Field Research in Soil Science 1993

(Soils Series #136)

Miscellaneous Publication 79–1993
Minnesota Agricultural Experiment Station
University of Minnesota

St. Paul, Minnesota

SOIL SERIES #136
Field Research in Soil Science

ACKNOWLEDGEMENTS

This 1993 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 1992 experiments and should be regarded on this basis. Since most of the data is from 1992 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.

Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Minnesota Agricultural Experiment Station or the University of Minnesota is implied.

Printed on recycled paper with agri-based inks.

Minnesota Agricultural Experiment Station
Branch Stations and Research Farms

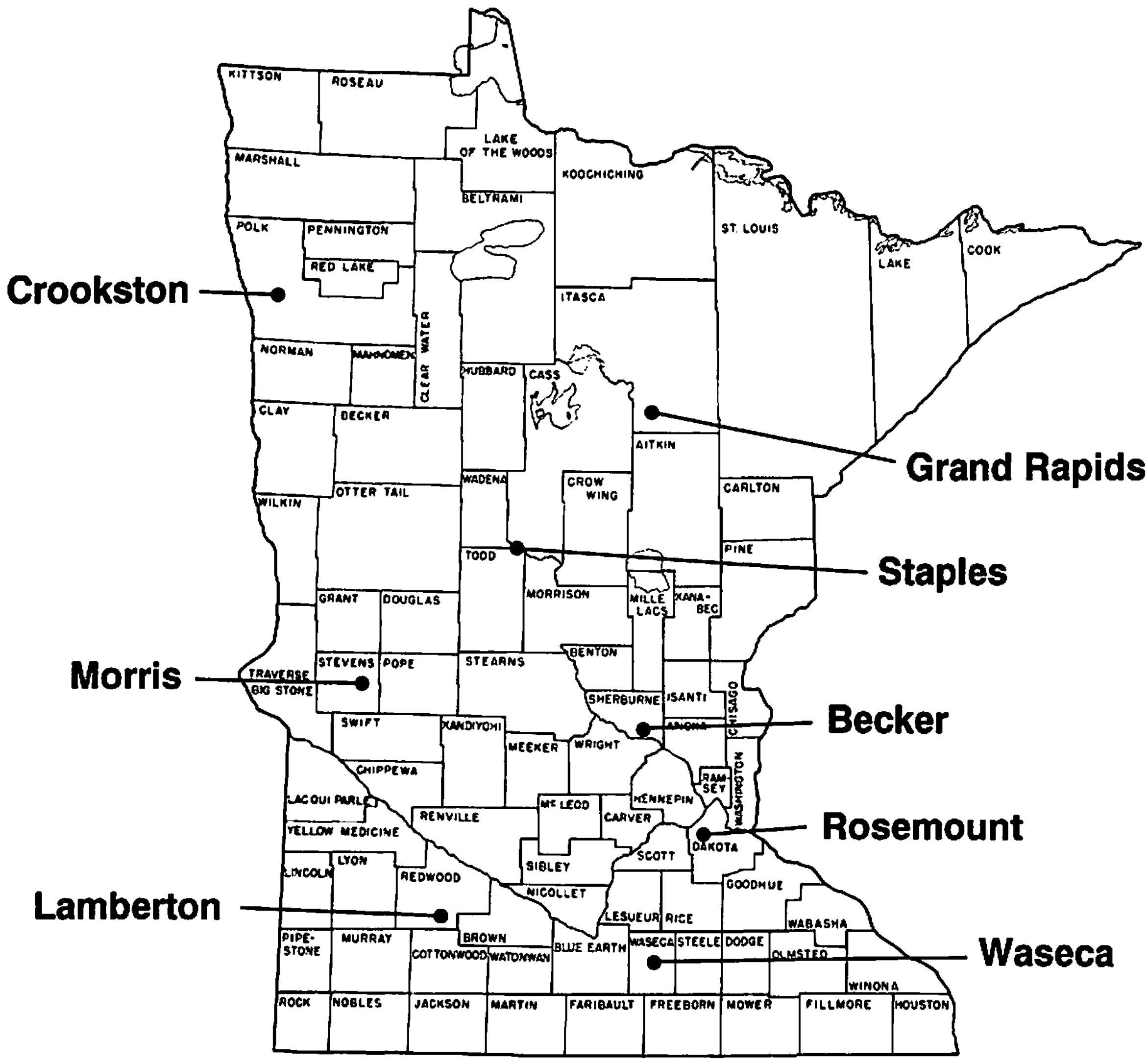


Table of Contents

Climate

Becker

Lamberton

Morris

Morris, Continued

Staples

Waseca

Westport

Corn

Forage Legumes

Nutrient Management

Farming By Soil

Agronomic Utilization of Waste Materials

Tillage

AGRICULTURAL CLIMATE SUMMARY FOR 1992[1]

M. W. Seeley, Greg J. Spoden, and D. G. Baker[2]

Planting Season: A cool wet April caused delays in small grain plantings this year, however, a very favorable first 10 days of May promoted timely planting of row crops across all parts of the state. Unfortunately, May was the only month of the 1992 growing season with significantly warmer than normal temperatures.

Frosts: Significant ground and air frosts occurred May 24-26 and most unusually during June 20-21 (summer solstice). There was some damage reported to corn fields, and an apparent interaction with soil cultivation in many places. For southern Minnesota, it was the first time since the late 19th century that a ground frost of this type had occurred so late in June. The growing season came to an end with the frosts of September 19-22 in southern counties.

Summer Conditions: The months of June through August averaged 4 to 6 degrees below normal, marking the coolest or second coolest (behind 1915) summer of this century. In fact, for the astronomical summer of June 20 (summer solstice) to September 22 (autumnal equinox) it was the coldest on record! This is evident in the near record negative departures of growing degree days which led to late crop maturation and high harvest moisture (see attached maps). The lost degree days translated to equivalent planting dates showed that a climatic analogy would be a normal growing season with corn planting dates of May 30th to June 7th (see attached table).

Water used in irrigation was down considerably from normal, as precipitation was generally adequate, and with the cool temperatures crop water needs were lower as well. Because cooler air is less able to hold water vapor than warmer air, the cool summer meant a reduction in the atmosphere's evaporative power. Estimates indicate that 1992 summertime evaporation was approximately 15 to 20 percent less than average, and 40 percent less than the summer of 1988. Lakes, wetlands, land surfaces, etc. gave up two to four inches less water to the atmosphere than during an average summer, and as much as eight inches less than the summer of 1988.

The most notable precipitation event of the late summer occurred September 15th and 16th when seven or more inches of rain fell in a narrow band stretching from Scott county, through Dakota county, and into Wisconsin. The heavy rain led to road closures, mudslides, and flooding in some small streams and rivers.

The 1992 Water Year precipitation map (attached) indicates a typical pattern of decreasing precipitation from southeast to northwest. Wet spots included extreme southeastern and northeastern Minnesota, and much of Scott County. Drier areas were found in west central and central sections of the state. Reduced summer evaporation, and the psychological impact of the summer's coolness may have created the impression of above normal precipitation. However, much of Minnesota received near normal Water Year precipitation, and for sections of central Minnesota, totals were well below the norm. Because the precipitation deficit in central Minnesota was counterbalanced by reduced evaporation, no serious hydrologic imbalance unfolded.

Fall Recharge and Winter Outlook: Precipitation during September thrugh November of 1992 was generally less than normal in the north, considerably above normal in the south, and mixed across central Minnesota. Thus across southern Minnesota counties, greater than normal soil moisture has been stored for the winter. Near normal to moderately below normal levels of soil moisture exist elsewhere.

---

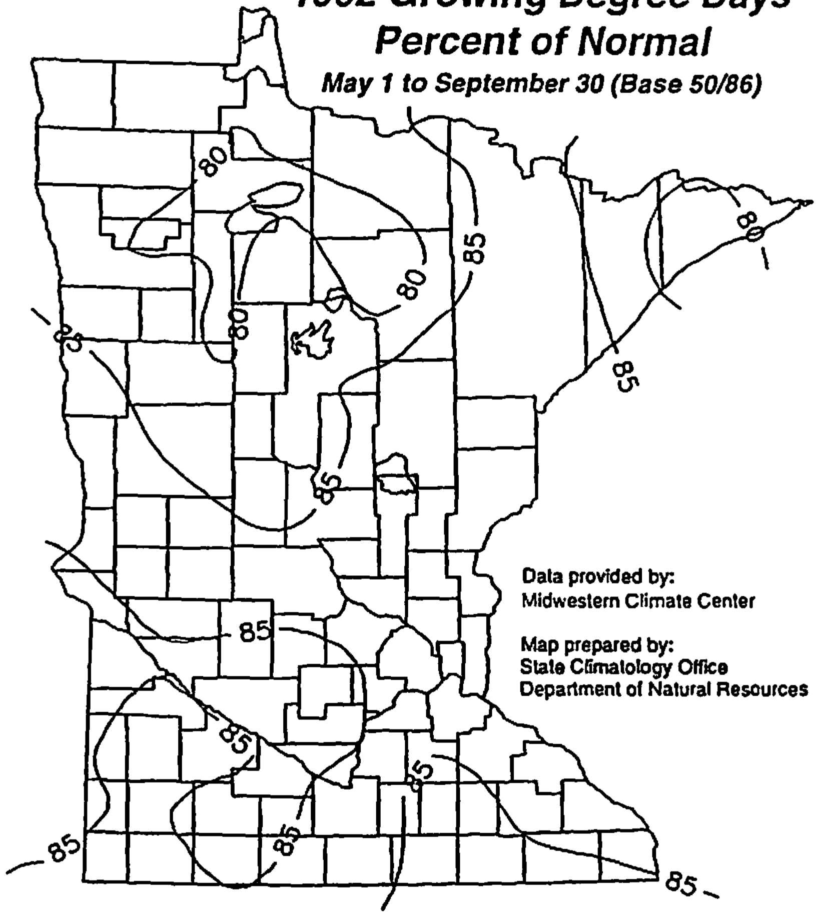
[1] *This was supported by the Minnesota Extension Service and the Soil Science Dept.*

[2] *M. W. Seeley, Professor, Soil Science Dept.; G. J. Spoden, Assistant State Climatologist, Dept. of Natural Resources, and D. G. Baker, Professor, Soil Science Dept.*

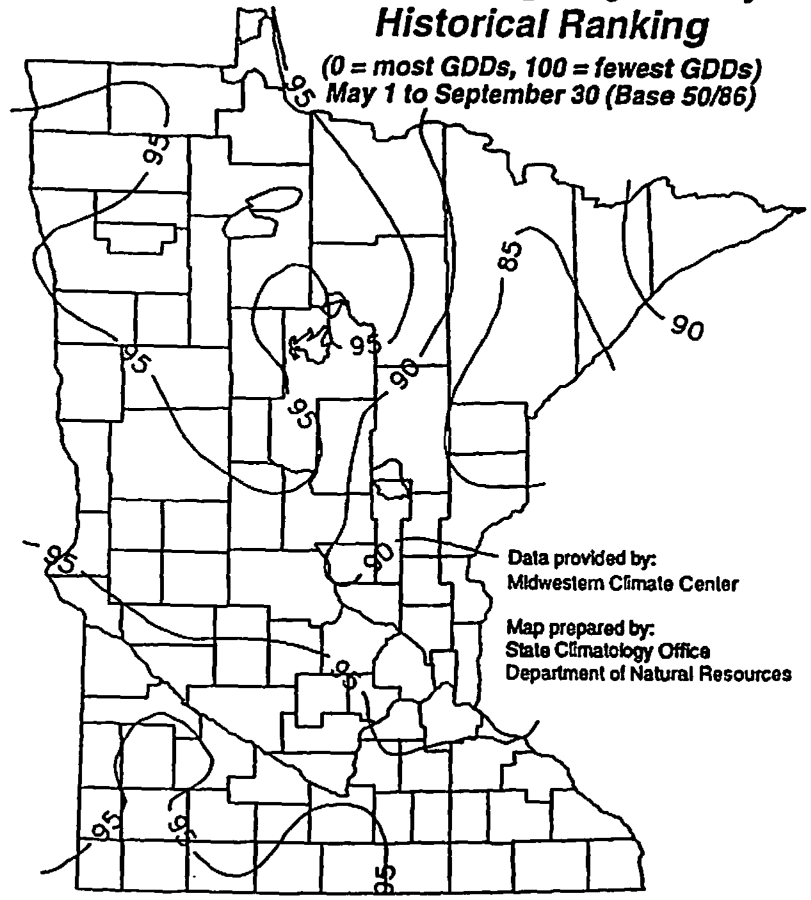
PERCENTAGE OF NORMAL GROWING DEGREE DAYS (BASE 50/86) FOR MAY THROUGH SEPTEMBER AND THE EQUIVALENT PLANTING DATE (CALCULATED AS A DEPARTURE FROM MAY 1) FOR SELECTED MINNESOTA LOCATIONS IN 1992. THE DATA SERVE TO ILLUSTRATE WHY ADAPTED CORN HYBRIDS EITHER DID NOT MATURE OR WERE HIGH MOISTURE AT HARVEST.

