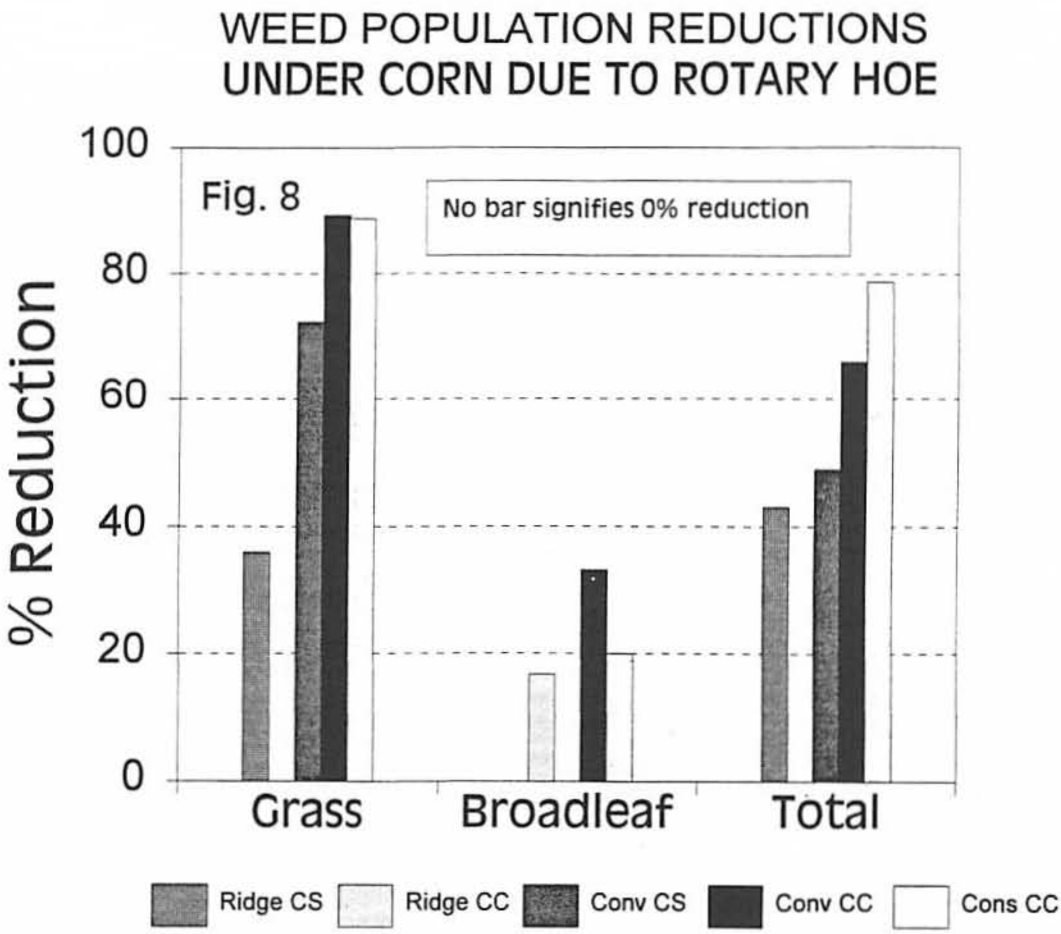


Table 1 Grain yields for the tillage study at Rosemount Study, 1993.

Treatment		Grain Yield			
Tillage	Rotation	1993 bu/ac	1993 mt/ha	92/93 avg. bu/ac	92/93 avg. mt/ha
Conventional (T1)	Cont.Corn	114.2	6.05	118.1	6.27
	Corn/Soy	123.9	6.57	138.0	7.33
	Soy/Corn	39.9	2.33	40.5	2.36
Conservation (T2)	Cont.Corn	99.2	5.26	102.6	5.44
	Corn/Soy	102.8	5.45	122.9	6.52
	Soy/Corn	39.9	2.33	40.5	2.36
Ridge-Till (T3)	Cont.Corn	104.0	5.51	121.0	6.42
	Corn/Soy	121.9	6.46	137.5	7.30
	Soy/Corn	36.4	2.13	37.2	2.18
Minimum-Till (T4)	Cont.Corn	85.1	4.51	93.1	4.93
	Corn/Soy	93.2	5.67	119.1	6.68
	Soy/Corn	40.5	2.37	38.8	2.28

THE EFFECT OF TILLAGE SYSTEM AND SOIL TYPE ON THE YIELD OF CORN AND SOYBEANS ON SOILS DEVELOPED IN GLACIAL TILL[1].

J.F. Moncrief, D.D. Breitbach, T.M. Coffman
J.R. Jirik, M.F. Taylor, D.F. Preisler, and P.M. Bongard[2]

Four tillage systems (moldboard and chisel plowing, subsoiling, and no till systems) were evaluated for corn and soybean production from 1989 to 1993 on poorly drained soils developed in glacial till. Corn yields were reduced in one year out of three when grown under no till conditions. Other systems resulted in similar corn grain yields. Soybean yields were reduced with crop residue management systems in both years (1990 and 1992) of the study. There was no interaction between soil type and tillage on corn grain yields in 1993.

A tillage demonstration was initiated in Rice County, MN in 1989 to evaluate the effect of tillage (moldboard and chisel plowing, subsoiling, and no till systems) on the yield of corn and soybeans. Plots were 12 rows wide and about 400 feet long. The plots were located on a side slope with the Kilkenny B slope soil near the top, the Kilkenny C slope soil in the middle, and the Hamel A slope soil at the bottom. The crop sequence is a corn-soybean rotation. Moldboard and chisel plowing as well as subsoiling was done in the fall. The planter was equipped with rolling spiked wheel type row cleaners.

Average soil cover estimates are shown in table 1. Cover with soybean residue is marginal for erosion control with all tillage systems except the no till. Soil cover with corn residue was adequate with all systems except the moldboard.

Corn yield was estimated be taking the center six rows of each plot with a combine. Corn yields were similar in 1989 and 1993 (table 3). In 1991 they were reduced 20 bushels per acre when grown with no tillage. This resulted in an average reduction of 5 bushels per acre with the no till system over the three year study period. The other tillage systems evaluated resulted in similar corn grain yields.

Soybean yields are shown in table 3. In both soybean years of the study moldboard plowing resulted in significantly higher yields than the other systems evaluated (on average, from 6 to 11 bushels per acre higher. Soybeans grown under no till conditions were lower than other systems evaluated. This is in contrast to the performance of no till grown soybeans in dryer years.

In 1994 corn yields were estimated by hand picking two 20 ft. rows in each soil type within each tillage plot to evaluate the possible interaction of tillage and soil type. There was no interaction between tillage and soil type in 1993 for corn grain moisture or yields (table 5). Soil type did affect corn grain yields. The Hammel and Kilkenny C slope soils resulted in a 20 to 30 bushel lower grain yields than the Kilkenny B slope soil. Consistent with the combine yield estimates there was no effect of tillage on grain yields due to tillage. Hand picked corn yields were about 10 percent higher than the combine estimates.

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[1] This project was jointly supported by the Soil Conservation Service and the Minnesota Extension Service.

[2] J.F. Moncrief is an Extension Specialist in the Soil Science Department at the University of MN, St. Paul, MN. D.D. Breitbach, T.M. Coffman, J.R. Jirik, and M.F. Taylor are the State Agronomist, St. Paul, MN and District Conservationists in Rice, Waseca, and Le Seur Counties, MN respectively. D.F. Preisler is the Extension Educator in Le Seur County, MN. P.M. Bongard is a free lance data processor.

Table 1. Cultural practices used at the tillage demonstration at the Dave Judd Farm, Rice County, MN, 1989 - 1993.

	1989	1990	1991
Primary tillage			
Moldboard	White 18"-7 bottom	J.D. 5 bottom	White 18"-5 bottom
Chisel plow	2"straight shank	9 shank Case coulter with 4" twists	Mohawk straight point
V-Rip	J.D. 5 shank 30" spacing	same	same
Date	10/18/88	10/10/89	10/5/90
Secondary tillage			
Field cultivator (John Deere)	May 10	April 19	June 8 (also disked)
Planting			
Date	May 11	May 8	June 8
Variety	Pioneer 3737	Hardin	Pioneer 3737
Rate	23,700 seeds/A	57 lb/A	26,200 seeds/A
Planter	12-row J.D.7100 MaxEmerge with trash whippers	same	
Fertilizer			
Anhydrous Amm.	160 lb. AA/A (April 21)	-	160 lb N/A with N-serve (November, 1990)
10-34-0	15 gal/A at planting	8 gal/A at planting	- -
9-23-30	-	-	200 lb/A at planting
Weed control			
Herbicide	Ranger (3 pt/A) (May 3) Tandem (1.5 pt/A) & Extrazine (2.2 lb/A) (May 23)	Basagran (1 pt/A) with 1 qt. COC & 1 qt. 28% (May 29)	Gramoxone (1.5 pt/A) (June 7) Banvel (1 pt/A) (June 18) Accent (.66 oz/A) (June 28 no-till only)
Cultivation	June 12	July 2	June 27 (except no-till)
Harvest			
Date	October 6	October 2	October 22
Rainfall	April-September	April-October	April-September
Inches	9.45	24.26	25.11

	1992	1993
Primary tillage		
Moldboard	J.D. 5 bottom	none
Chisel plow	13 ' J.D. 3" twisted shank	none
V-Rip	J.D. 5 shank	none
Date	10/31/91	-
Secondary tillage		
Field cultivator	May 8 (2x except no-till)	May 21 (except no-till)
Planting		
Date	May 8	May 21
Variety	Sturdy	Pioneer 3751
Rate	62 lb/A	29,700 seeds/A
Planter	12-row JD 7100	12-row JD 7100 w/ Yetter trash whippers
Fertilizer		
10-34-0	-	8 gal/A at planting
28% N	-	140 lb N/A (sidedressed June 28)
Weed control		
Herbicide	Pursuit (4 oz/A) w/ COC & 28% (June 6)	Dual (2.8 pt/A) & Marksman (3 pt/A) (May 26)
Cultivation	June 27	-
Harvest Date	October 15	November 4
Rainfall	April-October	April-October
Inches	20.83	26.4

Table 2. Effect of tillage on surface residue cover after planting at the Dave Judd Farm, Faribault.

			Tillage[2]			
		Previous	Mld	Ch	Sb	NT
Year	Crop	Crop	--% cover--			
1989	Corn	Soybeans	2	10	10	25
1990	Soybeans	Corn	5	31	31	72
1991	Corn	Soybeans	2	4	5	44
1992	Soybeans	Corn	12	43	44	85
1993[1]	Corn	Soybeans	16	28	27	54
Avg.	Corn	Soybeans	2	7	8	41
	Soybeans	Corn	8	37	38	78

1. No fall tillage performed in 1992; plots were field cultivated the following spring (except no-till plots).
2. Tillage: Mld-fall moldboard plowed, Ch-fall chisel plowed, fall Sb-subsoiled, NT-no till.