LOCATION	PCT OF NORMAL GDD IN 1992	EQUIVALENT PLANTING DATE (DEPARTING FROM MAY 1)
ARGYLE	86	5/30
FOSSTON	82	6/7
HALLOCK	81	6/8
BROWNS VALLEY	83	6/6
CANBY	84	6/6
ALEXANDRIA	87	5/29
FERGUS FALLS	86	5/31
WADENA	82	6/4
GAYLORD	84	6/7
HUTCHINSON	83	6/8
ST CLOUD	88	5/30
WILLMAR	85	6/3
JORDAN	86	6/1
AITKIN	88	5/29
CAMBRIDGE	84	6/4
BRAINERD	86	6/1
MSP	86	6/1
MARSHALL	88	5/29
WORTHINGTON	88	5/30
PIPESTONE	85	6/2
REDWOOD FALLS	86	6/2
TRACY	86	6/1
LAMBERTON	87	5/31
ALBERT LEA	84	6/3
FARIBAULT	84	6/2
MANKATO	86	6/1
FAIRMONT	88	5/29
SPRINGFIELD	85	6/2
WINNEBAGO	88	5/30
GRAND MEADOW	84	6/4
ROCHESTER	86	6/2
WINONA	86	6/3
CALEDONIA	85	6/2

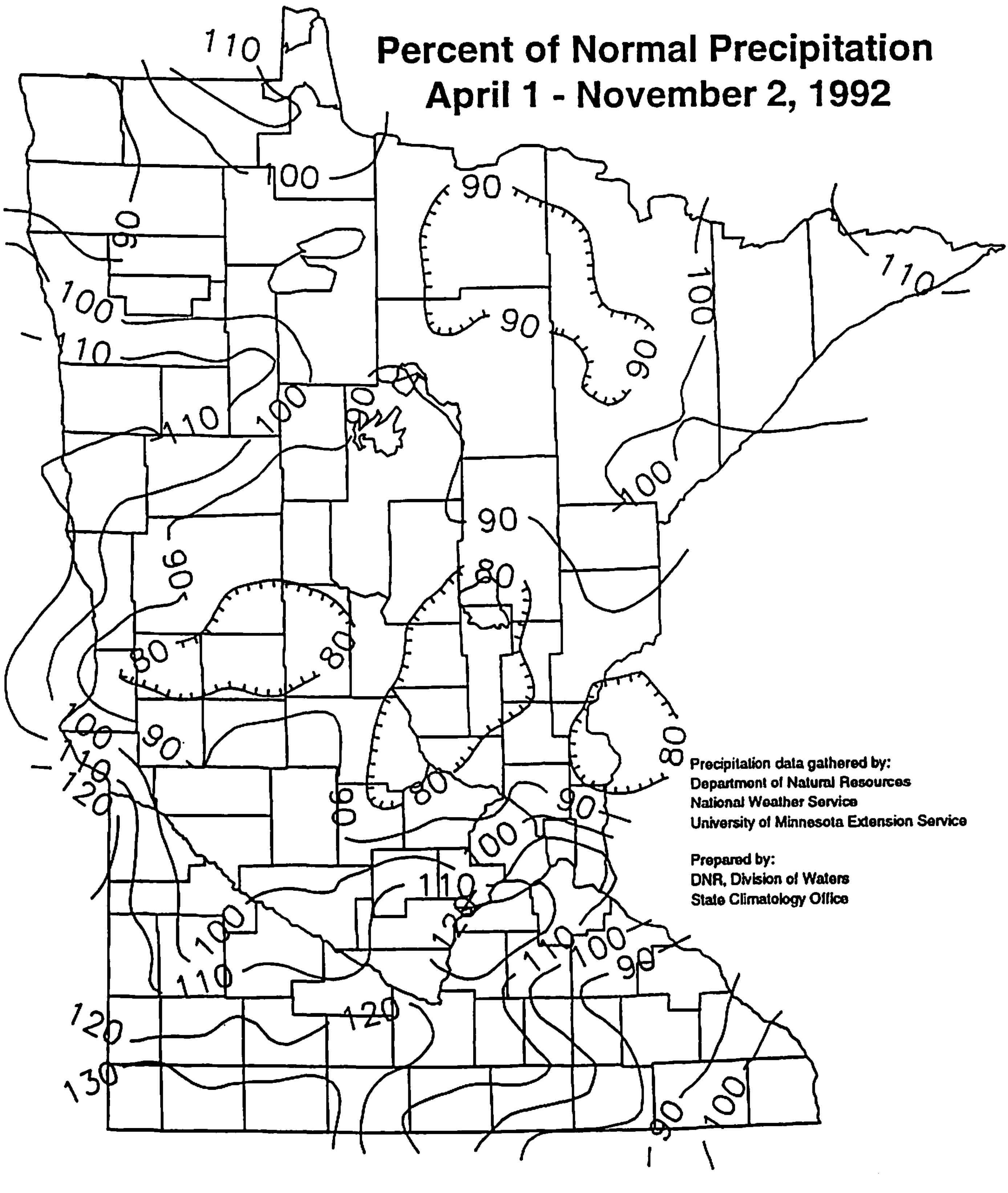
1992 Growing Degree Days
Percent of Normal
May 1 to September 30 (Base 50/86)



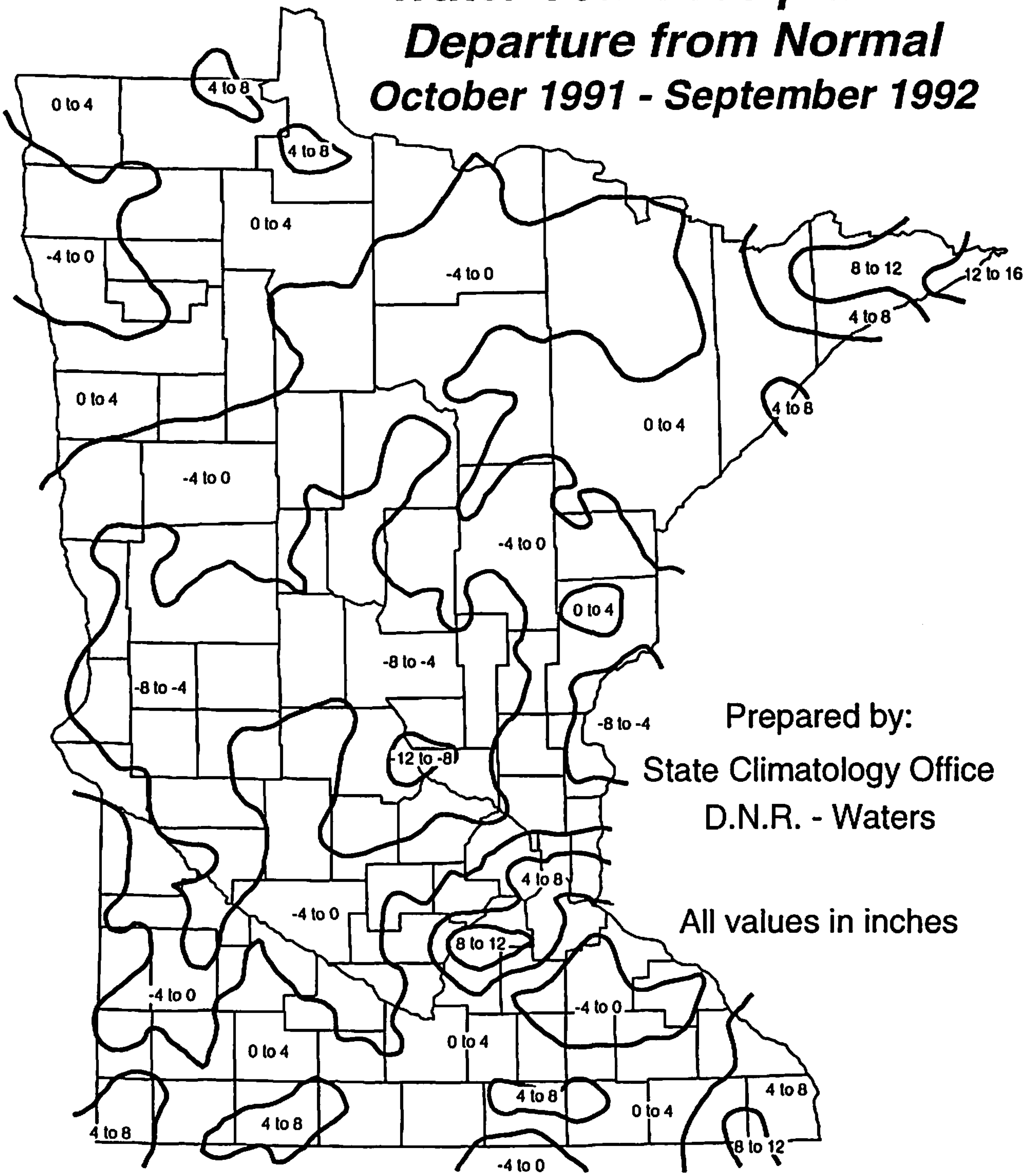
1992 Growing Degree Days
Historical Ranking
(0 = most GDDs, 100 = fewest GDDs)
May 1 to September 30 (Base 50/86)



A ranking of 95 means that only 5 out of 100 years had fewer growing degree days than 1992.


Percent of Normal Precipitation
April 1 - November 2, 1992
Precipitation data gathered by:
Department of Natural Resources
National Weather Service
University of Minnesota Extension Service
Prepared by:
DNR, Division of Waters
State Climatology Office

Water Year Precipitation Departure from Normal
October 1991 - September 1992



Prepared by:
State Climatology Office
D.N.R. - Waters

All values in inches

Data source: National Weather Service, Soil & Water Conservation Districts, DNR Forestry, Metro Mosquito Control, Back Yard Rain Gauge Network, Future Farmers of America, Deep Portage Conservation Reserve, Minnesota Association of Watersheds

1992 SOIL MOISTURE RESULTS[1]

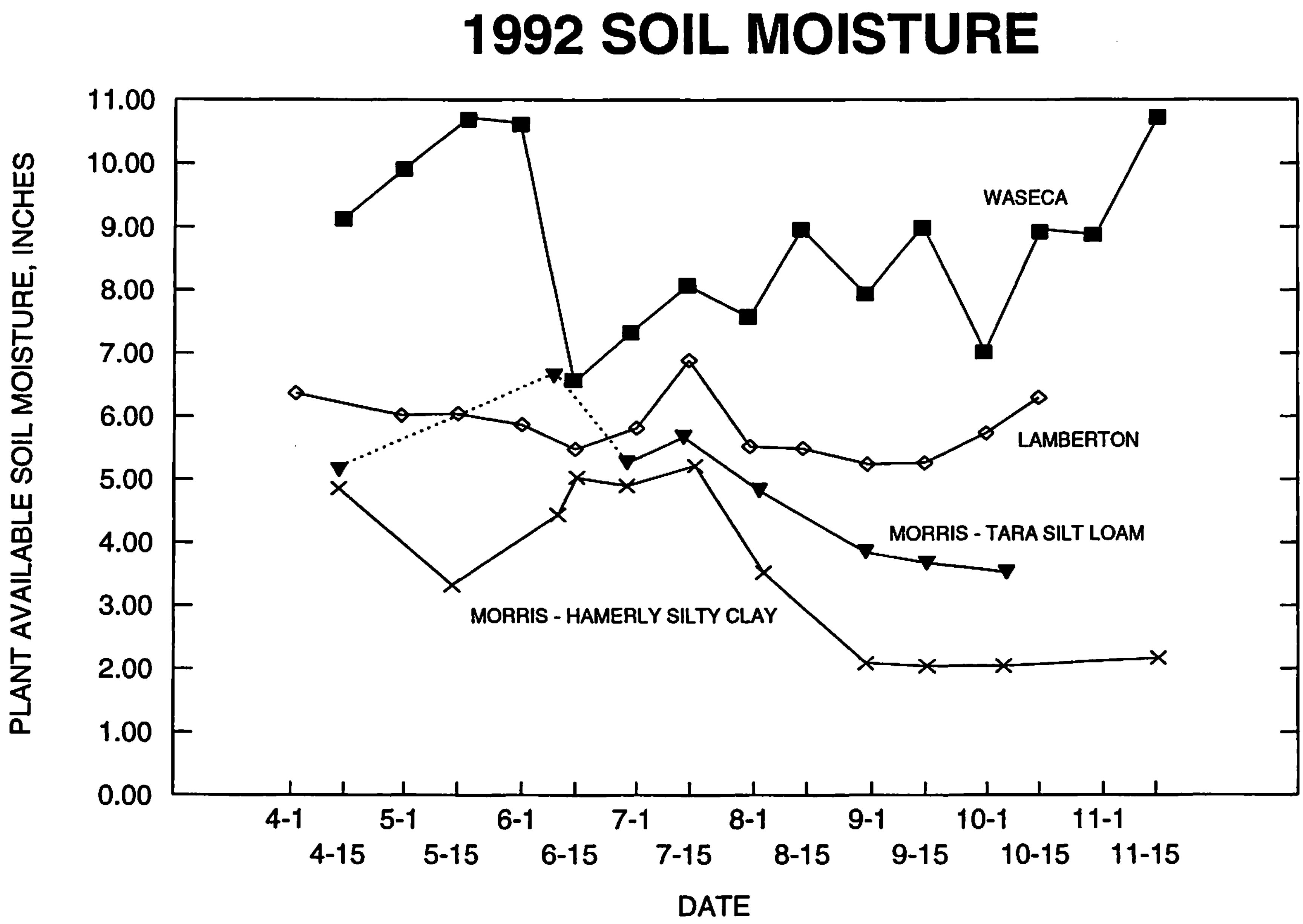
S. Evans, G. Randall, D. Fuchs, D. Ruschy, and D. Baker[2]

Results of the 1992 season are shown in the accompanying figure. Except for a brief period in late May, Waseca remained in good moisture condition, and it ended the year with nearly full profile. Lamberton's historic mid-June soil moisture maximum was not reached until about July 15. An unusual feature is that the precipitation was such that the soils did not experience the usual drawdown that has been so typical in the past. In other years the minimum of about 2.5-3.0 inches would be reached in late August or early September. The last sample at Lamberton indicates a better than average content with 6.3 inches in mid-October instead of the 4-inch average.

At Morris the typical mid-season drawdown of soil moisture supplies was delayed about two weeks. And, unlike the other two stations, the soil moisture supplies do not exhibit the typical end-of-the-season recharge.

[1]*This project was supported by the Minn. Agric. Exp. Sta.*

[2]*Professor, West Central Experiment Station, Professor, Southern Experiment Station, Scientist, Southwest Experiment Station, Asst. Scientist, Soil Science Dept., and Professor, Soil Science Dept., respectively.*


1992 SOIL MOISTURE
PLANT AVAILABLE SOIL MOISTURE, INCHES
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4-1
5-1
6-1
7-1
8-1
9-1
10-1
11-1
4-15
5-15
6-15
7-15
8-15
9-15
10-15
11-15
DATE
WASECA
LAMBERTON
MORRIS - TARA SILT LOAM
MORRIS - HAMERLY SILTY CLAY

PRECIPITATION NETWORK DENSITY REQUIREMENTS FOR SHORT TERM ANALYSIS[1]

Rodney R. Swerman, Donald G. Baker, and David L. Ruschy[2]

Precipitation not only is one of the most important climatological elements, but it is also the most highly variable in terms of amount and areal distribution. Thus, in order to arrive at an acceptable estimate of precipitation in a given area, the density of the gauges is important. The objective of this study was to determine the number of gauges to be recommended for areas of varying sizes. The results are based on the samplnig of different kinds of daily precipitation events with networks of varying density of gauges.

INTRODUCTION

Knowing the variability of rainfall from a single storm over a small area is of concern, for example, to drainage engineers and to those involved in small watershed runoff simulations. Accurate estimates of the amount and areal extent of a storm during a short period are of obvious importance to these and other related interests.

Within Minnesota, the National Weather Service (NWS) has a cooperative observer network of about 175 stations. With a land area of some 84,068 square miles each station in Minnesota represents an average of 480 square miles. An earlier study determined that this density was inadequate for total daily precipitation sampling for time periods of a single month to a season.

Study Area

The study area chosen measures 33 miles on a side or 1089 sq. miles, large enough to capture a single storm event, yet small enough to be comparable to certain watersheds. The test area selected is centered on the Twin Cities Metropolitan area, and includes all of Ramsey Co., the southern third of Anoka Co., the eastern two-thirds of Hennepin Co., the extreme eastern edge of Carver Co., the NE corner of Scott Co., the northern half of Dakota Co., and the western half of Washington Co. Within this 1089 sq. mile area there are as many as 150 rain gauge reports for an individual summertime rainfall event. This gives a density of 1 gauge per 7.3 miles, certainly sufficient for most analyses. Five storm events were selected to represent 5 different precipitation event types. All had good to excellent temporal isolation as determined from the weather records of the St. Paul Campus Observatory.

Networks were randomly selected with a specific number of rain gauges for the five storm events to determine the accuracy with which the reduced networks represent the rainfall pattern within the study area. Networks of 1, 3, 5, 9, 16, 25, 35, and 50 gauges were randomly selected from the complete network data set for each precipitation event. For sample networks of more than 50 gauges, the number of gauges was increased by increments of either 15 or 20 gauges, i.e., 50, 65, 80,..., or 50, 70, 90,..., up to the full density available for each event.

For each network density used in this study 10 sample networks were randomly selected from the full network. In effect the same storm was recorded by 10 different networks of 3 gauges, then 10 networks of 5 gauges, then 10 networks of 9 gauges, and son, up to the full density. A mean areal rainfall estimate was determined from each of these network densities. A sample size of about 10 was necessary in order to determine a reliable average and a standard deviation of the mean areal rainfall estimates at each network density.

The full density network for each precipitation event was analyzed and used as the "true" estimate of the mean areal rainfall. The reduced networks of 1, 3, 5, 9, 16,... gauges were tested against the "true" estimate to determine how accurately a network of a limited number of rain gauges can estimate the mean areal rainfall within the study area.

ANALYSIS

Once the series of reduced density networks were randomly selected, each network's rain gauge data were gridded onto the entire study area. The gridding method used was the kriging technique, as adapted by Golden Software, Inc. (1983).

---

[1]*This project was supported by the Minn. Agr. Exp. Sta.*

[2]*Former graduate student Soil Science Dept., and Professor and Assistant Scientist, Soil Science Dept., St. Paul, respectively.*

For this study, the data were gridded to a 33 by 33 grid field, or 1089 gridpoints. This was done to give one gridpoint and rainfall estimate per square mile. For the mean areal rainfall estimate the average of these 1089 gridpoints was determined. And for each network density the 10 mean areal rainfall estimates were then averaged and the standard deviation calculated. From the standard deviation the 95% confidence interval was calculated for the mean areal rainfall estimate at each network density. An example is shown in Fig. 1.

RESULTS AND DISCUSSION

Fig. 1 depicts the average mean areal rainfall estimates (MARE) and a 95% confidence interval for each estimate as the network density was increased for each event. Several interesting features are found in Fig. 1. For the low network densities, networks of 1 to 9 guages, (> 100 sq. miles/gauge), MARE are very unreliable. As the number of gauges in the network for a 1089 sq. mile area is increased from a density of more than 100 sq. miles per gauge to about 20 sq. miles per gauge (a 9 to a 50 gauge network), the MARE stabilizes and the confidence interval surrounding the estimate narrows, as expected, for all event types.

Increasing the network from 50 to 70 gauges, (22 sq. miles per gauge to 15.5 sq. miles per gauge), produces the last noticeable increase in the accuracy of the MARE for almost all events. In general, increasing the number of gauges in the network above 70 gave little if any increase in accuracy of the MARE.

Results from the analysis of these five storm cases show that different storm types do require slightly differing rain gauge densities in order to adequately detect, sample, and determine an accurate mean areal estimate of the rainfall. The ideal or "true" network density required for cyclonic-type events is on the order of 1 gauge per 22 sq. miles, while for an intense localized event of the convective-type the ideal density is near 1 gauge per 22 sq. miles, while for an intense localized event of the convective-type the ideal density is near 1 gauge per 13 sq. miles.

RECOMMENDATIONS

Among the five event types studies there seems to be a relationship between the rainfall intensity, the rainfall totals, and the number of gauges required within a given area to adequately detect and determine an accurate MARE. In general, as the rainfall rate (inches/hr, intensity) increases, so too does the spatial variability of the precipitation pattern. Increasing the spatial variability of a short term event will increase the density of rain gauges required to maintain the same degree of accuracy in determination of a MARE.

It is essential to note that as the mean rainfall and the size of the target area increase, the density (sq. miles/gauge) requirement decreases, although the total number of gauges increases. In general, the smaller the target area and the greater the detail required, the higher is the network density requirement. Data from Beebe (1952), Causey (1953), Baker and Kuehnast (1973) and this study are plotted in Figure 2. They show the ideal density of a network that is suggested for a "true" sample of daily total rainfall for any area up to 100,000 sq. miles. Results can be expected to vary a bit from month to month, but Figure 2 provides a good first approximation.

Our recommendations can probably be applied to most areas of the state, since short term precipitation patterns and storm characteristics do not differ appreciably across most of Minnesota. Only in some portions of northern and northeastern Minnesota are we unsure of the applicability of our recommendations. This is because some of these areas are currently so very poorly represented by rain gauge reports that their true storm characteristics are yet to be determined.

REFERENCES

Baker, D. G. and E. L. Kuehnast. 1973. *Climate of Minnesota, Part VII. Areal Distribution and Probabilities of Precipitation in the Minneapolis-St. Paul Metropolitan Area*, Minn., Agr. Exp. Sta. Bull. 293.

Beebe, R. G. 1952. The Distribution of Summer Showers Over a Small Area. *Mon. Weather Rev.*, 80:95-98.

Causey, O. Y. 1953. The Distribution of Summer Showers Over Small Areas. *Mon. Weather Rev.*, 81:111-114.

Golden Software, Inc. 1983. *Golden Graphics System*, Golden, Colorado.

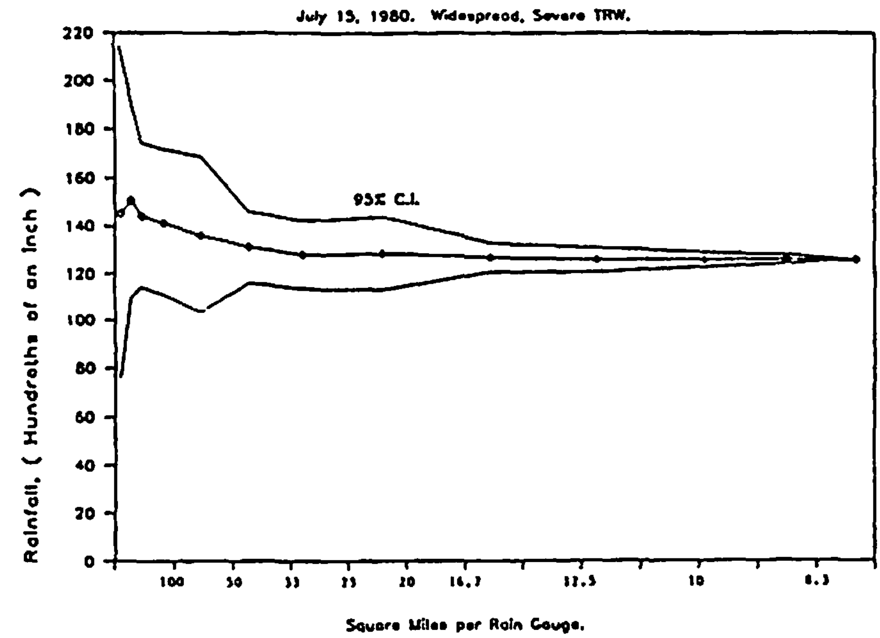


Fig. 1. Mean areal rainfall estimate. Each mean and standard derivation is calculated from 10 random samples at each density of rain gages. 95% C.I. is the 95% confidence interval.

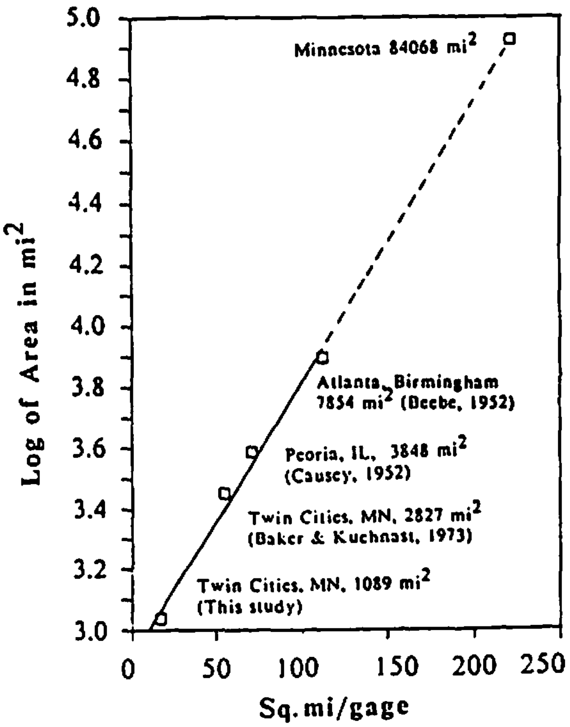


Fig. 2. Ideal sampling densities (square miles/rain gage) required for indicated areas. (A log of 3 = 1,000 mi^2, log 4 = 10,000 mi^2, and log 5 = 100,000 mi^2.)

CALCIUM NITRATE AS A SOURCE OF CALCIUM AND NITROGEN FOR POTATO PRODUCTION[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 calcium nitrate as a calcium and nitrogen source for potato production. The effects of potassium nitrate on potato production were also examined. Total and marketable Russet Burbank yields obtained when calcium nitrate was provided were similar to those when urea or potassium nitrate was used. Calcium nitrate increased calcium concentrations in leaf tissue at mid-season. Potassium nitrate increased leaf potassium. Calcium nitrate increased calcium concentrations in tuber skin, especially when post-hilling applications were made. None of the treatments tested significantly affected tuber flesh (medulla) calcium. Potassium nitrate did not affect tuber skin or flesh concentrations of potassium.

Calcium is a nutrient that has been implicated in improved storage qualities of potatoes. Yield increases have also been reported with calcium applications when potatoes are grown on low Ca soils. One of the most readily available forms of calcium is calcium nitrate; however, the effect of this calcium source on potato production in Minnesota has not been evaluated. The objective of this research was to determine the effects of calcium nitrate on potato yield, nutrient composition, and tuber quality under irrigated conditions. The results presented are from the second year of a two year study.