Table 3. Effect of tillage on corn yields at the Judd Farm, Faribault.

	1989	1991	1993	Avg.
	-----bu/A-----			
Moldboard	141.1a[1]	98.9a	107.6a	115.9
V-Rip	139.9a	97.4a	106.7a	114.7
Chisel	142.7a	97.2a	107.6a	115.8
No-till	141.5a	79.1b	108.2a	109.6
Pr>F	0.67	0.0002	0.77	

1. Yields followed by the same letter in the same group are not significantly different at the 0.10 level.

Table 4. Effect of tillage on soybean yields at the Judd Farm, Rice County, MN.

Tillage	1990	1992	Avg.
	-----bu/A-----		
Moldboard	47.0a[1]	53.1a	50.0
V-Rip	42.9b	45.6b	44.2
Chisel	40.2bc	45.2b	42.7
No-till	38.2c	39.7b	39.0
Pr>F	0.004	0.028	

1. Yields followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 5. Effect of tillage and soil type on hand-harvested corn yields at the Dave Judd demonstration site, Rice Co., November 4, 1993.

Tillage	Soil Type	Moisture	Yield
		---%---	--Bu/a--
Moldboard	Kilkenny B	38.8fg[1]	134.4a
	Kilkenny C	42.3cde	103.4cde
	Hamel	45.6a	82.1e
V-Rip	Kilkenny B	37.8g	129.6ab
	Kilkenny C	41.4def	122.1abcd
	Hamel	45.4ab	101.2de
Chisel	Kilkenny B	41.1ef	129.6ab
	Kilkenny C	44.2abc	102.9cde
	Hamel	43.4abcd	109.0bcd
No-till	Kilkenny B	40.2efg	126.7abc
	Kilkenny C	45.1ab	118.2abcd
	Hamel	42.8bcde	108.3bcd
Soil type			
Kilkenny B		39.5b	130.0a
Kilkenny C		43.3a	111.6b
Hamel		44.3a	100.1b
Tillage			
Moldboard		42.7	117.8
Chisel		41.5	117.6
V rip		42.9	113.8
No till		42.3	106.6
Pr>F Soil		0.0006	0.032
Tillage		0.63	0.22
Tillage*Soil type		0.12	0.76

1. Data followed by the same letter in the same column group are not significantly different at the .10 level.

INTEGRATION OF MANURE AND ALFALFA N SOURCES INTO RESIDUE MANAGEMENT SYSTEMS FOR KARST AREAS OF MN[1]

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Seven studies on five farms in southeastern Minnesota were used to evaluate integration of manure into residue management systems. Aspect and timing of alfalfa kill dramatically affected no till corn growth and yield. There were relatively small differences in early growth and development of both corn and soybeans under high residue systems. The growth delay persisted through flowering and physiological maturity. Yield differences due to N source and tillage were variable.

This study was initiated in the spring of 1993 to evaluate manure utilization strategies within residue management systems in southeastern MN. Farmer cooperators were identified in five counties in the karst area of MN. Each demonstration was tailored to fit within the project guidelines and also address particular farmer interests. Residue management systems are the convention in this part of the state due to the erosive nature of the soils.

Daryl Highum Farm

Treatments at this site are tillage and N source. Tillage systems evaluated are chisel plowing followed by discing and a no till approach. Nitrogen sources are anhydrous ammonia and liquid hog manure. Manure application was made in the spring followed by tillage and planting. Anhydrous ammonia was applied side dress June 15. The results from this demonstration is presented in tables 1a-1g. Back ground information for is shown in table 1a.

The manure source at this site has a high concentration of N. As is characteristic of hog manure more of the nitrogen was in the ammonium form (60 vs 40% for mineral and organic respectively). Manure and anhydrous ammonia were applied at very similar rates.

Corn planted with only a fluted coulters resulted in a delay of the emergence rate and .3 leaves per plant in development (table 1b. Final stands were similar and at adequate levels. The delay in growth was the result of 3% vs 10% soil cover in the row with soybean residue (table 1c). Soil cover between the row was 6% and 20% for the chisel and no till systems respectively. Corn plants grown with the no till system tasseled and silked slightly later than with chisel plowing (table 1d).

Anhydrous ammonia resulted in higher levels of late season ammonium (table 1e). Total soil mineral N levels were similar between N sources and tillage, however. Soil nitrate was concentrated in the top foot of soil (table 1f). Soil mineral N in the row was inversely correlated with early growth (table 1g).
Although corn phenology was affected by tillage and N source, differences were small and grain moisture was not affected (table 1h). Yields were relatively high and there was no affect of tillage or N source on grain yields. Grain N concentrations were higher with chisel plowing and the anhydrous ammonia source. This is consistent with other research.

Dan Graskamp Farm

Two rates of N as liquid hog manure were compared to anhydrous ammonia. The design is a randomized complete block with split plots. Main plots at this site were nitrogen source and rate. Subplots were row cultivation. Corn following soybeans was the test crop.

N source did not affect corn stands (table 2b). Row cultivation reduced stands by about 1,000 plants per acre. Soil cover with soybean residue was low. Cultivation reduced soil cover.

The high rate of manure increased the development of corn by about .2 leaves per plant. This affect carried through to silk emergence (table 2c).

The dominant weed at this site was wirestem muhly followed by velvet leaf. Horse tail numbers were reduced with cultivation by other species were not affected (tables 1d and e).

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[1] This study is supported by the Legislative Commission on Minnesota Resources the Minnesota Extension Service, and the Soil Conservation Service. Their support is greatly appreciated.

[2] J.F. Moncrief and B.J. Johnson are Extension Soil Scientist and Assistant Scientist respectively; B.A. Christensen, J.A. Tesmer, N.R. Broadwater, C.R. Schwartau, T.L. Wagar, P.M. Bongard, are Extension Educators; C.G. Eide is an udergraduate research assistant.

Soil ammonium and nitrate were similar between the low rate of manure and anhydrous ammonia. The high rate of manure increased mineral nitrogen concentrations in the row slightly and doubled concentrations between the row (table 2f). As expected, anhydrous ammonia, although applied at two thirds of the ammonium rate of the low rate of manure resulted in higher concentrations of late season ammonium due to the self inhibition of nitrification of this N source.

The manure N source resulted in a small but statistically significant increase in grain yields (3-5 bu/acre, table 2h). The low rate of manure and anhydrous ammonia (158 and 80 lbs N/acre, respectively) resulted in similar grain N concentrations. The high rate of manure (358 lbs N/acre) increased grain N significantly (table 2i).

Tony and Walter Hammel Farm

At this site corn was grown following alfalfa with a no till system. The treatments evaluated include: fall vs spring killed alfalfa; and north and south aspect. The design is a randomized complete block with timing main plots and aspect subplots. Data from this site are presented in tables 3a-k.

The time of the year that alfalfa was killed with herbicides did not affect corn stands (table 3b). Aspect and timing did affect early corn growth however (.2 and .6 leaves respectively). Spring killed alfalfa and northern aspect reduced growth.

Before row cultivation spring killed alfalfa resulted in about a 10% increase in soil cover (table 3c). Soil cover was not affected by aspect. After row cultivation soil cover was much reduced and northern aspect had slightly lower soil cover.

There was an interaction between aspect and timing of alfalfa kill on phenology later in the season (tassel and silk emergence, table 3d). Aspect was more important on spring killed alfalfa than fall killed.

Treatments did not affect weeds present in the row (table 3e). Between the row there was more foxtail and alfalfa with the spring killed alfalfa treatment (table 3f).

There was no affect of treatments on late season soil mineral nitrogen (table 3h).

Soils ranged in thickness from 32 to >69 inches (table 3j). The surface texture is silt loam with argillic horizons below.

Aspect affected grain moisture 4.1% at harvest. Earlier differences in development were greater at harvest due to aspect. Time of alfalfa kill resulted in a difference in grain moisture at harvest of 2.7%. This trend was opposite of the earlier affects of aspect and timing.

Fall killed alfalfa sod resulted in a yield increase of 30 bushels per acre over the spring kill treatment. Northern aspect reduced grain yields about 20 bushels per acre. Grain N concentrations were higher with the spring killed alfalfa, likely the result of dilution.

Jim Holty Farm

At this site there are three studies. The first is looking at the effect of aspect on corn response in a spring discing tillage approach. The design is a randomized complete block with two replications. The second study is evaluation of no till corn into corn. The design is a randomized complete block with two replications. The third study is evaluation of no till, drilled soybeans into corn stalks. The design is a randomized complete block with two replications.

The results of the aspect study are presented in tables 4b to 4d. Aspect did not affect stand establishment, early growth, or yield.

The results of the demonstration contrasting a disc/plant system to a no till approach for corn after corn are shown in tables 5a to 5d. Stand and early growth were not affected by tillage system. Weeds were higher with the no till system. The predominant weed species present was foxtail.

Corn grown no till after corn resulted in statistically similar yields. There is a trend for reduced yields with the no till approach that appears to be related to weed control.

The study evaluating tillage effects on soybeans grown after corn is summarized in tables 6a to 6c. The tillage evaluated were no till and chisel plowing systems. There was no difference in soybean stand due to tillage (table 6a). Early growth was delayed .4 nodes per plant under no till conditions. This due to the high "in row" cover with the no till system and the cool growing season in 1993.

Soybean yields were statistically similar between tillage treatments (table 6c).

Francis and Paul Kottshade Farm

The tillage approach at this site is light field cultivation for corn following soybeans. The N sources evaluated were liquid hog manure, anhydrous ammonia, and an unfertilized check. The design is a randomized complete block.

Soybean residue levels were at modest levels after the spring field cultivation (table 7a). The N sources did not affect stand establishment. Early corn growth was reduced with nitrogen stress (table 7b).

Although corn yields and N uptake tended to be higher with both N sources there was no statistically significant differences (table 7d).

Table 1a. Cultural practices used in the demonstration at the Daryl Highum Farm, 1993.

<u>Experimental Design</u>
Treatments at this site are tillage and N source. Tillage systems evaluated are chisel plowing followed by discing and a no till approach. Nitrogen sources are anhydrous ammonia and liquid hog manure. Plots were arranged in a completely randomized design. Manure application was made in the spring followed by tillage and planting. Anhydrous ammonia was applied side dress June 15.