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 - 5.3; Organic Matter - 3%; Bray P1 - 34 ppm; NH_4OAc K, Ca, Mg - 79, 522, 80 ppm, respectively; 2N KCl nitrate-N (0-2ft) - 19 lb/A. The previous crop was rye. The cultivar 'Russet Burbank' was planted April 20, 1992. Prior to planting, 230 lbs 0-0-22/A were broadcast and incorporated over the entire field. At planting, all plots received 750 lb 8-10-30 as a band with urea as the N source. There were six treatments arranged in a randomized complete block design with four replications. The six treatments were:

	Time of application					
Treatment	Planting	Emergence	Hilling	3 weeks post-hilling	5 weeks post-hilling	Total N applied
	N rate (lb/A) and source					lb N/A
1.	60 Urea	75 Urea	75 Urea	0	0	210
2.	60 Urea	75 Urea	75 Ca Nit	0	0	210
3.	60 Urea	40 Urea	75 Ca Nit	35 Ca Nit	0	210
4.	60 Urea	40 Urea	35 K Nit	35 K Nit	35 K Nit	205
5.	60 Urea	40 Urea	35 Urea	35 Urea	35 Urea	205
6.	60 Urea	40 Urea	35 Ca Nit	35 Ca Nit	35 Ca Nit	205

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. Leaf samples were collected on July 1 and August 3 for nutrient analyses. Plots were harvested on September 9 and tubers were separated according to size. Subsamples of tubers were also collected for specific gravity determinations and nutrient analyses. Total leaf nitrogen was determined using Kjeldahl procedures (with nitrate reduction) and other elements in leaf and tuber tissue were determined on ashed samples using ICP techniques. Petiole nitrate was determined on water extracts.

RESULTS:

All treatments tested resulted in statistically similar potato yields (Table 1). However, treatments with posthilling applications, regardless of nitrogen source, tended to have lower total yields. Specific gravity was high, but not affected by treatment.

At the first sampling date, leaf nitrogen concentrations and petiole nitrate concentrations were highest when all the nitrogen was applied by the hilling stage (Table 2). This result is not surprising, since the posthilling nitrogen treatments had not yet been applied. By the second sampling date, the highest petiole nitrate levels were in the post-hilling treatments (Table 3). Leaf concentrations of phosphorus, iron, zinc,

[1] Partial support for this project was provided by WGM/Hydro and Cedar Chemical Corp.
[2] Extension Soil Scientist and Junior Scientist, Department of Soil Science

copper, and boron were not affected by treatment. Leaf calcium concentrations increased with calcium treatment at the first sampling date, but were not affected by treatment by the second sampling date. Leaf potassium increased with application of potassium nitrate at the second sampling date. Leaf magnesium was lowest when potassium nitrate was used. Leaf manganese tended to be lower when nitrogen was higher. In other words, high nitrogen tended to depress leaf manganese concentrations.

Tuber skin calcium concentrations were 4-5 times higher than calcium concentrations in tuber flesh (Table 4). Calcium nitrate tended to increase tuber calcium compared to urea or potassium nitrate, especially when the calcium nitrate was applied post-hilling. It is interesting to note, however, that post-hilling applications of nitrogen, regardless of nitrogen source, tended to increase tuber skin calcium compared to application of all the nitrogen by hilling. Calcium levels in tuber flesh were not significantly affected by treatment. Potassium concentrations in tuber skin and flesh were not affected by treatment.

Table 1. Comparative effects of calcium nitrate, potassium nitrate, and urea on 'Russet Burbank' potato yield and specific gravity. (Becker, 1992)

	Treatment											
	Time of application						Tuber size					Specific
Trt	Planting	Emergence	Hilling	3wk PH[1]	5wk PH	Knobs	<3 oz	3-7 oz	7-14 oz	<14 oz	Total	Gravity
-#-	N rate (lb N/A) and source[2]					cwt/A						
1	60 U	75 U	75 U	0	0	40.6	81.6	284.0	149.9	10.1	566.3	1.0921
2	60 U	75 U	75 C	0	0	25.8	91.2	310.5	124.6	4.3	556.4	1.0924
3	60 U	40 U	75 C	35 C	0	43.1	94.1	299.7	118.5	6.1	561.5	1.0930
4	60 U	40 U	35 K	35 K	35 K	23.2	77.5	275.5	130.7	16.3	523.2	1.0915
5	60 U	40 U	35 U	35 U	35 U	36.4	84.4	299.9	113.0	8.1	541.7	1.0921
6	60 U	40 U	35 C	35 C	35 C	33.5	89.7	277.9	109.4	6.2	516.7	1.0905
Significance						NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant
[1]wk PH = weeks post hilling
[2]U = urea, C = calcium nitrate, K = potassium nitrate

Table 2. Comparative effects of calcium nitrate, potassium nitrate, and urea on nitrate nitrogen content of petioles, and elemental concentrations in leaves (petioles + leaflets), sampled July 1. (Becker, 1992)

Treatment[1]	dry weight petiole NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	ppm	%					ppm				
1. (60U, 75U, 75U, 0, 0)	15231	5.76	0.36	4.26	0.67	0.56	115	256	27	11	26
2. (60U, 75U, 75C, 0, 0)	18426	5.84	0.39	4.28	0.77	0.57	118	326	29	12	25
3. (60U, 40U, 75C, 35C, 0)	14242	5.54	0.37	4.44	0.85	0.61	119	315	28	11	27
4. (60U, 40U, 35K, 35K, 35K)	7900	5.19	0.36	4.62	0.68	0.55	107	258	28	11	27
5. (60U, 40U, 35U, 35U, 35U)	6690	4.94	0.32	4.40	0.67	0.53	108	265	28	10	27
6. (60U, 40U, 35C, 35C, 35C)	9227	5.15	0.36	4.34	0.82	0.58	118	264	27	11	26
Significance	**	**	NS	NS	*	NS	NS	*	NS	NS	NS
LSD (5% level)	2169	0.41	--	--	0.14	--	--	56	--	--	--

NS = not significant; *, ** = significant at 5% and 1%, respectively.
U = urea, C = calcium nitrate, K = potassium nitrate
[1]Respective timing of N applications are: (planting, emergence, hilling, 3 weeks post-hilling, 5 weeks post-hilling)

Table 3. Comparative effects of calcium nitrate, potassium nitrate, and urea on nitrate nitrogen content of petioles, and elemental concentrations in leaves (petioles + leaflets), sampled August 3. (Becker, 1992)

Treatment[1]	dry weight petiole NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	-----ppm-----			%					ppm		
1. (60U, 75U, 75U, 0, 0)	1877	3.47	0.19	4.31	1.43	0.72	68	350	9	47	25
2. (60U, 75U, 75C, 0, 0)	581	3.54	0.20	4.42	1.51	0.73	71	321	9	52	25
3. (60U, 40U, 75C, 35C, 0)	1585	3.52	0.20	4.47	1.47	0.68	68	291	9	29	26
4. (60U, 40U, 35K, 35K, 35K)	5250	3.69	0.20	5.42	1.25	0.64	66	221	9	85	26
5. (60U, 40U, 35U, 35U, 35U)	7729	3.76	0.19	4.39	1.45	0.83	67	250	9	45	25
6. (60U, 40U, 35C, 35C, 35C)	5719	3.82	0.20	4.15	1.55	0.76	68	213	10	39	25
Significance	**	NS	NS	**	NS	**	NS	*	NS	NS	NS
LSD (5% level)	3258	--	--	0.43	--	0.09	--	88	--	--	--

Elemental Concentration in Leaves: N, P, K, Ca, Mg (%); Fe, Mn, Zn, Cu, B (ppm).

NS = not significant; *, ** = significant at 5% and 1%, respectively.
U = urea, C = calcium nitrate, K = potassium nitrate.
[1]Respective timing of N applications are: (planting, emergence, hilling, 3 weeks post-hilling, 5 weeks post-hilling).

Table 4. Comparative effects of calcium nitrate, potassium nitrate, and urea on calcium and potassium concentrations in tuber skin and flesh at harvest. (Becker, 1992)

Treatment[1]	Calcium concentration Skin	Calcium concentration Flesh	Potassium concentration Skin	Potassium concentration Flesh
	-- ppm dry weight --		--- ppm dry weight ---	
1. (60 U, 75 U, 75 U, 0, 0)	842	166	34492	17098
2. (60 U, 75 U, 75 C, 0, 0)	921	182	32815	17248
3. (60 U, 40 U, 75 C, 35 C, 0)	1021	189	35298	17111
4. (60 U, 40 U, 35 K, 35 K, 35 K)	944	180	35357	17628
5. (60 U, 40 U, 35 U, 35 U, 35 U)	1021	213	36141	17002
6. (60 U, 40 U, 35 C, 35 C, 35 C)	1097	198	35183	16744
Significance	*	NS	NS	NS
LSD (5% level)	175	--	--	--

NS = nonsignificant; * = significant at 5%.
U = urea, C = calcium nitrate, K = potassium nitrate
[1]Respective timing of N applications are: (planting, emergence, hilling, 3 weeks post-hilling, 5 weeks post-hilling).

NITROGEN FERTILIZATION STUDIES ON IRRIGATED POTATOES: NITROGEN USE, SOIL NITRATE MOVEMENT, AND PETIOLE SAP NITRATE ANALYSIS FOR PREDICTING NITROGEN NEEDS - 1992[1]

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

ABSTRACT: The second 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 calibrate a quick petiole nitrate sap test for determining nitrogen status of the crop and predicting nitrogen needs. Increasing the rate of nitrogen in the starter fertilizer up to 120 lbs N/A at planting did not affect total or marketable yields, but did result in greater nitrate leaching. Delaying nitrogen application until emergence had no detrimental effect on yield, but did reduce nitrate leaching. At equivalent rates and times of application, use of urea as the nitrogen source resulted in less nitrate leaching than ammonium nitrate with similar effects on yield. Slow release fertilizer (Nutralene) resulted in the least nitrate movement, but yields tended to be lower when compared to equivalent rates of ammonium nitrate. Low rates of N fertilizer applied up to hilling, followed by two post-hilling applications of N resulted in lower yield than if all the N was applied by hilling. Nitrate leaching, however, was less when extended applications were used. In a low leaching year such as 1992, potatoes seem to benefit from higher applications of fertilizer N applied at emergence and hilling. Petiole sap nitrate concentrations were highly correlated with conventional petiole analysis, suggesting that quick tests can determine nitrogen status of the crop.

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 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 second year of a two 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, 6.7; organic matter, 2.5%; phosphorus, 33 ppm; potassium, 106 ppm; sulfur, 4 ppm. Residual nitrate-N in the top 3 feet of soil was 20 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 27, 1992 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
1) Control	0	0	0	0
2) Ammonium nitrate	0	120	120	0
3) Ammonium nitrate	40	100	100	0
4) Ammonium nitrate	80	80	80	0
5) Ammonium nitrate	120	60	60	0
6) Ammonium nitrate	80	80	0	0
7) Slow Release[1]	80	80	0	0
8) Ammonium nitrate	40	40	40	0
9) Ammonium nitrate	40	40	40	based on sap test
10) Urea	80	80	80	0

[1]Slow release fertilizer was Nutralene (40-0-0).

[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. Assnt., Ext. Soil Sci., Prof., Prof., and Jr. Sci., respectively, Dept. Soil Sci.

Nitrogen applied at planting was banded with the P and K fertilizer. Nitrogen applied at emergence (May 28) 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 treatment #9 were applied on June 25 and July 17. Applications were made by broadcasting ammonium nitrate over the plot by hand and then irrigating in. The June 25 application was based on a sap nitrate-N critical value of 1300 ppm. The July 16 application was based on a critical sap value of 900 ppm.

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 21.5 inches and was supplemented with 8.6 inches of irrigation. The nitrate-N concentration in the irrigation water averaged 10 ppm. Given that 8.6 inches of irrigation were applied, approximately 20 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. NOTE: In contrast to the previous year, nitrate-N concentrations were accurately determined using nondiluted sap. The reason for inconsistent results using nondiluted sap in 1991 is believed to be due to a faulty membrane.

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 two days before harvest. Samples consisted of 3 cores from an individual plot taken to a depth of 3 feet at 1 foot increments. Two sets of samples at each depth were collected from each plot: one from between rows and the other within rows. 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. To calculate lbs nitrate-N/A, it was assumed that half the field was 'within row' and the other half 'between row'.

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 at 2.5 and 4.5 ft depths. 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 every two weeks starting one week before hilling. Samples were dried and weighed to determine dry weight accumulation through the season. Samples were ground and total N was determined using the salicylic Kjeldahl method. At harvest, vines were cut and weighed one week prior to harvest. Potatoes were mechanically harvested on September 15. Subsamples of vines and tubers were collected to determine dry matter and N accumulation using methods described above for the three plant samples.

RESULTS

Rainfall and Soil Nitrate Movement. Weekly precipitation over the course of the season is presented in Figure 1. Leaching events (> 2" irrigation + rainfall) only occurred once, at 68 days after planting. In contrast, five leaching events occurred in 1991, two of which occurred before hilling.

Seasonal nitrate-N concentrations in soil water extracted with the suction tubes at depths of 2.5' and 4.5' 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 higher than expected concentrations of nitrate-N (> 20 ppm) during the first 12 weeks of the growing season (Figure 2). Reasons for these high nitrate-N levels are unclear, but may have been due to some contamination of the samplers during installation.

Starter N fertilizer had dramatic effects on nitrate movement (Figures 3 to 6). The 80 and 120 lb N/A starter fertilizer rates had the highest concentrations of nitrate-N in the soil water between 12 and 18 weeks after planting compared to the other treatments. Delaying application of N to the emergence stage significantly reduced nitrate movement between 12 and 18 weeks after planting, even though the same total amount of N was applied. However, at the end of the season some nitrate-N was still moving downward regardless of starter N rate.

Slow release N fertilizer reduced nitrate movement compared to ammonium nitrate (Figures 7 vs. 8). The use of urea also reduced nitrate movement compared to ammonium nitrate (Figures 11 vs. 5). These results suggest that in terms of potential N losses, early applications of fertilizer N in the nitrate form should be avoided. Post-hilling applications of N resulted in slightly elevated nitrate-N levels at the end of the season (Figures 8 vs. 9). However, compared to treatments where higher rates of N applied up to hilling (240 lb N/A), N losses were less when post-hilling applications were used.
By the end of the season, nitrate-N was basically at background levels and differences among treatments were not detectable (Table 1).

Tuber Yield, Specific Gravity, and Vine Yield. The effects of the various N treatments on tuber yield, specific gravity, and vine yield are presented in Table 2. Total yield increased with N rate with most of the yield increase occurring between the control treatment and 120 lb N/A. 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 higher than in the those receiving N. Starter N had no significant effect on total tuber yield, but 7-14 oz tubers increased as starter rate decreased and the rate at emergence increased. Starter N had no effect on vine yield. Specific gravity increased with increasing starter N rates. At similar N rates and timing of application, there was little difference between urea and ammonium nitrate on vine and tuber yields. Specific gravity was similar for the urea and ammonium nitrate treatments when applied at equal rates. Total tuber yield with slow release N was lower than that obtained with an equivalent rate of ammonium nitrate. Specific gravity was higher with slow release, while vine yield was not affected. The post-hilling N application treatment resulted in 200 lb N/A (120 lb N/A before hilling and 80 lb N/A after hilling). This additional N after hilling increased tuber size (7-14 oz) and vine yield compared to the 120 lb N/A rate. However, tuber and vine yields were significantly lower in the post-hilling N treatment compared to those obtained in the 240 lb N/A rate applied in three equal applications up to hilling (treatment 4).

Tuber number per plant over the course of the season is presented in Table 3. Although some effects on tuber number per plant were detected during the season, no differences due to N management were detected by the time of harvest. Differences that were obtained were not consistent through the season. Because of small sample size (three plants per plot), variability was high and, therefore, these data should be interpreted with some caution.

Dry Matter and Nitrogen Accumulation. Dry matter accumulation and N content of vines, tubers, and roots through the growing season for each treatment are provided in Figures 12 to 21. Tuber bulking started at about 8 weeks after planting and continued in a linear manner until harvest. Nitrogen accumulation in the tubers followed the general pattern of dry matter accumulation. Dry weight accumulation in vines reached a peak between 6 and 8 weeks after planting and then leveled off or declined for most treatments. Nitrogen accumulation also peaked between 6 and 8 weeks after planting, but then declined dramatically after this time. Vines reached maximum dry weight and N accumulation about two weeks earlier when N was limiting. The peak in vine dry weight and N accumulation were delayed by two weeks when urea or post-hilling applications of N were applied.

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 and N accumulation increased with increasing N rate. The effect of starter N was not significant, indicating that losses of N due to early N application were minimal. Nitrogen accumulation tended to be greater in tubers when ammonium nitrate was used compared to urea or slow release nitrogen. Apparently, some immobilization of ammonium occurred during the season, since nitrate movement also tended to be lower in these treatments. The post-hilling treatment increased N accumulation in tubers, but had no effect on dry matter accumulation in vines or tubers. Reasons for lack of a response to post-hilling N are unclear, since higher rates of N applied up through hilling significantly increased N and dry matter accumulation. These results suggest that while efficiency of N use will be improved with post-hilling N applications, production may not necessarily be increased unless leaching rains occur early in the growing season.

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 the first sampling date, conventional analysis seemed to detect more subtle differences in nitrate status of the petiole compared to sap analysis. In all methods of analysis, differences due to N rate were apparent, particularly after the first sampling date. By the July 1 sampling date, differences due to starter N, N rate, N source and post-hilling N applications were apparent using all methods of analysis. Similar nitrate concentrations were obtained when the electrodes were used; however, the Wescan method gave slightly lower readings. At later sampling dates, the differences among the three methods for sap analysis were not as great.

Linear correlations between the sap nitrate analysis and conventional nitrate analysis are presented in Figures 22, 23, and 24. All R^2 values were above 0.890, indicating a strong relationship between sap analysis and conventional petiole analysis. Sap values can be inserted in the linear equation to determine whether nitrate-N levels are in an adequate range as predicted from conventional analysis. Both sap and conventional analysis predicted N applications when 120 lb N/A was applied up to hilling. An increase in 7-14 oz potatoes resulted from this application of N; however, yields were still not as great as when all the N was applied up to hilling. While the sap test does seem to be useful for determining N status of the plant, use of the technique to predict post-hilling N requirements still requires additional research.

SUMMARY

The 1992 season at Becker was one where leaching losses of N were minimal. Nitrogen source, rate, and management significantly affected nitrate losses under irrigated potatoes. Greatest losses were observed when N was applied early (before emergence), although some nitrate was still moving downward at the end of the season from the top 5 feet of soil. Use of urea and slow release N minimized N losses compared to ammonium nitrate. 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 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. Assumes half the field was in-row and the other half was between-row. Becker, MN.

	Treatment		In-row	Between-row	Field total
	N source	N timing			
			Pounds per acre		
1.	Control	(0 N/A)	5.51 ± 1.23	6.32 ± 1.42	11.83 ± 2.41
2.	(34-0-0)	(0,120,120)[1]	9.81 ± 4.53	9.54 ± 3.76	19.35 ± 4.97
3.	(34-0-0)	(40,100,100)	14.03 ± 12.25	8.60 ± 1.27	22.62 ± 11.82
4.	(34-0-0)	(80,80,80)	10.97 ± 4.58	11.08 ± 3.07	22.05 ± 4.53
5.	(34-0-0)	(120,60,60)	8.67 ± 4.47	8.84 ± 2.89	17.51 ± 7.11
6.	(34-0-0)	(80,80,0)	9.53 ± 1.17	7.70 ± 1.40	17.22 ± 1.76
7.	SR[2]	(80,80,0)	7.66 ± 1.13	10.91 ± 4.85	18.57 ± 5.33
8.	(34-0-0)	(40,40,40)	9.44 ± 1.44	7.67 ± 0.46	17.10 ± 1.88
9.	(34-0-0)	(40,40,40,40+40)[3]	8.06 ± 1.48	7.31 ± 1.06	15.36 ± 2.33
10.	(46-0-0)	(80,80,80)	11.55 ± 3.71	7.84 ± 0.73	19.39 ± 3.29

[1] = Planting, emergence, and hilling respectively. [2] = Slow release fertilizer. [3] = Two post-hilling applications, based on sap analysis.

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

Treatment	N source	N timing	Vines Tons/A	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total	Specific Gravity
				Fresh weight cwt/A						
1.	Control	(0 N/A)	0.71	3.8	59.4	214.1	26.1	0.0	303.5	1.0967
2.	(34-0-0)	(0,120,120)[1]	5.65	30.4	33.9	231.3	270.1	36.1	601.8	1.0883
3.	(34-0-0)	(40,100,100)	4.46	16.9	46.5	249.5	221.3	33.8	568.0	1.0879
4.	(34-0-0)	(80,80,80)	5.11	30.7	53.1	281.8	222.9	12.1	600.5	1.0901
5.	(34-0-0)	(120,60,60)	4.93	29.0	49.1	268.0	199.0	13.7	558.8	1.0877
6.	(34-0-0)	(80,80,0)	2.97	19.8	53.9	294.0	156.1	5.4	529.2	1.0879
7.	SR[2]	(80,80,0)	1.74	24.9	46.0	286.7	132.9	0.8	491.3	1.0908
8.	(34-0-0)	(40,40,40)	1.83	32.0	57.9	266.8	158.4	2.8	517.9	1.0907
9.	(34-0-0)	(40,40,40,40+40)[3]	3.51	28.9	57.9	246.0	195.0	13.9	541.7	1.0893
10.	(46-0-0)	(80,80,80)	4.99	36.4	41.0	238.8	232.7	18.3	567.2	1.0877
Significance			**	**	**	**	**	++	**	**
BLSD (0.05)			1.80	15.1	11.9	30.8	40.6	33.0	33.9	0.0023
Contrasts										
Lin Starter N (2, 3, 4, 5)			NS	NS	**	**	**	*	NS	NS
Quad Starter N (2, 3, 4, 5)			NS	NS	*	NS	NS	NS	NS	NS
Lin Rate N (1, 8, 4)			**	**	NS	**	**	NS	**	**
Quad Rate N (1, 8, 4)			NS	*	NS	NS	++	NS	**	*
Treatment 4 vs 10			NS	NS	*	**	NS	NS	++	++
Treatment 6 vs 7			NS	NS	NS	NS	NS	NS	*	*
Treatment 8 vs 9			++	NS	NS	NS	++	NS	NS	NS
Treatment 4 vs 7			**	NS	NS	NS	**	NS	**	NS
Treatment 4 vs 9			++	NS	NS	*	NS	NS	**	NS

[1] = Planting, emergence and hilling respectively. [2] = Slow release fertilizer. [3] = Two post-hilling applications, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 3. Effect of nitrogen treatments on the number of tubers per plant. Becker, MN.

Treatment	N source	N timing	June 10	June 25	July 17	Aug. 5	Aug. 26
			Date: Number of tubers per plant				
1.	Control	(0 N/A)	2.58	9.92	7.17	7.58	9.33
2.	(34-0-0)	(0,120,120)[1]	0.83	8.67	10.17	10.08	9.42
3.	(34-0-0)	(40,100,100)	2.08	10.92	13.50	11.67	8.50
4.	(34-0-0)	(80,80,80)	2.58	9.42	10.00	10.33	9.92
5.	(34-0-0)	(120,60,60)	1.58	8.83	13.08	9.50	10.75
6.	(34-0-0)	(80,80,0)	2.92	8.25	10.33	13.50	10.08
7.	SR[2]	(80,80,0)	3.33	12.00	10.17	10.08	9.33
8.	(34-0-0)	(40,40,40)	1.75	10.00	13.33	12.50	8.83
9.	(34-0-0)	(40,40,40,40+40)[3]	1.42	10.33	12.50	9.92	9.58
10.	(46-0-0)	(80,80,80)	0.75	10.42	9.75	9.75	10.17
Significance			NS	NS	NS	**	NS
BLSD (0.05)			--	--	--	2.74	--
Contrasts							
Lin Starter N (2, 3, 4, 5)			NS	NS	NS	NS	NS
Quad Starter N (2, 3, 4, 5)			NS	NS	NS	NS	NS
Lin Rate N (1, 8, 4)			NS	NS	NS	*	NS
Quad Rate N (1, 8, 4)			NS	NS	*	**	NS
Treatment 4 vs 10			NS	NS	NS	NS	NS
Treatment 6 vs 7			NS	*	NS	**	NS
Treatment 8 vs 9			NS	NS	NS	*	NS
Treatment 4 vs 7			NS	NS	NS	NS	NS
Treatment 4 vs 9			NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Slow release fertilizer. [3] = Two post-hilling applications, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

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

	Treatment N source	N timing	Nitrogen content Vines	Tubers	Total	N concentration Vine	Tubers	Dry matter Vines	Tubers	Total
			lbs/A			% N		Tons/A		
1.	Control	(0 N/A)	9.0	64.8	75.3	1.63	0.92	0.24	3.54	3.78
2.	(34-0-0)	(0,120,120)[1]	22.6	183.9	209.1	1.65	1.40	0.69	6.58	7.27
3.	(34-0-0)	(40,100,100)	19.7	181.0	203.2	1.41	1.45	0.69	6.25	6.94
4.	(34-0-0)	(80,80,80)	24.0	195.8	223.2	1.58	1.53	0.72	6.42	7.14
5.	(34-0-0)	(120,60,60)	23.3	185.3	211.4	1.44	1.46	0.79	6.34	7.13
6.	(34-0-0)	(80,80,0)	12.8	157.1	172.2	1.10	1.37	0.58	5.76	6.34
7.	SR[2]	(80,80,0)	12.8	125.8	140.5	1.06	1.14	0.59	5.54	6.12
8.	(34-0-0)	(40,40,40)	11.8	148.3	162.0	1.11	1.30	0.52	5.72	6.24
9.	(34-0-0)	(40,40,40,40+40)[3]	16.1	179.6	198.0	1.64	1.51	0.50	5.97	6.47
10.	(46-0-0)	(80,80,80)	22.6	177.1	203.6	1.55	1.45	0.70	6.14	6.84
Significance			**	**	**	*	**	**	**	**
BLSD (0.05)			7.9	17.9	19.6	0.52	0.16	0.18	0.48	0.49
Contrasts										
Lin Starter N (2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Quad Starter N (2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Lin Rate N (1, 8, 4)			**	**	**	NS	**	**	**	**
Quad Rate N (1, 8, 4)			NS	*	NS	*	NS	NS	**	**
Treatment 4 vs 10			NS	++	++	NS	NS	NS	NS	NS
Treatment 6 vs 7			NS	**	**	NS	*	NS	NS	NS
Treatment 8 vs 9			NS	**	**	*	*	NS	NS	NS
Treatment 4 vs 7			**	**	**	*	**	NS	**	**
Treatment 4 vs 9			*	NS	*	NS	NS	*	++	*