<u>Tillage Equipment</u>
Chisel plow Land All, 4" twisted shovels at 7.5" spacing, straight coulters at 15"
Disc 19' Ford with 20" discs

<u>Cropping history</u>
Previous crop Soybeans; planting date 4/30/93; hybrid Cargill 4327 (105 day); rate 35,500 in 30" rows
Planter Allis Chalmers with 2" fluted coulters

<u>Manure applications</u>
Hog manure (pit storage) 2500 gal/A
Total N 203 lb/A
NH_4-N 126 lb/A
Estimated Avail. N 153 lb/A
Application Broadcast 5/4/93 (worked in except on no-till plots)

Liquid Hog Manure Analysis

Sample	Solids	NH_4^+	NO_3^-	Tot.Min.-N	Org.N[1]	Total N	Est.Avail.N[2]	Est.Avl.N applied[3]
5/19/93	---%---			lbs/1000 gals.				--- lbs.N/a ---
1.	11.6	50.8	-	50.8	26.9	77.7	60.2	123
2.	6.6	50.3	-	50.3	34.5	84.8	62.3	
3.	10.4	50.8	-	50.8	31.6	81.4	61.9	
4.	12.5	49.9	-	49.9	32.6	82.6	61.4	
5.	8.6	51.1	-	51.1	30.5	81.6	61.8	
6.	8.6	50.4	-	50.4	29.1	79.5	60.5	
Avg.	**9.7**	**50.6**	**-**	**50.6**	**30.9**	**81.2**	**61.4**	

1.Organic nitrogen = Total nitrogen - Total mineral nitrogen (from laboratory analysis).
2.Estimated available nitrogen =(Org.-N x .35) + Tot.Min.-N. It is assumed that all of the mineral N and 30% of the Org.N is available during the first year of application
3.The rate of manure applied for plot area was 2,000 gal./acre from a pit. Broadcasted on 5/4/93 and worked in on chisel plots and broadcast only on no till plots.

<u>Fertilizer</u>
82-0-0 125 lb N/A side-dressed 6/15/93; 9-23-30 180 lb/A applied as starter

<u>Soil type</u> Recent Alluvium, loam to sandy loam texture.

<u>Weed control</u>
2,4-D 1 pt/A applied 5/14/93
Lasso (alachlor) 2 qt/A applied 5/14/93
Bladex (cyanazine) 2 qt/A applied 5/14/93

Table 1b. Effect of tillage and nitrogen source on early season corn population and leaf numbers at the Daryl Highum farm demonstration near Rushford in Fillmore County, 1993.

		stand			early growth		
		6/12	7/2	avg.	6/10	7/2	avg.
tillage	N source	---plt/Ax 1000---			-leaves/plant-		
No-till	AN. NH_3	29.2a[1]	30.7a	30.0	4.9b	7.7c	6.3
	Hog Manure	28.8a	30.3a	29.6	4.9b	8.0bc	6.4
Chisel	An. NH_3	30.8a	29.6a	30.2	5.0b	8.1b	6.6
Plow	Hog Manure	29.4a	29.6a	29.5	5.4a	8.4a	6.9
No-till		29.0b	30.5a	29.8	4.9b	7.9b	6.4
Chisel Plow		30.1a	29.6a	29.9	5.2a	8.2a	6.7
An. NH_3		30.0a	30.2a	30.1	4.9a	7.9b	6.4
Hog Manure		29.2a	30.0a	29.6	5.2a	8.2a	6.7
Pr>F tillage		<0.10	>>0.10		<0.10	<0.05	
N Source		>0.10	>>0.10		>0.10	<0.05	
tillagexN		>0.10	>>0.10		>0.10	>>0.10	

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 1c. Effect of tillage and nitrogen source on soybean residue at the Highum Farm demonstration, 1993.

		in row cover			between row cover		
		6/12	7/2	Avg.	6/10	7/2	Avg.
Tillage	N Source	--------------------%--------------------					
No-till	an. NH_3	11.2a[1]	10.0a	10.6	21.7a	15.0a	18.4
	Hog Manure	7.5b	10.4a	9.0	18.3a	16.7a	17.5
Chisel	An. NH_3	3.3c	3.8b	3.6	7.1b	5.8b	6.4
Plow	Hog Manure	2.5c	3.8b	3.2	4.6b	5.8b	5.2
No-till		9.2a	10.2a	9.7	20.0a	15.8a	17.9
Chisel Plow		2.9b	3.8b	3.4	5.8b	5.8b	5.8
An. NH_3		7.0a	6.9a	7.0	14.4a	10.4a	12.4
Hog Manure		5.0b	7.1a	6.0	11.4b	11.2a	11.3
Pr>F Tillage		<0.01	<.05		<<.01	<0.01	
N Source		<0.10	>>0.10		<0.10	>>0.10	
tillagexN Source		>0.10	>>0.10		>>0.10	>>0.10	

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 1d. Effect of tillage and nitrogen source on percent of corn plants tasselling and silking at the Highum Farm demonstration, 1993.

		Tasselling		Silking	
		7/26	7/30	7/26	7/30
		-----------%-----------			
No-till	An. NH_3	66.9a[1]	92.2a	21.6b	71.2b
	Hog Manure	75.8a	95.1a	29.2b	92.3a
Chisel	An. NH_3	81.6a	91.6a	45.6a	82.0ab
Plow	Hog Manure	84.1a	97.2a	41.4a	94.2a
No-till		71.4a	93.6a	25.4b	81.8a
Chisel Plow		82.8a	94.4a	43.5a	88.1a
An. NH_3		74.2a	91.9a	33.6a	76.6b
Hog Manure		80.0a	96.2a	35.6a	93.2a
Pr>F Tillage		>0.10	>>0.10	<0.05	>0.10
N Source		>>0.10	>0.10	>0.10	<0.05
tillagexNwource		>>0.10	>>0.10	>0.10	>0.10

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 1e. Effect of tillage and nitrogen source on total inorganic soil nitrogen concentrations to a 3 foot depth at the Highum farm demonstration, August 27, 1993.

	$NH_4^+ + NO_3^-$	NH_4^+	NO_3^-
	--------lb/A--------		
No-till An. NH_3	130.4a[1]	70.3a	60.1a
Hog manure	83.1a	48.9c	32.9a
Chisel An. NH_3	105.9a	62.9ab	43.0a
plow Hog manure	96.8a	57.2bc	39.6a
No-till	106.8a	59.6a	46.5a
Chisel plow	101.4a	60.0a	41.3a
An. Ammonia	118.2a	66.6a	51.6a
Hog manure	90.0a	53.0a	36.2a
In-row	101.5a	59.9a	40.9a
Between-row	106.6a	59.7a	46.9a
Pr>F Treatment	0.24	0.04	0.47
Tillage	0.53	0.69	0.55
N Source	0.34	0.17	0.46
Row position	0.60	0.96	0.44
Treatment*Row	0.73	0.81	0.78

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 1f. Effect of tillage and nitrogen source on inorganic nitrogen concentrations at three soil depths at the Highum farm, August 27, 1993.

	depth	$NH_4^+ + NO_3^-$	NH_4^+	NO_3^-
		--------lb/A----------		
No-till An. NH_3	0-12"	50.8a	20.3bcd	30.5a
	12-24"	39.3bc	23.0abc	16.3bcd
	24-36"	40.3abc	27.0a	13.3cde
Hog manure	0-12"	38.1bc	13.3e	23.5ab
	12-24"	22.8d	18.0d	4.8e
	24-36"	22.2d	17.5d	4.7e
Chisel An. NH_3	0-12"	42.9ab	16.8de	26.1a
	12-24"	31.4cd	22.5bc	8.8de
	24-36"	31.7cd	23.6abc	8.1de
Hog manure	0-12"	34.1bc	13.5e	20.6bc
	12-24"	32.0bcd	19.7cd	12.3cde
	24-36"	30.7cd	24.0ab	6.6e
Treatment				
No-till An. NH_3		43.5a	23.4a	20.0a
Hog manure		27.7a	16.3c	11.0a
ChiselAn. NH_3		35.3a	21.0ab	14.3a
Hog manure		32.2a	19.1bc	13.2a
Row position				
In-row		33.8a	20.0a	13.6a
Between-row		35.5a	19.9a	15.6a
Depth				
0-12"		41.4a	16.0b	25.2a
12-24"		31.4b	20.8a	10.6b
24-36"		31.2b	23.0a	8.2b
Pr>F Treatment		0.242	0.038	0.471
Row position		0.606	0.956	0.441
Depth		0.001	0.0004	0.0001
TreatmentxRow position		0.732	0.810	0.776
TreatmentxDepth		0.665	0.822	0.813
Row positionxDepth		0.424	0.374	0.821
TrtmentxRowxDepth		0.840	0.577	0.944

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 1g. Correlation of inorganic soil nitrogen concentrations at the 0-12" depth with corn phenology and yields at the Highum farm, 1993.

	leaf numbers		Silking		
Row position	6/11	7/12	7/26	7/30	Yield
In-row soil N	-0.631	-0.089	-0.282	0.069	-0.065
Between soil N	-0.284	0.115	-0.313	-0.033	0.131
Pr>F In row N	0.011	0.752	0.309	0.806	0.817
Between row N	0.304	0.683	0.256	0.908	0.643

Table 1h. Effect of tillage and nitrogen source on corn grain yields, moisture and nitrogen content at the Highum farm, October 28, 1993.

	moisture	yield	nitrogen
	--%--	-bu/a-	--%--
No-till an. NH_3	21.1a[1]	171a	1.20a
Hog manure	20.1a	163a	1.11b
Chisel An. NH_3	19.8a	176a	1.21a
plow hog manure	19.5a	175a	1.17a
Tillage			
No-till	20.6a	167a	1.16b
Chisel plow	19.6a	176a	1.19a
N source			
An. NH_3	20.4a	174a	1.21a
Hog manure	19.8a	169a	1.14b
Pr>F Treatment	0.41	0.56	0.01
Tillage	0.27	0.32	0.03
N Source	0.26	0.56	0.07

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 2a. Cultural practices at the Dan Graskamp farm, 1993.

Tillage equipment
Field cultivator (21') 2" shanks at 6" spacing
Row cultivator 13' John Deere (4-38" row)
(6/27/93) 2-5" sweeps between rows

Cropping history
Previous crop Soybeans
Planting date 5/8/93
Variety McCurdies 5222 (110 day)
Planting population 28,500

Experimental Design

Two rates of N as liquid hog manure were compared to anhydrous ammonia. The design is a randomized complete block with split plots. Main plots at this site were nitrogen source and rate. Subplots were row cultivation.

Manure	High rate	Low rate
Hog manure	6300 gal/A	3145 gal/A
Total N	450 lb/A	226 lb/A
NH_4-N	243 lb/A	122 lb/A
Est. Avail. N	316 lb/A	158 lb/A

Application Broadcast 5/11/93 and worked in

Liquid Hog Manure Analysis

Sample	Solids	NH_4^+	NO_3^-	Tot.Min.-N	Org.N[1]	Total N	Est.Avail.N[2]	Est.Avl.N applied[3]
5/19/93	---%---	--------	--------	-------lbs/1000 gals.	--------	--------	--------	--- lbs.N/a ---
1.	9.5	39.2	-	39.2	34.1	73.3	51.2	* Hi= 311
2.	8.5	43.6	-	43.6	28.7	72.3	53.6	* Lo= 156
3.	9.1	41.8	-	41.8	28.9	70.6	51.9	
4.	4.3	29.8	-	29.8	41.2	70.9	44.2	
Avg.	10.4	38.6	-	38.6	33.2	71.8	50.2	

1.Organic nitrogen = Total nitrogen - Total mineral nitrogen (from laboratory analysis).
2.Estimated available nitrogen =(Org.-N * .35) + Tot.Min.-N. It is assumed that all of the mineral N and 30% of the Org.N is available during the first year of application.
3.The rate of manure applied for plot area was 6,200 gal./acre for the Hi and 3,100 gal/acre for the Lo treatment. Storage was a pit, surface applied by broadcast on 5/11/93 and worked in.