[1] = Planting, emergence and hilling respectively. [2] = Slow release fertilizer. [3] = Two post-hilling applications, 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 N source	N timing	June 9 dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	June 23 dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	6559	463	402	454	261	89	60	45
2.	(34-0-0)	(0,120,120)[1]	17513	1005	918	981	18912	1438	1380	1294
3.	(34-0-0)	(40,100,100)	20534	1375	1265	1278	19565	1300	1267	1244
4.	(34-0-0)	(80,80,80)	22306	1375	1354	1349	18748	1275	1235	1164
5.	(34-0-0)	(120,60,60)	23290	1450	1380	1454	18817	1350	1230	1261
6.	(34-0-0)	(80,80,0)	22207	1338	1289	1308	18248	1200	1135	1105
7.	SR[2]	(80,80,0)	20474	1313	1219	1243	13571	944	834	834
8.	(34-0-0)	(40,40,40)	20405	1288	1191	1217	16651	1061	1130	1097
9.	(34-0-0)	(40,40,40,40+40)[3]	20599	1325	1209	1275	18162	1163	1171	1073
10.	(46-0-0)	(80,80,80)	20068	1275	1168	1250	20211	1375	1282	1281
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			1396	110	146	143	1281	109	116	95
Contrasts										
Lin Starter N (2, 3, 4, 5)			**	**	**	**	NS	NS	*	NS
Quad Starter N (2, 3, 4, 5)			++	**	**	++	NS	*	NS	++
Lin Rate N (1, 8, 4)			**	**	**	**	**	**	**	**
Quad Rate N (1, 8, 4)			**	**	**	**	**	**	**	**
Treatment 4 vs 10			**	NS	*	NS	*	NS	NS	*
Treatment 6 vs 7			*	NS	NS	NS	**	**	**	**
Treatment 8 vs 9			NS	NS	NS	NS	*	++	NS	NS
Treatment 4 vs 7			*	NS	++	NS	**	**	**	**
Treatment 4 vs 9			*	NS	++	NS	NS	++	NS	++

[1] = Planting, emergence and hilling respectively. [2] = Slow release fertilizer. [3] = Two post-hilling applications 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 7				July 21			
			dry weight	sap	sap	sap	dry weight	sap	sap	sap
	N source	N timing	Petiole-N	Horiba	Hach	Wescan	Petiole-N	Horiba	Hach	Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	24	75	44	10	34	69	54	8
2.	(34-0-0)	(0,120,120)[1]	19482	1438	1433	1480	13782	1238	1210	1193
3.	(34-0-0)	(40,100,100)	17879	1388	1368	1452	10196	1073	1006	986
4.	(34-0-0)	(80,80,80)	15901	1225	1160	1198	9460	919	820	783
5.	(34-0-0)	(120,60,60)	16315	1275	1271	1269	8821	793	689	669
6.	(34-0-0)	(80,80,0)	10146	822	792	810	4468	444	377	354
7.	SR[2]	(80,80,0)	1505	221	187	178	373	93	75	26
8.	(34-0-0)	(40,40,40)	6130	628	596	601	1260	224	193	154
9.	(34-0-0)	(40,40,40,40+40)[3]	11520	949	968	950	7664	784	732	710
10.	(46-0-0)	(80,80,80)	16805	1350	1215	1345	11142	1040	929	920
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			2028	125	124	146	2222	161	151	155
Contrasts										
Lin Starter N (2, 3, 4, 5)			**	**	**	**	**	**	**	**
Quad Starter N (2, 3, 4, 5)			NS	NS	++	NS	++	NS	NS	NS
Lin Rate N (1, 8, 4)			**	**	**	**	**	**	**	**
Quad Rate N (1, 8, 4)			++	NS	NS	NS	**	**	**	**
Treatment 4 vs 10			NS	++	NS	++	NS	NS	NS	NS
Treatment 6 vs 7			**	**	**	**	**	**	**	**
Treatment 8 vs 9			**	**	**	**	**	**	**	**
Treatment 4 vs 7			**	**	**	**	**	**	**	**
Treatment 4 vs 9			**	**	**	**	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Slow release fertilizer. [3] = Two post-hilling applications, 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			
			dry weight	sap	sap	sap
	N source	N timing	Petiole-N	Horiba	Hach	Wescan
			ppm NO_3-N			
1.	Control	(0 N/A)	30	103	49	5
2.	(34-0-0)	(0,120,120)[1]	8074	878	907	846
3.	(34-0-0)	(40,100,100)	4515	489	474	422
4.	(34-0-0)	(80,80,80)	3693	433	403	347
5.	(34-0-0)	(120,60,60)	3105	386	358	307
6.	(34-0-0)	(80,80,0)	966	189	140	91
7.	SR[2]	(80,80,0)	79	119	57	18
8.	(34-0-0)	(40,40,40)	445	163	125	74
9.	(34-0-0)	(40,40,40,40+40)[3]	11657	1040	1159	1094
10.	(46-0-0)	(80,80,80)	6207	583	597	538
Significance			**	**	**	**
BLSD (0.05)			1758	127	135	127
Contrasts						
Lin Starter N (2, 3, 4, 5)			**	**	**	**
Quad Starter N (2, 3, 4, 5)			*	**	**	**
Lin Rate N (1, 8, 4)			**	**	**	**
Quad Rate N (1, 8, 4)			++	++	NS	++
Treatment 4 vs 10			*	*	*	**
Treatment 6 vs 7			NS	NS	NS	NS
Treatment 8 vs 9			**	**	**	**
Treatment 4 vs 7			**	**	**	**
Treatment 4 vs 9			**	**	**	**

[1] = Planting, emergence and hilling respectively. [2] = Slow release fertilizer. [3] = Two post-hilling applications, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

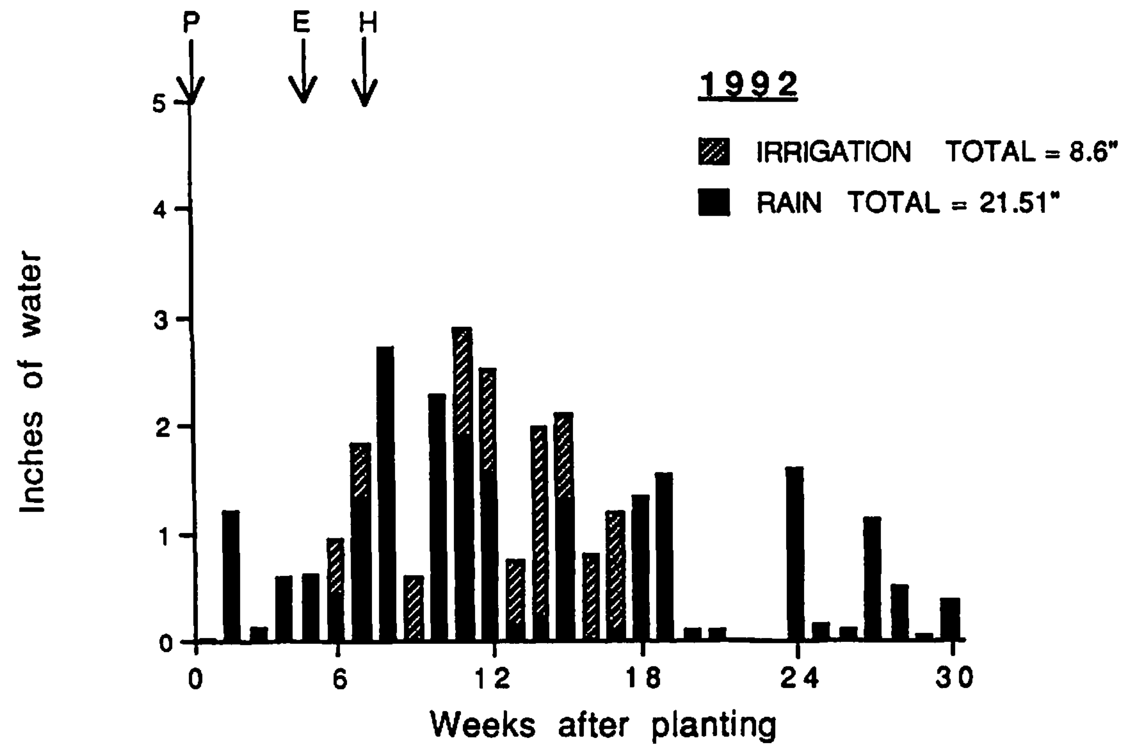


Figure 1. Rainfall and irrigation at Becker, MN during the 1992 growing season. P, E and H = planting, emergence and hilling, respectively.

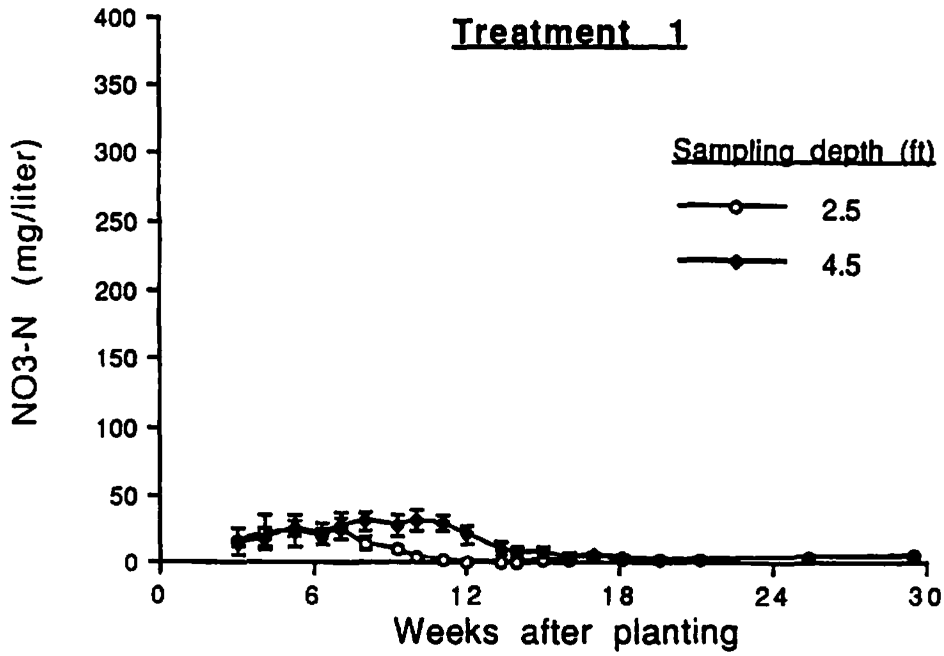


Figure 2. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: no nitrogen. Error bars represent SE of the mean.

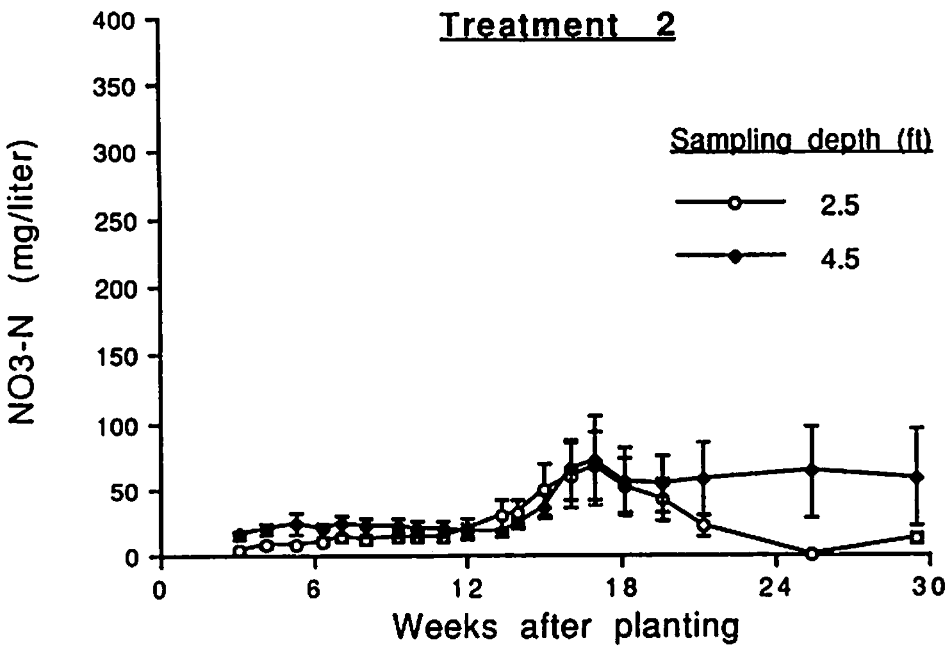


Figure 3. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 120 lb N/A at emergence and hilling (34-0-0). Error bars represent SE of the mean.

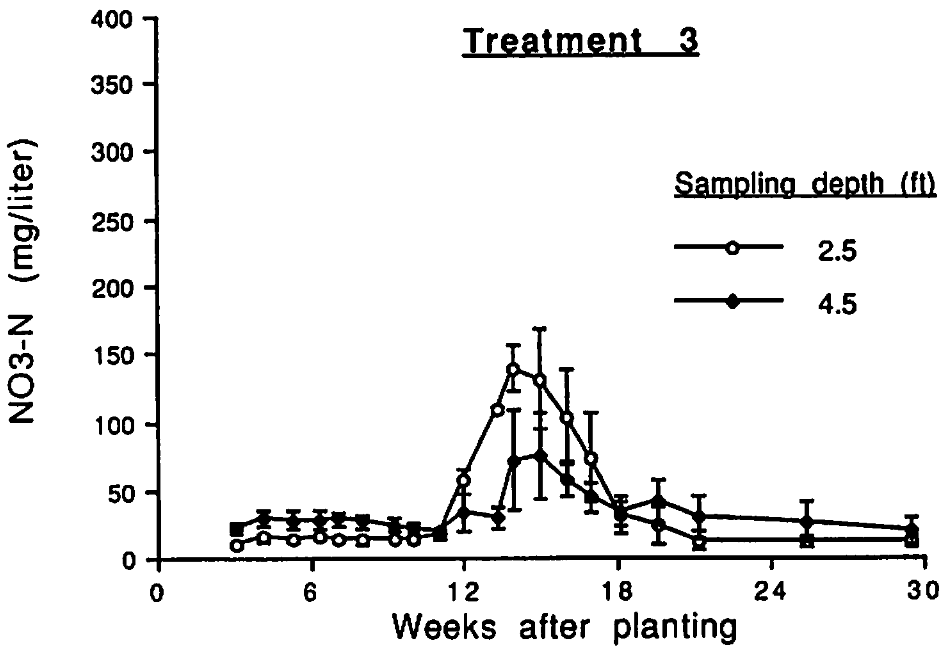


Figure 4. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

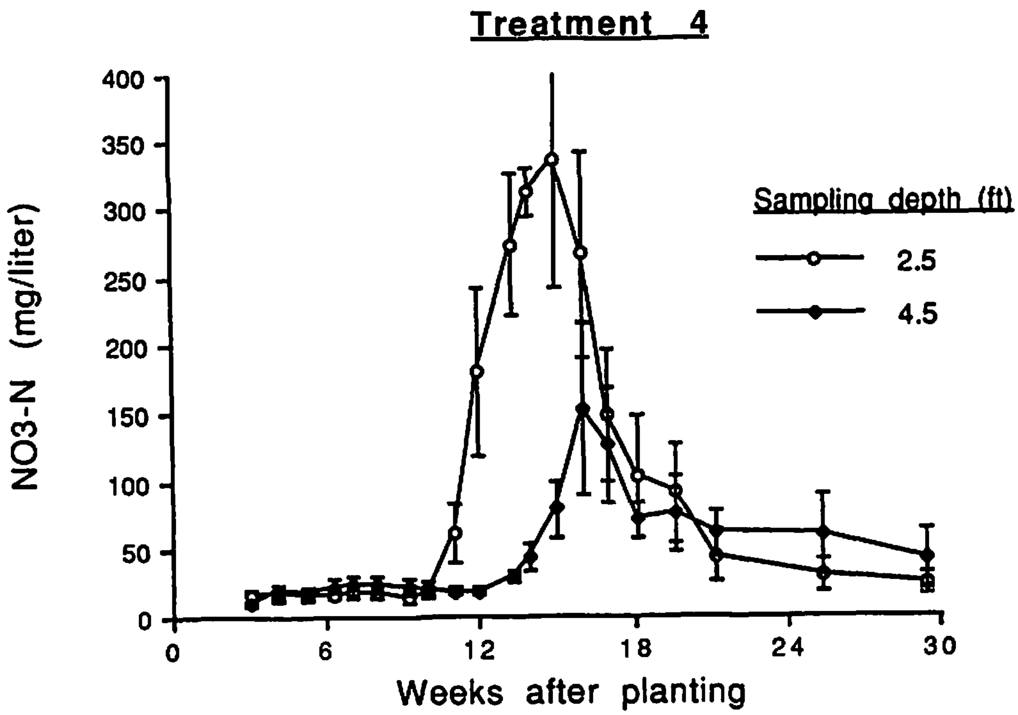


Figure 5. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting, emergence and hilling (34-0-0). Error bars represent SE of the mean.

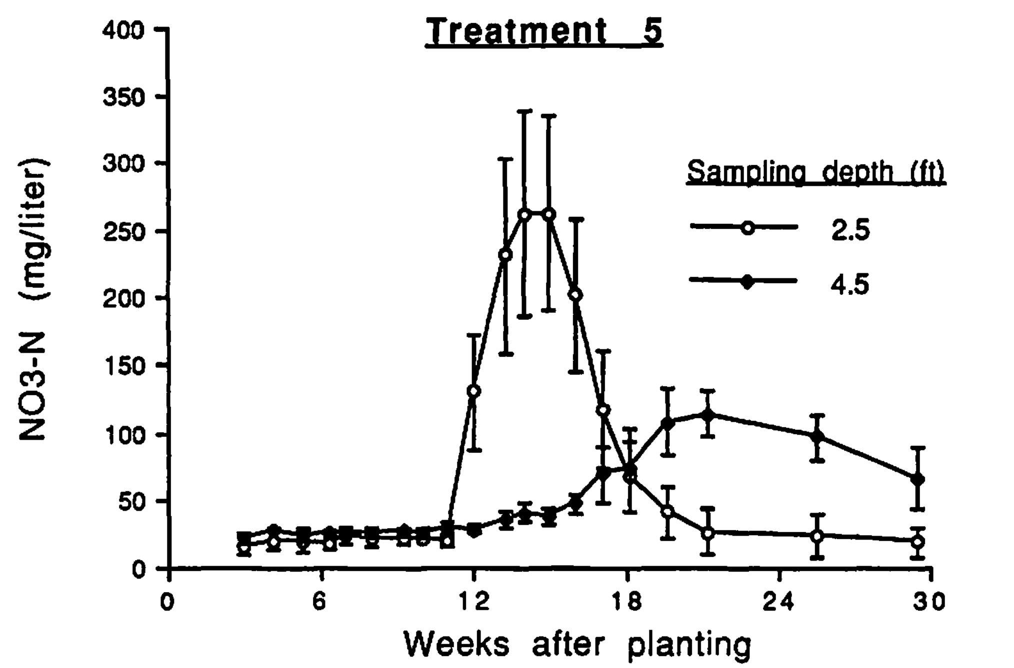


Figure 6. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 120 lb N/A at planting, 60 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

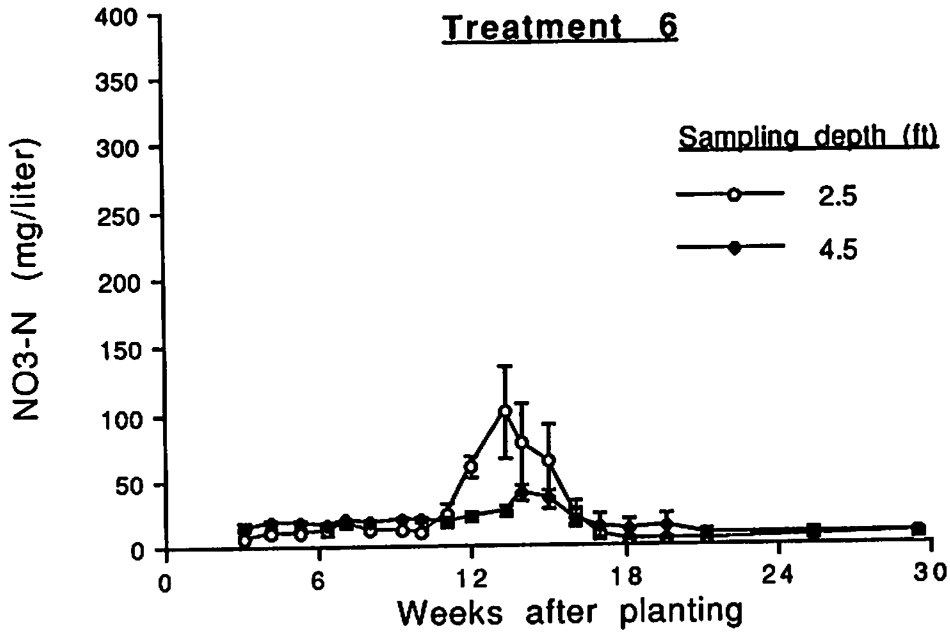


Figure 7. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting and emergence (34-0-0). Error bars represent SE of the mean.

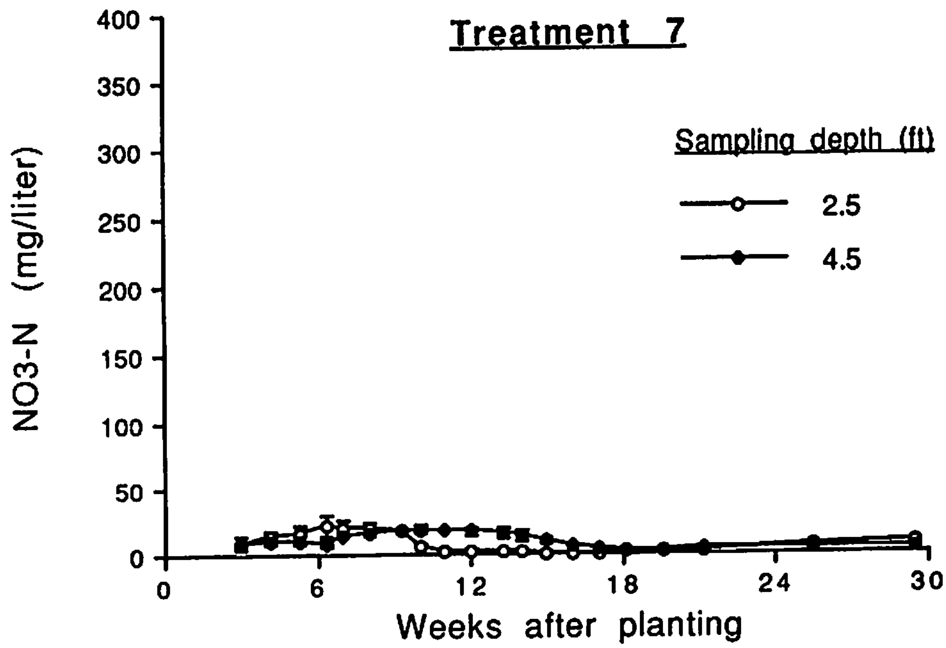


Figure 8. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting and emergence (slow release). Error bars represent SE of the mean.

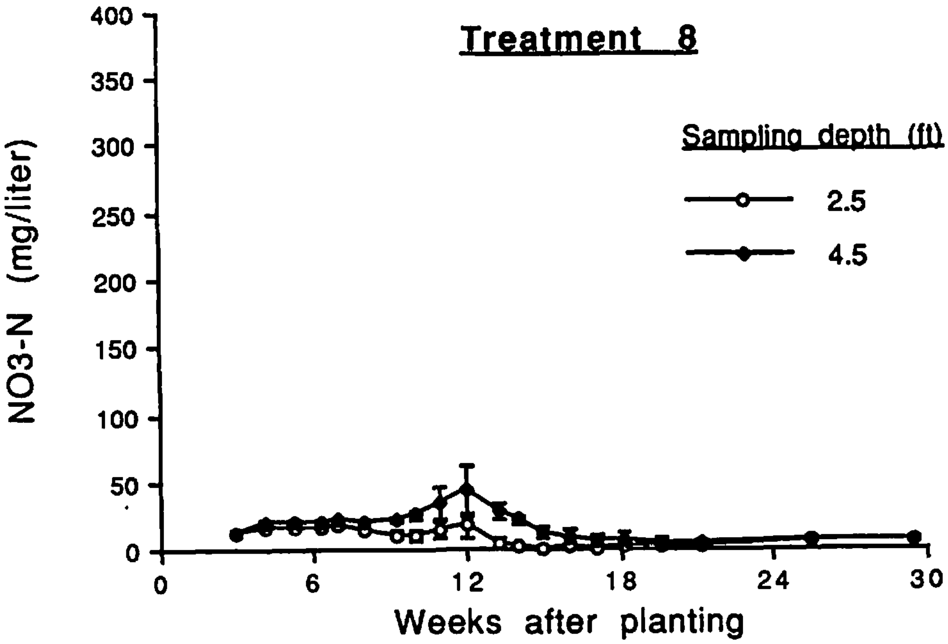


Figure 9. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling (34-0-0). Error bars represent SE of the mean.

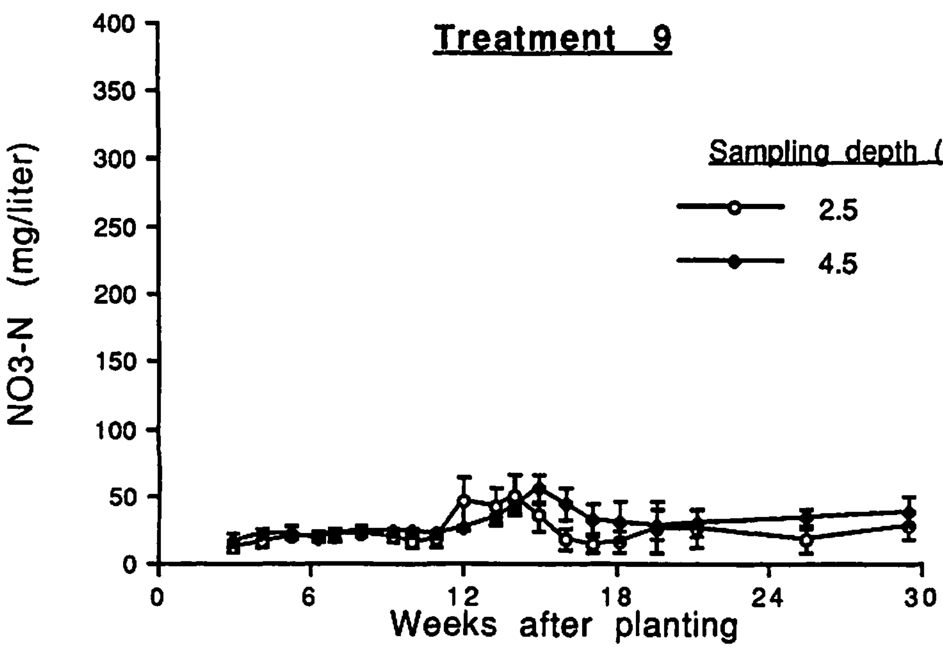


Figure 10. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 40 lb N/A at planting,emergence, hilling and two post-hillings (34-0-0). Error bars represent SE of the mean.