Fertilizer 9-23-30 100 lb/A applied as starter; anhydrous 80 lb N/A

Soil Fayette silt loam 2-6% slope

Weed control
Prowl (3.3E)2.5 pt/A applied 5/17/93; Marksman2.5 pt/A applied 5/17/93; Bladex (4 F)1 lb/A applied 5/17/93

Table 2b. Effect of nitrogen source and cultivation (6/27/93) on early season plant population and soybean residue at the Dan Graskamp farm demonstration near Fountain in Fillmore County, 1993.

N source	N rate	cul[1]	stand 6/9	stand 6/29	in row 6/9	in row 6/29	between row 6/9	between row 6/29
	-lb/A-		--plt/A---		---------%----------			
An. NH_3	80	Yes	-	24.3A[1]	-	2.7B	-	3.3C
		No	-	25.4A	-	4.2AB	-	6.5AB
Hog manure	316	Yes	-	24.4A	-	5.8A	-	4.6BC
		No	-	26.0A	-	1.8B	-	8.8A
Hog manure	158	Yes	-	24.5A	-	4.0AB	-	4.4B
		No	-	26.2A	-	3.8AB	-	6.4AB
AA	80		24.6A	24.9A	7.9A	3.3A	12.9A	5.0A
Hog manure	316		25.4A	25.2A	9.0A	3.8A	13.8A	6.7A
Hog manure	158		24.3A	25.4A	7.6A	3.8A	13.8A	5.4A
Cultivation			-	24.4B	-	6.8A	-	4.1B
No cultivation			-	25.9A	-	6.8A	-	7.2A
Pr>F N Source			0.16	0.82	0.52	0.93	0.80	0.36
Cultivation			-	0.03	-	0.18	-	0.0002
NxCultivation			-	0.91	-	0.02	-	0.25

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 2c. Effect of nitrogen source and cultivation (6/27) on corn phenology at the Graskamp Farm, 1993.

N source		Cult	early growth 6/9	early growth 6/29	silking 8/13
	-lb/a-		-leaves/plant-		-score-
An. NH_3	80	Yes	-	6.7b[2]	1.5c
		No	-	6.8ab	1.6c
Hog manure	316	Yes	-	7.0a	2.6a
		No	-	6.9ab	2.4ab
Hog manure	158	Yes	-	6.8ab	2.0abc
		No	-	6.8ab	1.8bc
Aa	80		2.8a	6.7b	1.6b
Hog manure	316		2.8a	6.9a	2.5a
Hog manure	158		2.9a	6.8ab	1.9b
Cultivation			-	6.8a	2.0a
No cultivation			-	6.8a	1.9a
Pr>f n source			0.20	0.08	0.04
Cultivation			-	0.63	0.49
Nxcultivation			-	0.77	0.61

[1]Silking score based on color: 1=white or yellow (not pollinated) 5=brown (pollinated).
[2]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 2d. Effect of nitrogen source and cultivation (6/27) on weed counts and species composition **in the row** at the Graskamp farm, July 19, 1993.

		Cult	Count	Wirestem Muhly	Horse Tail	Quack-Grass
	-Lb/a-		#/Ft[2]	-------%-------		
AA. NH_3	80	Yes	1.1a[2]	91.7	8.3	-
		No	1.3a	54.3	45.7	-
Hog Manure	316	Yes	1.1a	67.5	27.5	5.0
		No	1.2a	86.6	13.4	-
Hog Manure	158	Yes	1.4a	95.8	4.2	-
		No	1.0a	94.5	5.6	-
AA	80		1.2a	73.0	27.0	-
Hog Manure	316		1.2a	77.1	20.4	2.5
Hog Manure	158		1.1a	95.1	4.9	-
Cultivation			1.2a	85.0	13.3	1.7
No Cultivation			1.2a	78.5	21.5	-
Pr>F N Source			0.97	0.11	0.33	
Cultivation			0.80	0.12	0.68	
NxCultivation			0.34	0.14	0.12	

[1]W.Muhly=Wirestem muhly; Vel.leaf=Velvetleaf.
[2]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 2e. Effect of nitrogen source and cultivation (6/27) on weed counts and species composition **between the row** at the Graskamp farm, July 19, 1993.

		Cult	count	Wirestem Muhly	Horse tail	Vel. leaf	Common lambs
	-lb/A-		#/Ft²	--------% cover---------			
An. NH_3	80	Yes	5.8a[2]	94.1ab	1.7b	0.8	3.3
		No	6.5a	85.7b	10.2a	1.4	2.8
Hog Manure	316	Yes	5.4a	91.8ab	4.0ab	3.9	0.4
		No	6.4a	84.7b	6.7ab	1.1	7.3
Hog Manure	158	Yes	5.6a	98.2a	1.5b	0.4	-
		No	3.4a	91.7ab	7.2ab	1.1	-
AA	80	-	6.1a	89.9a	5.9a	1.1	3.0
Hog Manure	316	-	5.9a	88.3a	5.4a	2.5	3.8
Hog Manure	158	-	4.5a	94.9a	4.3a	0.7	-
Cultivation			5.6a	94.7a	2.4a	1.7	1.2
No Cultivation			5.4a	87.4b	8.0b	1.2	3.3
Pr>F N Source			0.52	0.31	0.89	0.17	0.42
Cultivation			0.89	0.08	0.02	0.60	0.38
NxCultivation			0.38	0.97	0.52	0.17	0.38

[1]W.Muhly=Wirestem Muhly; H.tail=Horsetail; V.leaf=Velvetleaf; Common Lambsquarters
[2]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 2f. Effect of nitrogen source and cultivation (6/27) on total inorganic soil nitrogen concentrations to a 3 foot depth at the Graskamp farm, August 28, 1993[1].

			In-row			Between-row		
			$NH_4^+ + NO_3^-$	NH_4^+	NO_3^-	$NH_4^+ + NO_3^-$	NH_4^+	NO_3^-
		cult	-------------lb/A--------------					
Anhydrous	80	Yes	120	112	8.1	71	58.2	13.0
		No	121	104	16.5	101	91.0	10.3
Hog manure	316	Yes	147	113	33.6	147	102.0	44.9
(high rate)		No	183	132	50.8	218	159.0	58.5
Hog manure	158	Yes	91	73	17.7	85	57.7	27.2
(low rate)		No	163	152	11.4	74	58.1	15.6
Anhydrous	80		120	108	12.3	86	74.6	11.6
Hog manure	316		165	122	42.2	182	130.5	51.7
Hog manure	158		127	112	14.6	80	57.9	21.4
Cultivation			119	99	19.8	101	72.6	28.4
No Cultivation			156	129	26.2	131	102.7	28.1
In-row			138	114	23.0			
Between-row			116	88	28.2			

1. These data represent one replication which did not allow statistical analysis.

Table 2g. Effect of nitrogen source and cultivation (6/27) on inorganic soil nitrogen concentrations at three depths at the Graskamp farm, August 28, 1993.

N Source	Cult	Depth	In-row $NH_4^+ + NO_3^-$	In-row NH_4^+	In-row NO_3^-	Between-row $NH_4^+ + NO_3^-$	Between-row NH_4^+	Between-row NO_3^-
			-----------------	-----------------	lb/A	-----------------	-----------------	-----------------
Anhydrous	Yes	0-12"	83.1	77.9	5.26	45.6	35.6	10.01
		12-24"	36.9	34.1	2.82	25.6	22.6	3.03
		24-36"						
	No	0-12"	44.6	36.5	8.03	34.9	30.1	4.84
		12-24"	38.6	34.2	4.33	33.6	32.0	1.54
		24-36"	37.7	33.6	4.16	32.8	28.9	3.95
Hog manure	Yes	0-12"	65.2	52.2	13.02	47.1	31.7	15.42
(high rate)		12-24"	38.1	31.4	6.74	47.1	37.9	9.21
		24-36"	43.7	29.8	13.89	52.5	32.3	20.28
	No	0-12"	56.8	29.2	27.58	62.4	44.5	17.84
		12-24"	82.8	73.6	9.20	76.0	55.1	20.83
		24-36"	43.5	29.6	14.0	79.1	59.2	19.90
Hog manure	Yes	0-12"	32.2	23.8	8.42	44.2	27.5	16.70
(low rate)		12-24"	29.9	25.4	4.50	40.7	30.2	10.49
		24-36"	28.6	23.8	4.76	---		
	No	0-12"	73.7	69.1	4.60	35.2	25.0	10.20
		12-24"	51.0	49.5	1.44	7.0	6.0	0.91
		24-36"	38.6	33.3	5.36	31.6	27.1	4.45
Anhydrous			50.1	45.5	4.56	28.7	24.8	3.90
Hog manure (high rate)			55.0	40.9	14.07	60.7	43.4	17.25
Hog manure (low rate)			42.3	39.4	4.85	26.4	19.3	7.12
Cultivation			46.4	39.5	6.90	33.6	24.2	9.46
No Cultivation			51.9	43.2	8.74	43.6	34.2	9.38
0-12"			59.3	48.1	11.15	44.9	32.4	12.50
12-24"			46.2	41.3	4.84	38.3	30.6	7.67
24-36"			42.0	34.5	7.48	32.7	24.6	8.10
In-row			49.2	41.3	7.82			
Between-row sampling			38.6	29.2	9.42			

Table 2h. Effect of nitrogen source and cultivation (6/27) on corn grain yields, moisture contents, and nitrogen concentrations at the Graskamp farm, 1993.

	cult	moist.	yield	N
		--%---	-bu/A-	-%-
An. NH_3	Yes	25.4a[1]	114c	1.31a
	No	26.1a	115c	1.28b
Hog Manure	Yes	25.1a	119ab	1.34a
(High Rate)	No	25.1a	123a	1.34a
Hog Manure	Yes	24.9a	119ab	1.30a
(Low Rate)	No	25.4a	118bc	1.24b
An NH_3		25.8a	115b	1.30b
Hog Manure(high)		25.2a	121a	1.34a
Hog Manure(low)		25.2a	118a	1.27b
Cultivation		25.2a	117a	1.31a
No Cultivation		25.5a	119a	1.29b
Pr>F N Source		0.43	0.02	0.04
Cultivation		0.47	0.56	0.03
NxCultivation		0.50	0.29	0.17

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3a. Cultural practices used at the Hammel Farm demonstration, 1993.

Tillage equipment
Row cultivator Dakon 4-38" rows (late June) 5 Danish tine/row

Cropping history
Previous crop Alfalfa
Planting date 5/8/93
Variety DeKalb 451 (100 day)
Planting population 29,900 seeds/A
Planter New Idea with Kinsey planting units & 2" fluted coulters

Experimental Design
The treatments evaluated at this site include: fall vs spring killed alfalfa; and north and south aspect. The design is a randomized complete block with timing main plots and aspect subplots.

Fertilizer
Urea 50 lb N/A

Soils
Black Hammer-Southridge silty clay loam
Nodine-Rollingstone silty clay loam

Weed control
Ranger (alfalfa kill) 3 pt/A

Aspect	avg.	std.	range
North slope	13%	(1.6)	10-14
South slope	16%	(3.2)	12-20

Table 3b. Effect of alfalfa-kill timing and aspect on early season plant population and corn leaf numbers at the Tony and Walter Hammel Farm demonstration near Caledonia in Houston County, 1993.

sod		stand			early growth		
		6/21	7/10	avg.	6/21	7/10	avg.
kill	aspect	---plt/A x1000---			-leaves/plant-		
Fall	North	26.7a[1]	28.6a	27.6	5.4a	7.8a	6.6
	South	28.3a	29.3a	28.8	5.5a	8.0a	6.8
Spring	North	26.1a	24.9a	25.5	4.7a	6.8b	5.8
	South	25.4a	25.9a	25.6	4.9a	7.3ab	6.1
Sod Kill							
Fall		27.5a	29.0a	28.2	5.4a	7.8a	6.6
Spring		25.8a	25.4a	25.6	4.8a	7.1b	6.0
Aspect							
North		26.4a	26.8a	26.6	5.0b	7.3a	6.2
South		27.0a	27.7a	27.4	5.2a	7.6a	6.4
Pr>F	Sod kill	0.47	0.38		0.17	0.08	
	Aspect	0.82	0.30		0.06	0.26	
SdkillxAspect		0.59	0.84		0.70	0.70	

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3c. Effect of alfalfa-kill timing and aspect on alfalfa residue at the Hammel Farm, 1993[1].

Sod		In Row			Between Row		
		6/21	7/10	Avg.	6/21	7/10	Avg.
Kill	Aspect	--Plt/a X1000---			--------%---------		
Fall	North	14.6a[2]	4.2c	9.4	24.2c	2.6a	13.4
	South	20.4a	5.7bc	13.0	30.8bc	3.1a	17.0
Spring	North	23.3a	7.3ab	15.3	35.8ab	2.6a	19.2
	South	31.2a	8.3a	19.8	49.2a	5.2a	27.2
Sod Kill							
Fall		17.5b	5.0b	11.2	27.5b	2.9a	15.2
Spring		27.5a	7.5a	17.5	42.5a	3.9a	23.2
Aspect							
North		19.2a	5.8a	12.5	30.0a	2.6b	16.3
South		25.8a	7.0a	16.4	40.0a	4.2a	22.1
Pr>F							
Sodkill		0.00	0.04		0.03	0.69	
Aspect		0.32	0.14		0.16	0.05	
SodkillxAspect		0.86	0.73		0.57	0.13	

[1]Plots were cultivated between 6/21 and 7/10/93.
[2]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3d. Effect of sodkill and aspect on corn silking and tasselling at the Hammel Farm, 1993.

		Tasseling		Silking	
		7/30	8/4	7/30	8/4
Kill	Aspect	---------------%---------------			
Fall	North	89.0ab[1]	100.0a	67.2ab	97.4a
	South	92.4a	98.8a	70.6a	88.7a
Spring	North	55.9b	97.5a	5.0c	62.8b
	South	75.3ab	98.1a	42.0b	93.8a
Sodkill					
Fall		90.7a	99.4a	68.9a	93.0a
Spring		65.6b	97.8a	23.5b	78.3b
Aspect					
North		72.4a	98.8a	36.1a	80.1b
South		83.8a	98.4a	56.3a	91.2a
Pr>F	Sodkill	0.08	0.50	0.04	0.03
Aspect		0.31	0.42	0.13	0.08
SodkillxAspect		0.44	0.10	0.17	0.03

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3e. Effect of sodkill and aspect on weed counts and species composition in the row (cultivation late June) at the Hammel farm, July 9-12, 1993.

Sod Kill		Weed Count #/Ft[1]	Species Composition[1] Qg	Fxt.sp.	Dand.	Yns	Alf.	Rrpw	Vele
			------------------	------	%	------	------	------	------
Fall	North	3.7a[2]	74.9a	20.7	3.4	-	-	1.1	-
	South	3.6a	66.0a	-	34.0	-	-	-	-
Spring	North	15.8a	39.4a	50.0	-	6.3	4.4	-	-
	South	6.9a	74.4a	-	1.8	-	17.3	4.8	1.8
Sod Kill									
Fall		3.6a	70.4a	10.4	18.7	-	-	0.6	-
Spring		11.4a	56.9a	25.0	0.9	3.1	10.8	2.4	0.9
Aspect									
North		9.8a	57.1a	35.4	1.7	3.2	2.2	0.6	-
South		5.2a	70.2a	-	17.9	-	8.7	2.4	0.9
Pr>F	Sod kill	0.24	0.82						
	Aspect	0.44	0.62						
SodkillxAspect		0.45	0.46						

[1]QG=Quackgrass; Fxt.sp=Foxtail sp.; Dand.=Dandelion; YNS=Yellow nutsedge; Alf.=Alfalfa; RRPW=Redroot pigweed; Vele=Velvetleaf.
[2]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3f. Effect of sodkill and aspect on weed counts and species composition between the row (cultivation late June) at the Hammel farm, July 9-12, 1993.

Kill	Aspect	Weed Count #/Ft[2]	Species Composition[1] Qg	Fxt.sp.	dand.	Yns	Alf.	Rrpw
			---------------	------	%	------	------	------
Fall	North	2.1ab[2]	88.2a	-	9.3	-	-	2.5
	South	1.5b	71.4a	-	28.6	-	-	-
Spring	North	5.1a	39.8a	48.4	-	5.3	5.3	1.4
	Spring	3.5ab	81.5a	-	-	-	16.3	2.3
Sod Kill								
Fall		1.8b	79.8a	-	19.0	-	-	1.3
Spring		4.3a	60.6a	24.2	-	2.6	10.8	1.8
Aspect								
North		3.6a	64.0a	24.2	4.7	2.6	2.6	1.9
South		2.5a	76.4a	-	14.3	-	8.1	1.2
Pr>F	Sodkill	0.03	0.65					
Aspect		0.40	0.65					
SodkillxAspect		0.69	0.34					

[1]QG=Quackgrass; Fxt.sp=Foxtail sp.; Dand.=Dandelion; YNS=Yellow nutsedge; Alf.=Alfalfa; RRPW=Redroot pigweed.
[2]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3g. Effect of sodkill and aspect on total soil N at 3-foot depth at the Hammel Farm, August 26, 1993.

Sod kill	aspect	$NH_4^+ + NO_3^-$	NH_4^+	NO_3^-
		--------	lb/A	--------
Fall	North	141a[1]	88.2a	52.5a
	South	84a	69.8a	13.8a
Spring	North	134a	100.8a	32.2a
	South	144a	89.2a	54.5a
Fall		112a	79.0a	33.1a
Spring		139a	95.0a	43.4a
North		137a	94.5a	42.4a
South		113a	79.5a	34.1a
In-ro		129a	88.9a	40.4a
Between-row		121a	85.1a	36.1a
Pr>F	Sodkill	0.17	0.18	0.56
	Aspect	0.63	0.50	0.78
SodkillxAspect		0.50	0.87	0.36
Row position		0.52	0.72	0.34
Row pos.xSodkill		0.77	0.36	0.18
Row pos.xAspect		0.67	0.62	0.91
Rowpos*Sodkill*Aspect		0.46	0.79	0.16

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3h. Effect of sodkill, aspect, and depth on soil nitrogen concentrations at the one- and two-foot depths at the Hammel farm, August 26, 1993.

sod kill	aspect	depth	$NH_4^+ + NO_3^-$	NH_4^+	NO_3^-
			--------lb/A---------		
Fall	North	0-12"	48.2a[1]	27.5a	20.7ab
		12-24"	46.6a	28.1a	18.4ab
	South	0-12"	41.0a	29.8a	11.4ab
		12-24"	41.8a	39.7a	2.1b
Spring	North	0-12"	45.6a	28.1a	17.6ab
		12-24"	43.0a	35.1a	8.1ab
	South	0-12"	50.0a	27.1a	23.0a
		12-24"	45.6a	29.4a	16.2ab
Fall			44.4a	31.3a	13.1a
Spring			46.2a	29.9a	16.2a
North			46.0a	29.7a	16.2a
South			44.6a	31.5a	13.2a
0-12"			46.3a	28.1a	18.2a
12-24"			44.3a	33.1a	11.2b
In-row			44.9a	30.0a	13.6a
Between-row			45.7a	31.2a	15.6a
Pr>F Sodkill			0.77	0.26	0.66
Aspect			0.93	0.77	0.76
SodkillxAspect			0.75	0.44	0.37
Row position			0.81	0.64	0.76
Depth			0.64	0.14	0.00
DepthxSodkill			0.60	0.91	0.45
DepthxAspect			0.96	0.68	0.50
SodkillxAspectxDepth			0.72	0.26	0.17

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3i. Correlation of inorganic soil nitrogen concentrations at the 0-12" depth with corn phenology and yields at the Hammel farm, 1993.

	Leaf Numbers		Silking		
Row Position	6/21	7/10	7/30	8/4	Yield
In-row soil N	0.072	0.144	-.004	0.186	-0.245
Between-row soil N	-0.180	0.147	-0.042	0.087	-0.296
Pr>F					
In-row soil N	0.86	0.73	0.99	0.66	0.56
Between-row soil N	0.67	0.73	0.92	0.84	0.48

Table 3j. Soil core sampling data from the Hammel Farm, July 21, 1993.

Core	Sodkill	Aspect	Horizon	Depth	Soil Description
1	Spring	South	A	0-30"	Silt loam (Alluvium)
			B	30-55"	Si. clay loam, lt. brown (Argillic)
			C	55-69"	Mottled clay
				69"+	Rock
2	Spring	North	A	0-10"	Silt loam
			B_1	10-24"	Red clay (Argillic)
			B_2	24-38"	White clay
			C	38"+	Sandstone
3	Fall	North	A	0-8"	Silt loam
			B_1	8-30"	Brown clay
			B_2	30-42"	Clay (light color)
			C	42"+	Rock
4	Fall	South	A	0-8"	Silt loam
			B_1	8-20"	Silty clay loam
			B	20-42"	Brown clay
				42"+	Rock
5	Spring	South	A	0-8"	Silt loam
			B_1	8-15"	Fine sandy loam
			B_2	15-36"	Fine sand
			C	36"+	Sandstone
6	Spring	North	A	0-8"	Silt loam
				8-14"	Silt loam
			B	14-24"	Silty clay loam
				24-50"	Silt loam
			C	50-52"	Sand
				52"+	Sandstone

Table 3k. Effect of sodkill and aspect on corn grain yields, moisture contents, and nitrogen contents at the Hammel farm study.

Kill	Aspect	Moisture --%---	Yield --Bu/a--	Nitrogen --%--
Fall	North	27.2b[1]	160.8a	1.27a
	South	24.2d	177.7a	1.27a
Spring	North	30.6a	129.0b	1.33a
	South	25.5c	148.8ab	1.33a
Sodkill				
Fall		25.7a	169.2a	1.27b
Spring		28.0a	138.9b	1.33a
Aspect				
North		28.9a	144.9b	1.30a
South		24.8b	163.2a	1.30a
Pr>FSodkill		0.15	0.08	0.03
Aspect		0.01	0.04	0.98
SodkillxAspect		0.15	0.73	0.94

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 4a. Cultural practices used in the demonstrations at Jim Holty's Farm, 1993.

Experimental design

At this site there are three studies. The first is looking at the effect of aspect on corn response in a spring discing tillage approach. The design is a randomized complete block with two replications. The second study is evaluation of no till corn into corn. The design is a randomized complete block with two replications. The third study is evaluation of no till, drilled soybeans into corn stalks. The design is a randomized complete block with two replications.

	Corn Aspect	Corn No-till	Soybean No-till
Tillage equipment			
	Disc 14' Case International	none	none
Cropping history			
Previous crop	Corn	Corn	Corn
Planting date	5/10/93	5/13/93	5/22/93
Variety	Pioneer 3563 (103 day)	Pioneer 3702 (101 day)	
Planting pop.	28,500	28,500	
Planter	Case IH 800 with Yetter rolling finger trash wipers	Case IH 800Case	IH Grain drill
Fertilizer			
82-0-0	131 lb N/A	131 lb N/A	-
9-23-30	150 lb/A	150 lb/A	-
Beef manure	40 ton/A	-	-
Soil			
Port Byron silt loam 3-6% slope at all three sites.			
Weed control	Confidence (2.08 lb/A) Atrazine (0.7 lb/A) Bladex (1.67 lb/A) May 17	Confidence (2.08 lb/A) Atrazine (0.7 lb/A) Marksman (1.3 qt/A) May 20	Pursuit (4 oz/A)
Insect control	Counter	Counter	-

Table 4b. Effect of aspect on early season plant population and crop residue, at the Richard and Jim Holty's Farm near Spring Grove in Houston County, 1993.

	Population			Cover with Corn Residue			
				In-row		Between Row	
	6/15	7/6	Avg.	6/15	7/6	6/15	7/6
Aspect	----1000s Plt/a----			--------------%--------------			
North Facing	25.3a[1]	23.2a	24.2	24.2a	29.2a	76.7a	81.2a
South Facing	24.8a	23.2a	24.0	27.5a	31.2a	81.2a	85.4a
Pr>F Aspect	0.82	0.98		0.84	0.75	0.50	0.50

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 4c. Effect of aspect on common stalk borer damage, corn leaf numbers and corn silking at the Holty Farm, 1993.

	Common Stalk Borer Damage	Leaf Numbers			Silking[1]
		6/15	7/6	Avg.	8/13
Aspect	--%--	-Leaves/plant--			Score
North Facing	6.3a[2]	3.1a	6.4a	4.8	1.0a
South Facing	10.0a	3.0a	6.6a	4.8	1.2a
Pr>F Aspect	0.45	0.80	0.20		0.50

[1]Silking score based on color: 1=white or yellow (not pollinated), 5=brown (pollinated).
[2]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 4d. Effect of aspect on corn grain yield and moisture at the Holty farm, 1993.

Aspect	Grain Moisture	Corn Yield
Aspect	--%--	-Bu/a-
North	27.2a[1]	101a
South	26.5a	103a
Pr>F Aspect	0.96	0.46

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 5a. Effect of tillage on early season corn population and corn residue at the Holty Farm near Spring Grove in Houston County, 1993.

	Population			In-row		Between Row	
	6/15	7/6	Avg.	6/15	7/6	6/15	7/6
	----Plt/a(x1000)--			-----------%-------------			
No-till	27.6a[1]	27.3a	27.4	17.5a	12.9a	73.3a	66.7a
Disc/plant	27.0a	27.3a	27.2	10.0a	6.7a	22.5b	25.4b
Pr>F Tillage	0.66	1.0		0.55	0.50	0.08	0.03

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 5b. Effect of tillage on corn leaf numbers and silking at the Holty Farm, 1993.

	Leaf Numbers			Silking[1]
	6/15	7/6	Avg.	8/13
	--Leaves/plant--			Score
No-till	2.6a[2]	6.8a	4.7	1.5a
Disc/plant	2.8a	7.1a	5.0	1.5a
Pr>F Tillage	0.30	0.50		1.0

[1]Silking score based on color: 1=white or yellow (not pollinated) to 5=brown (pollinated).
[2]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 5c. Effect of tillage on weed counts and species composition in and between the rows at the Holty Farm, July 12, 1993.

	Weed Counts		Species Composition: Foxtail Sp.		Species Composition: Velvetleaf	
	In-row	Between	In-row	Between	In-row	Between
	---No./ft^2----		-------% ground cover--------			
No-till	10.8a[1]	2.6a	92.2a	100.0a	7.8a	-
Disc/plant	7.2a	0.7b	83.1a	70.0a	17.0a	30.0
Pr>F Tillage	0.59	0.03	0.47	0.50	0.47	

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 5d. Effect of tillage on corn grain moisture, test weight, and yield, Holty Farm, 1993.

	tst.wt	moi.	yield
	lb/bu	-%-	bu/ac
No-till	47.2a	24.9a	89.6a
Disc/plant	47.5a	24.4a	96.8a
Pr>F	0.80	0.67	0.34

Table 6a. Effect of tillage on early soybean populations, node numbers and corn residue at the Holty Farm, Houston County, 1993.

	Soybean Population			Node Numbers		
	6/15	7/6	Avg.	6/15	7/6	Avg.
	---Plt/a(x1000)----			--Nodes/plant---		
No-till	165a[1]	179a	172	2.7a	5.3b	4.0
Chisel Plow	187a	201a	194	2.9a	5.8a	4.4
Pr>F Tillage	0.40	0.65		0.20	0.07	

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 6b. Effect of tillage on corn residue at the Holty Farm, Houston County, 1993.

	Corn Residue: In-row		Corn Residue: Between Row	
	6/15	7/6	6/15	7/6
	--------------%------------			
No-till	42.1a[1]	46.2a	40.8a	39.2a
Chisel Plow	17.5a	17.5b	20.4a	21.7a
Pr>F Tillage	0.22	0.10	0.15	0.20

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 6c. The effect of tillage on soybean test weight, moisture, and yield, Holty Farm, 1993.

	tst.wt	moi.	yield
	lb/bu	-%-	bu/ac
No-till	57.8a	11.2a	33.4a
chisel plow	57.5a	11.6a	38.4a
Pr>F	0.50	0.30	0.27

Table 7a. Cultural practices used at the Kottschade Farm, 1993.

Experimental Design

The tillage approach at this site is light field cultivation for corn following soybeans. The N sources evaluated are liquid hog manure, anhydrous ammonia, and an unfertilized check. The design is a randomized complete block.

Tillage equipment
Field cultivator International
Row cultivator International

Cropping history
Previous crop soybeans; planting date 5/18/93; variety Pioneer 3751 (97 day); planting population 27,800
Planter John Deere 7000 (6-30" rows) with 1" fluted coulters

Manure applications
Hog manure
(stored pit under slots) 3,825 gal/A
Total N 236 lb/A
NH_4-N 137 lb/A
Estimated Available N 170 lb/A
Application Injected 5/9/93

Liquid Hog Manure Analysis

Sample	Solids	NH_4^+	NO_3^-	Tot.Min.-N	Org.N	Total N	Est.Avail.N	Est.Avl.N applied[3]
5/19/93	---%---	-----------------lbs/1000 gals.						--- lbs.N/a ---
1.	7.8	37.3	-	37.3	24.3	61.6	44.6	170
2.	7.8	34.5	-	34.5	27.4	61.9	44.1	
Avg.	7.8	35.9	-	35.9	25.8	61.8	44.4	

1.Organic nitrogen = Total nitrogen - Total mineral nitrogen (from laboratory analysis).
2.Estimated available nitrogen =(Org.-N * .35) + Tot.Min.-N. It is assumed that all of the mineral N and 30% of the Org.N is available during the first year of application.
3.The rate of manure applied for plot area was 3,825 gal./acre on May 9,1993. Storage is a pit under slots and injected with 3 inch straight shovels.

Fertilizer
82-0-0 100 lb N/A; 11-30-20 105 lb/A applied with planter.

Soil Fayette silt loam

Weed control Lasso (alachlor) 2 qt/A applied 5/18/93; Hi-Depth 1 pt/A applied 7/3/93

Table 7b. Effect of nitrogen source on early season corn population and crop residue at a demonstration on Paul Kottschade's farm near Plainview in Wabasha County, 1993.

	Corn Population			Soybean Residue In-row		Soybean Residue Between-row	
	6/25	7/20	Avg.	6/25	7/20	6/25	7/20
	---Plt/a(x1000)----			----------%------------			
Check	28.7a[1]	25.8a	27.2	3.8a	2.1a	5.8a	3.3a
Anh.NH_3	27.1a	26.2a	26.6	5.4a	3.8a	5.8a	4.0a
Hog Man.	27.2a	25.3a	26.2	3.1a	1.2a	6.7a	1.9a
Pr>f N Source	0.91	0.95		0.18	0.43	0.90	0.53

[1]data Followed by the Same Letter in the Same Column Are Not Significantly Different at the 0.10 Level.

Table 7c. Effect of Nitrogen Source on Corn Leaf Numbers and Silking at the Kottschade Farm.

	Leaf Numbers			Silking[1]
	6/25	7/20	Avg.	8/20
	--Leaves/plant--			Score
Check	4.3a[2]	6.2b	5.2	2.5a
Anh.NH_3	4.4a	6.6a	5.5	2.7a
Hog Manure	4.2a	6.5a	5.4	2.8a
Pr>f N Source	0.50	0.04		0.90

[1]silking Score Based on Color: 1=white or Yellow (Not Pollinated) to 5=brown (Pollinated).
[2]data Followed by the Same Letter in the Same Column Are Not Significantly Different at the 0.10 Level.

Table 7d. Effect of nitrogen source on hand-harvested corn grain yields, moisture contents, and nitrogen concentrations at the Kottschade Farm, November 4, 1993.

	Moisture	Yield	Nitrogen
	--%---	bu/A	--%--
Check	20.4a[1]	117a	1.28a
Anhydrous	21.2a	134a	1.35a
Hog manure	21.4a	136a	1.36a

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

EVALUATION OF RESIDUE MANAGEMENT SYSTEMS FOR CORN, SOYBEANS, AND WHEAT PRODUCTION[1]

J.F. Moncrief, H.J. Stanislowski, B.J. Johnson, B.P. Peterson, and P.M. Bongard[2]

Soil cover in the row was variable between planter mounted tillage tools. When "in row" cover was high, early corn growth was delayed and in most cases persisted through the season. Corn yields were reduced in some instances. Tillage did not affect soybean or wheat yields.

This is the second year of a three year project to evaluate corn, soybean, and wheat production with residue management systems on highly erodible land in West Central Minnesota. These trials are replicated and plots range in size from 1 to 10 acres. Tillage treatments and grain yield estimates are accomplished with full size field equipment.

Julian and Dave Sjostrom Farm

This is the second year of corn following oats. Tillage systems evaluated are no till and chisel plowing. The planter is equipped with an "add on" yetter tool bar with a pair of ripple coulters one for dry fertilizer placement. The planter units have a set of concave clearing discs and down pressure spring kits installed. the Soil is a Chappett-Sisseton loam complex with a slope 12-20% slope with an average of about 15%. Liquid dairy manure was broadcast, spring applied before tillage both years of the study to meet the N needs of the corn.

Data is presented in tables 1a to 1e. Soil cover with corn residue, stand establishment, and early growth are shown in table 1b. The soil cover in the row and stands were similar between both tillage treatments. The chisel system resulted in a one leaf greater early growth.

Corn grown with the no till system had higher ear leaf P levels and lower K levels. Although the K is close, both are greater than critical levels (.25 and 1.8% respectively). There was no differences in micronutrients due to tillage.

There were no differences in grain test weight, moisture, or yield due to tillage. It is somewhat surprising that grain moisture differences do not reflect the early difference in growth.

Evert Gilbertson Farm

At this site no till and chisel plowing systems are being evaluated for corn grown in wheat residue. Data is presented in tables 2a to 2d. Soil cover with wheat residue was similar in the row with both systems. There was no difference in stand or early growth due to tillage.

Grain test weight and yield were lower with the no till system. Yields were very low at this site probably in part due to a volunteer wheat problem.

Dave Holt Farm

Two types of planter mounted tillage tools are being evaluated under no till and chisel plowing conditions for corn planted into wheat residue at this site. Data is presented in tables 3a to 3d. Soil cover with wheat residue was measured at two times. The rolling finger residue wheels were much more effective at clearing the row area of residue than the 1" fluted coulter. This difference had a great influence on stand and early growth. The differences in stand were due to row cleaners only. Early growth was affected by row cleaner type and tillage. The effect of row cleaners was on average 3 times greater than the tillage affect. The response was much greater with the no till system.

There was no difference in tissue levels of N, P, and K due to tillage.

At harvest the average row cleaner effect on grain moisture was 3% and the tillage affect 5%. The impact on row cleaner type on grain moisture was only present under no till conditions. Final grain yields were 3 and 12 bushels lower for the fluted coulter and no

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[1] This project is supported by a grant from the Minnesota Department of Agriculture's Energy and Sustainable Agriculture Program, the Minnesota Extension Service, the Soil Conservation Service, and the Ottertail Soil and Water Conservation District.

[2] J.F. Moncrief and B.J. Johnson are Extension Soil Specialist and Assistant Scientist in the Department of Soil Science at the University of Minnesota, H.J. Stanislowski and B.P. Peterson are an Extension Educator and Plot Coordinator, Ottertail County, MN, P.M. Bongard is a free lance data processor.

till treatments respectively.

Dan Jennen Farm

At this site a no till and chisel plowing system are evaluated for soybean production in corn residue. Data is presented in tables 4a and 4b. Plant stands are higher than necessary but there is no difference in stand or grain yields due to tillage system.

Tom Jennen Farm-soybeans

At this site two types of no till drills for soybeans planted into corn residue without tillage are being evaluated. Data is presented in tables 5a and 5b. Plant stands are much higher than necessary. There was a small but statistically significant difference in grain yield favoring the Hiniker sweep type unit.

Orland Ohe Farm

At this site a no till and chisel plowing system was evaluated for wheat production into soybean residue. Data is presented in tables 6a and 6b. There was no difference in wheat stand, test weight, protein, or yield due to tillage.

Tom Jennen Farm-wheat

This comparison contrasts chisel plowing and no till systems for wheat planted into soybean residue. Data is presented in tables 7a and 7b. Although there was a difference in plant stand due to tillage, there was no difference in test weight, protein, or yield.

Table 1a. Cultural practices used at the Sjostrom Farm, 1993.

Tillage
Chisel plow 4" shovels at 18" spacing 10/20/92
Field cultivator (20') 7" sweeps at 6" spacing

No till
Planter JD7000 4 row 36" spacing, equipped with concave disc row cleaners and yetter ripple coulters for dry starter fertilizer.

Experimental Design
Randomized complete block with three replications.

Crop history
Previous crop corn, planting date 5/5/93
Variety Sigco 1885 (85 day)
Planting rate 25,300 seeds/A

Fertilizer
30-10-10, 150 lb/A; Liquid manure 4000 gal/A, 1993

SJOSTROM LIQUID DAIRY MANURE ANALYSIS

6/15/92

	Solids									Est		
	Total	Vtl	Fxd	pH	Tl	Og	Mn	Am	Nit	Avl[2]	P_2O_5	K_2O
	--percent--				--Pounds per 1000 gals.----							
1.	7.84	81	19	6.6	32	17	16	15	.36	21	17	32
2.	11.38	83	17	6.9	39	22	17	17	.02	24	24	34
Avg.	9.61	82	18	6.8	36	19	16	16	.19	22	21	33

10/26/93

							Est
	Solids	NH_4^+	NO_3^-	Tl	Og	Tl	Avl
	---%---	-----lbs/1000 gals.-------					
1.	6.86	16	-	16	16	32	20
2.	6.97	19	-	19	13	32	23
3.	6.94	-	-	-	-	33	-
Avg.	6.92	17	-	17	14	32	22

1. Organic nitrogen = Total nitrogen - Total mineral nitrogen.
2. Estimated available nitrogen =(Org.-N * .30) + Tot.Min.-N
3. Rate of 4,000 gals./acre applied on Oct. 26, 1993. It is assumed that all of the mineral N and 30% of the Org.N is available during the first year of application.

Soil Chappett-Sisseton loam complex 100% of plot area with slope 12-20% with a 15% average.

Weed control
5/20/93 2,4-D (1/8 pt.) + Banvel (1/2 pt.)
6/2/93 2,4-D (1 pt) + Banvel (1/2 pt)
6/12/93 Accent (2/3 oz)

Table 1b. Effect of tillage on crop residue (5/17), corn populations (6/21) and leaf numbers (6/30) at the Julian Sjostrom Farm, 1993.

	residue			corn	early
	in	betw	across	stand	growth
tillage	---------	%	--------	-p/a-	-lvs/p-
chisel	24.6a[1]	44.9a	29.0b	22.9a	8.7
no-till	19.4a	71.0a	55.0a	22.9a	7.8
Pr>F	0.50	0.17	0.01	1.0	0.10

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 1c. Effect of tillage on ear leaf concentrations and harvest data at the Julian Sjostrom Farm, 1993.

	Ear leaf			grain		
	N	P	K	tst wt	moist	yield
tillage	---------	%	--------	lb/bu	--%--	-bu/A-
Chisel	3.06a	0.356a	1.96a	48.5a	33.8a	48.5a
No-till	2.96a	0.384b	1.91b	44.3a	33.9a	45.2a
Pr>F	0.27	0.06	0.06	0.42	0.93	0.15

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 1d. Effect of tillage on ear leaf concentrations at the Sjostrom farm, 1993.

	Ca	Mg	Na	Al	Fe	Mn	Zn
tillage	----------	----------	----------	ppm	----------	----------	----------
Chisel	7772a[1]	2475a	13.3a	30.0a	115a	91.6a	20.4a
No-till	7832a	2568a	17.4a	33.0a	121a	94.3a	21.4a
Pr>F	.79	.52	.33	.71	.30	.73	.38

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 1e. Effect of tillage on ear leaf concentrations at the Sjostrom farm, 1993.

	B	Pb	Ni	Cr	Cd
	----------	----------	ppm	----------	----------
Chisel	6.55a[1]	2.16a	0.927a	1.08a	0.159a
No-till	6.28a	2.16a	0.917a	1.12a	0.164a
Pr>F	0.76	1.00	0.91	0.76	0.37

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 2a. Cultural practices used at the Evert Gilbertson Farm.

Tillage
Disc (21') 10/5/92
Field cultivator (21') 7" sweeps at 4" spacing
Planter JD7000 6 row, 30" spacing, concave clearing disc

Experimental Design Randomized complete block with three replications.

Crop history
Previous crop Wheat
Planting date 5/14/93
Variety Cenex 232
Planting rate 26,000 seeds/A
planter equipped with row cleaners-fingers

Soil
Chappett loam 70% of plot area; slope 4%
Chappett-Sisseton loam complex 25% of plot area; slope 9%
Friberg Weetown loam complex 5% of plot area; slope 2%

Fertilizer
Urea 200 lb/A spring applied

Weed control
Herbicide
Dual (4.5 lb) in 14" bands-volunteer wheat problem
Accent (2/3 oz)
Banvel (1/2 pt)

Table 2b. Effect of tillage on wheat residue (5/26), plant populations (6/14), and leaf numbers (6/14) at the Everett Gilbertson Farm.

	Wheat residue			Corn	early
	in	between	across	stand	growth
	-----------%---------			-p/a-	
Chisel	16.3a[1]	31.8b	23.1b	21.8a	10.4 a
No-till	23.4a	84.3a	65.3a	25.1a	9.8 a
Pr>F	0.16	<.001	0.008	0.31	0.17

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 2c. Effect of tillage on ear leaf concentrations (6/14) and harvest data at the Gilbertson Farm, 1993.

	Ear leaf			grain		
	N	P	K	weight	moist	yld
	----------%--------			lb/bu	%	bu/A
Chisel	1.88a	0.388a	1.52a	42.3a	28.9a	22.7a
No-till	1.84a	0.349a	1.43a	41.0b	29.8a	17.6b
Pr>F	0.57	0.30	0.24	0.057	0.48	0.034

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 2d. Effect of tillage on corn ear leaf concentrations at the Gilbertson farm, 1993.

	Ca	Mg	Na	Al	Fe	Mn	Zn	B	Cu	Cr
	------------------ppm-------------------									
Chisel	5610a[1]	2570a	7.09a	23.0a	70.0a	36.4a	15.2a	4.87a	2.82a	0.617a
No-till	5441b	2656a	7.32a	26.3a	68.7a	37.1a	13.2a	4.64a	2.91a	0.553a
Pr>F	.0070	.52	0.83	0.52	0.76	0.94	0.21	0.72	0.85	0.30

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 3a. Cultural practices used at the Holt Farm, 1993.

Tillage
Disc/Chisel 3.5" twisted shovels at 12" spacings
Field Cultivator (40')
with drag 7" sweeps at 4" spacings
Planter JD7000 8 row 30" spacing, concave disc row cleaners.
Row Cleaners: coulter-1" fluted Fingers-spiked wheel residue managers

Experimental Design Randomized complete block with split plots (tillage main plots and row cleaners for subplots).

Crop history
Previous crop Wheat
Planting date 5/3/93
Variety DeKalb 421
Planting rate 26,000 seeds/A in 30" rows
Planter John Deere 7000 with finger row cleaners and coulters

Soil Sandberg loamy sand on 100% of the plot area; slope 4-9%

Fertilizer
15-38-10 110 lb/A applied as starter
Anhydrous Ammonia100 lb/A side-dressed at 10 leaf stage

Weed control
No-till strips 1.2 pt/A pre-plant
All plots Accent (2/3 pt) + Banvel (1/2 pt)

Table 3b. Effect of tillage on wheat residue (7/10), corn plant population (6/2), and leaf numbers (6/25) on the Holt farm, 1993.

		Wheat residue							
		in row		between row		across row			
		5/16	7/10	5/16	7/10	5/16	7/10	stand	growth
		%						-p/a-	-lvs/p-
Chisel	Coulters	23.3cd		47.0bc		28.0b		23.7bc	8.2b
	Fingers	4.3d		27.3cd		25.7b		26.4ab	9.3a
No-till	Coulters	81.7ab	95.7a	93.3a	91.3a	90.3a	92.7a	23.2c	7.6b
	Fingers	7.0d	61.0b	97.0a	88.0a	80.0a	82.7b	26.9a	9.0a
Chisel				25.5b[1]		26.8b		25.1a	8.7a
No-till				69.8a		85.2a		25.1a	8.3b
Coulters				61.3a		59.2a		23.5b	7.9b
Fingers				33.9b		52.8b		26.6a	9.1a
In row				29.1b					
Between Row				66.2a					
Pr>F Tillage				0.06		0.06		1.0	0.060
	Cleaners	0.002	0.005	0.377		0.005	0.022	0.008	0.011
	tlgxcln	0.11		0.02				0.488	0.617
	tlgxpos	0.03							
	posxcln	0.005							
	tlgxposxcln	0.005							

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3c. Effect of tillage on corn ear leaf concentrations and harvest data (10/19) at the Dave Holt Farm, 1993.

		ear leaf			corn yield		
		%			lb/bu	--%--	bu/A
		N	P	K	ts wt	moist	yield
Chisel	Coulters	2.71a	0.309a	1.53a	41.3a	27.7c	55.2a
	Fingers	2.66a	0.314a	1.59a	40.7a	28.4bc	57.7a
No-till	Coulters	2.92a	0.334a	1.47a	39.0b	36.4a	42.6c
	Fingers	2.78a	0.324a	1.49a	41.3a	30.1b	47.2b
Chisel		2.68a	0.311a	1.56a	41.0a	28.0b	56.4a
No-till		2.85a	0.329a	1.48a	40.2b	33.2a	44.9b
Coulters		2.82a	0.321a	1.50a	40.2a	32.1a	48.9b
Fingers		2.72a	0.319a	1.54a	41.0a	29.2b	52.5a
Pr>F tillage		0.165	0.147	0.476	0.010	0.013	0.014
row cleaners		0.410	0.742	0.620	0.137	0.020	0.063
tillagexcln		0.686	0.320	0.740	0.029	0.009	0.514

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 3d. Effect of tillage on corn ear leaf concentrations at the Holt Farm, 1993.

		ppm												
		Ca	Mg	Na	Al	Fe	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
Chisel	Coulter	6566a[1]	2845a	34.0a	24.8a	93.4a	114a	20.6a	6.84a	5.32b	1.75ab	0.595a	0.802a	0.136a
	Fingers	6008a	2909a	18.2a	24.2a	91.1a	101a	19.2a	7.78a	5.72a	1.68b	0.576a	0.835a	0.125a
No-till	Coulter	6808a	2740a	38.2a	20.8a	93.7a	115a	21.6a	6.25a	4.71c	1.86a	0.682a	0.911a	0.149a
	Fingers	6255a	2594a	21.8a	20.5a	91.4a	101a	21.8a	6.60a	5.57ab	1.80ab	0.555a	0.738a	0.127a
Chisel		6287a	2877a	26.1a	24.5a	92.2a	107a	19.9a	7.31a	5.52a	1.71b	0.585a	0.818a	0.130a
No-till		6532a	2667a	30.0a	20.7a	92.6a	108a	21.7a	6.42a	5.14b	1.83a	0.618a	0.825a	0.138a
Coulter		6687a	2793a	36.1a	22.8a	93.5a	114a	21.1a	6.54a	5.01b	1.80a	0.638a	0.856a	0.142a
Fingers		6132b	2752a	20.0a	22.4a	91.3a	101a	20.5a	7.19a	5.64a	1.74a	0.565a	0.787a	0.126a
Pr>F tillage		0.610	0.584	0.425	0.170	0.925	0.94	0.42	0.40	0.001	0.002	0.18	0.72	0.39
row cleaners		0.026	0.770	0.146	0.586	0.519	0.19	0.41	0.39	0.03	0.32	0.21	0.40	0.11
tlgxclns		0.986	0.472	0.975	0.831	0.994	0.96	0.29	0.68	0.30	0.98	0.33	0.24	0.51

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 4a. Cultural practices used at the Dan Jennen Farm, 1993.

Tillage
Chisel plow 5/29/93
Field cultivator 7" sweep at 7" spacings
Multiweeded 4/22/93

Crop history
Previous crop Corn
Planting dates 5/29/93-Chisel plots
6/4/93-No-till plots (too wet on 5/29/93)
Variety Ozzie
Planting rate 110 lb/A

Soil Type Barnes-Langhi loam complex 80% of plot area; slope 6-12%
Langhi-Barnes loam complex 15% of plot area; slope 12-20%
Lake Park loam; 5% of plot area; slope 2%

Fertilizer
None

Weed control
No-till plots Roundup (2 pt) + 2,4-D (3/4 pt) 5/20/93 good weed control an all plots

Chisel plots Trust (trifluralin) (2 pt) 5/21/93
Storm (1.5 pt) 7/8/93

Table 4b. Effect of tillage on corn residue (6/5), soybean population (6/5), and harvest data (10/7) at the Dan Jennen Farm, 1993.

	Across Residue	Stand	Test	moist	yield
	--%--	plt/A	lb/bu	--%--	bu/A
Chisel	8.7b[1]	285.6a	59.0a	10.5a	27.1a
No-till	88.0a	264.3a	59.2a	10.2a	25.2a
Pr>F	0.001	0.280	0.874	0.490	0.353

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 5a. Cultural practices used in the soybean demonstration at Tom Jennen's Farm, 1993.

Tillage
None

Crop history
Previous crop Corn; planting date 5/17/93; variety Pioneer 9091; planting rate 100 lb/A
Planters John Deere 750 and Hiniker sweep or air seeder

Fertilizer
None

Weed control
Preplant Roundup (1 qt); Postemergence Pursuit (3 oz) + Fusion (8 oz); Spot spray Basagran (1 qt) on thistles

Table 5b. Effect of planter on corn residue (6/16), soybean population (6/14), and harvest data at the Tom Jennen Farm, 1993.

Tillage	across residue	stand	test	moist	yield
	--%--	plt/A	-lb/bu-	-%-	bu/A
Hinniker	86.9a	465a	55.7a	9.9a	22.4a
John Deere	86.3a	462a	56.0a	9.9a	20.8b
Pr>F	0.88	0.77	0.67	0.85	0.10

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 6a. Cultural practices used at the Ohe Farm, 1993.

Tillage
Chisel plow (fall) 4" twisted shovel at 15" spacings

Crop history
Previous crop Soybeans; planting date 5/4/93; variety Prospect; planting rate 2 bu/A
Drill Haybuster (7" rows) single smooth coulter preceding double disc openers

Soil

Formdale-Buse Udic Haploboroll-Udorthentic Haploboroll complex clay loam slope 2-6% avg 4% 60% of plot area
Formdale-Langhi clay loam Udic Haploboroll- complex slope 6-12% avg. 9% 20% of plot area
Aazdahl clay loam Aquic Haploboroll slope 0-3% avg. 1% 20% of plot area

Fertilizer
Urea 100 lb/A (4/30); 15-38-10 120 lb/A drill applied

Weed control
Herbicides: Tiller, 2,4-D (1/2 pt) & Banvel (1/8 pt)

Table 6b. Effect of tillage on soybean residue (5/3), wheat population (5/17), and harvest data (9/7) at the Orland Ohe Farm, 1993.

	Cover	Stand	test	moist	protein	yld
	--%--	plt/A	lb/bu	-----%-----		bu/A
Chisel	14.9b[1]	771a	53.2a	13.9a	15.3a	44.9a
No-till	56.0a	806a	53.8a	13.8a	14.4a	42.7a
Pr>F	0.002	0.44	0.21	0.97	0.21	0.21

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 7a. Cultural practices used in the wheat demonstration on Tom Jennen's Farm, 1993.

Tillage
Chisel plow 3" twisted shovels at 12" spacing
Cultivator 9" shovels at 6" spacing
Planter JD9350 6" row spacing (conventional drill)

Crop history
Previous crop Soybeans; planting date 4/20/93; Hybrid P2375; planting rate 2 bu/A

Fertilizer
18-46-0 150 lb/A
fall application anhydrous ammonia 100 lb/A
(fall applied with spike applicator)

Soil Type

Fordum fine sandy loam 30% of plot area
Sandbery loamy sand 30% of plot area
Langhei loam 40% of plot area

Weed control
Herbicide MCPA (3/4 pt/A)

Table 7a. Effect of tillage on residue (late April), wheat population (5/20), and harvest data (8/19) at Tom Jennen's farm, 1993.

	cover	stand	test	moist	protein	yld
	--%---	plt/A	lb/bu	-----%-----		bu/A
Chisel	17.6[1]a	1002a	56.2a	17.8a	14.0a	53.4a
No-till	21.3a	767b	56.0a	18.0a	13.8a	47.7a
Pr>F	0.39	0.007	0.81	0.87	0.42	0.30

[1]Data followed by the same letter in the same column are not significantly different at the 0.10 level.