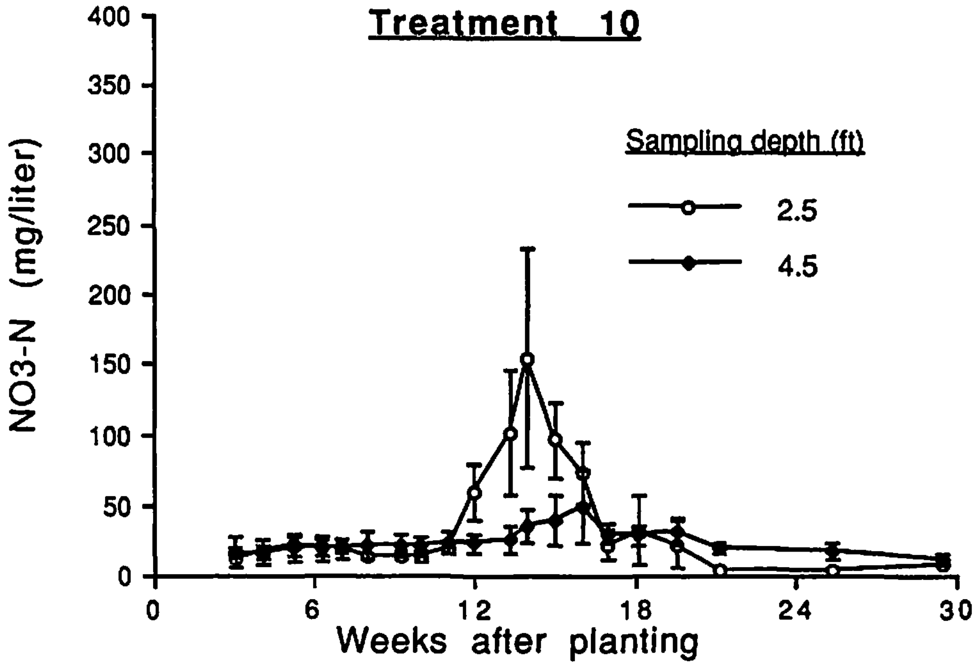


Figure 11. Nitrate - N concentration in soil water at two depths over the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting, emergence and hilling (46-0-0). Error bars represent SE of the mean.

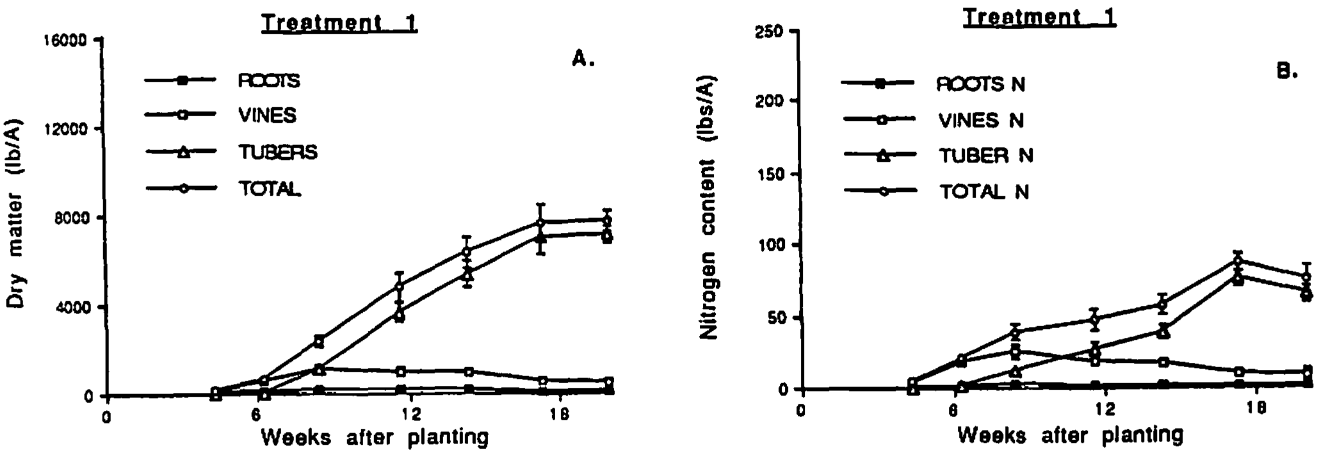


Figure 12. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: no nitrogen.

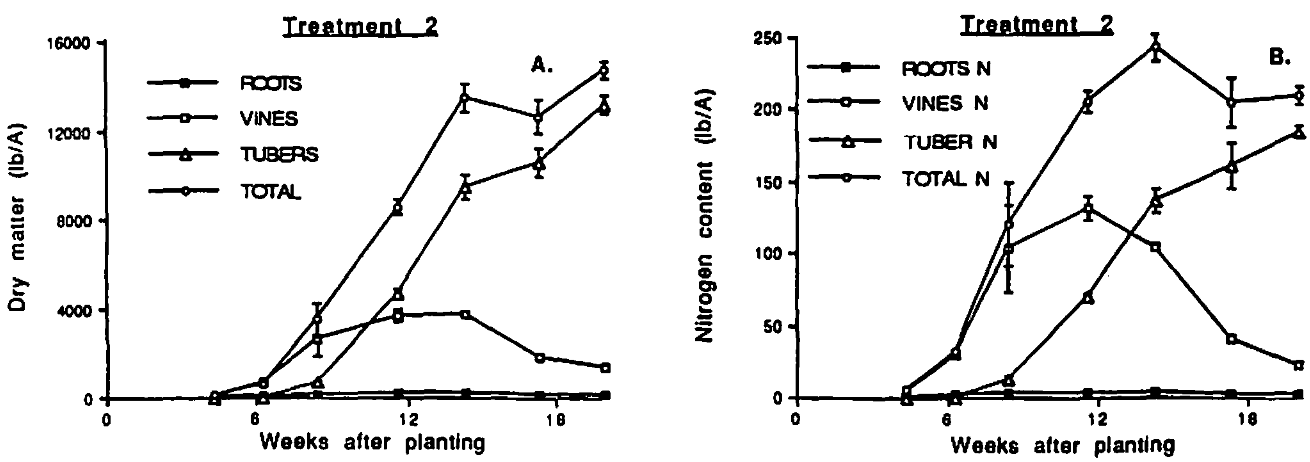


Figure 13. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 120 lb N/A at emergence and hilling (34-0-0).

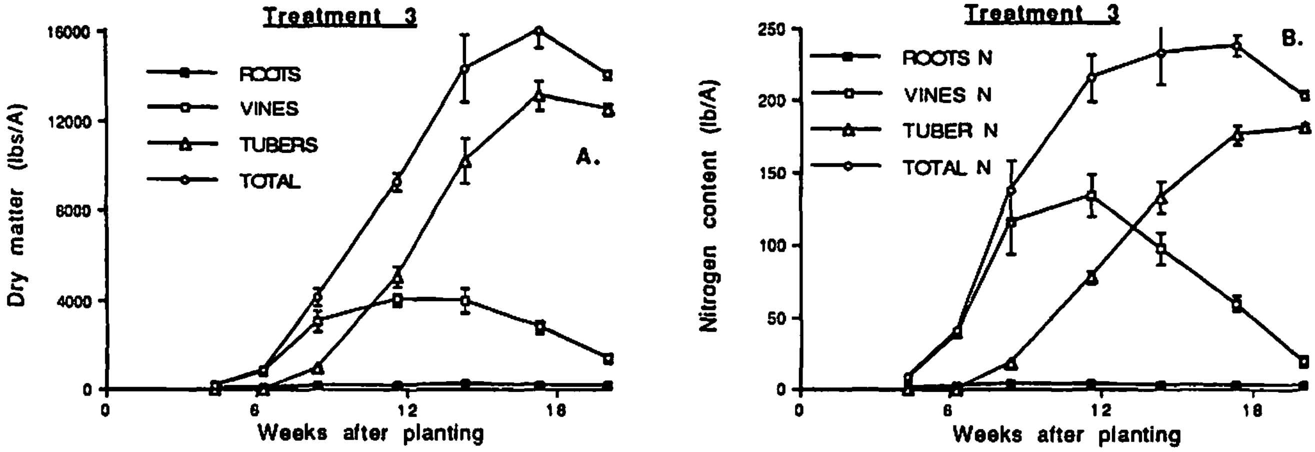


Figure 14. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (34-0-0).

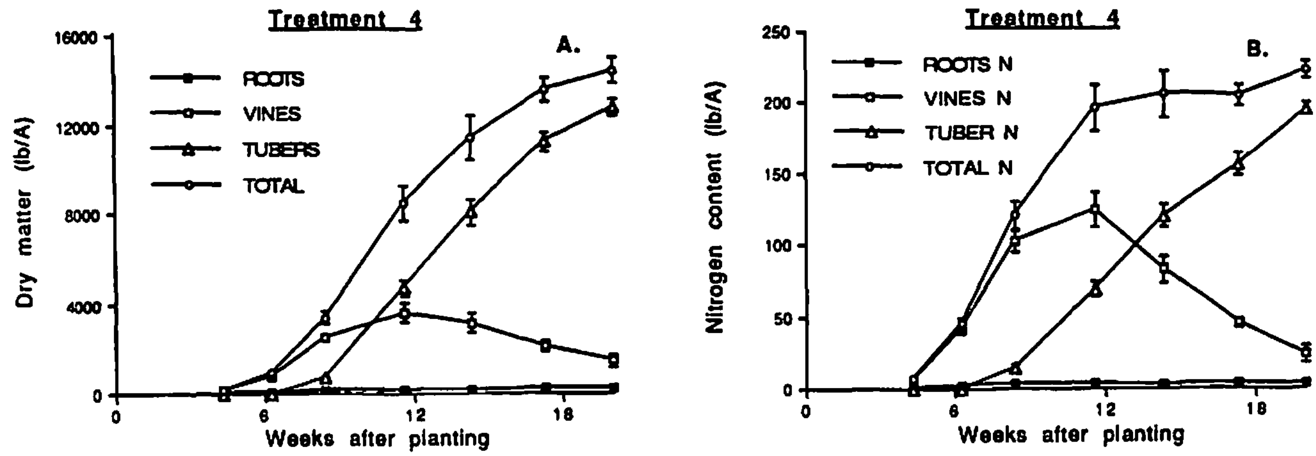


Figure 15. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting, emergence and hilling (34-0-0).

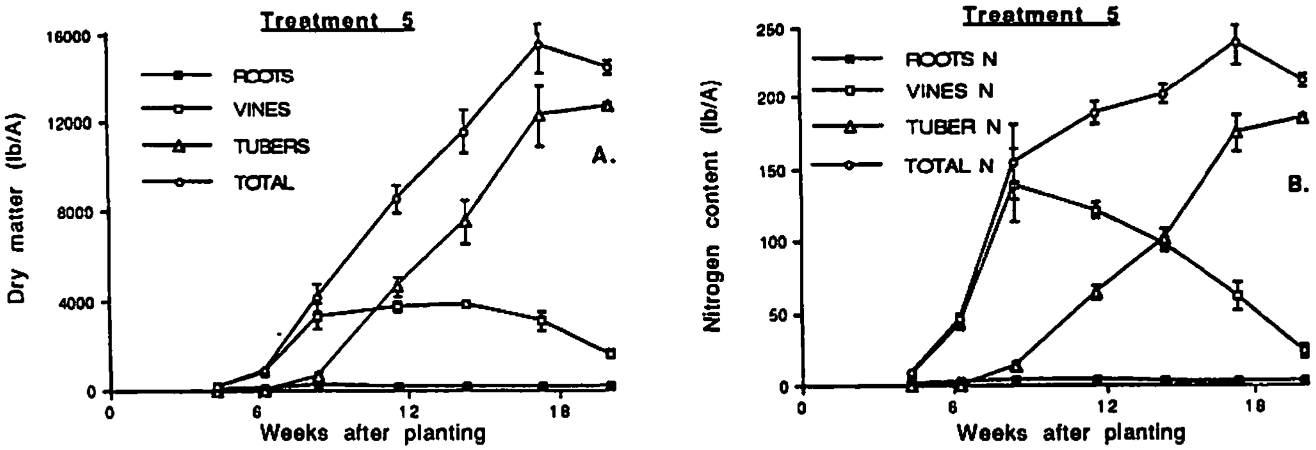


Figure 16. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 120 lb N/A at planting, 60 lb at emergence and hilling (34-0-0).

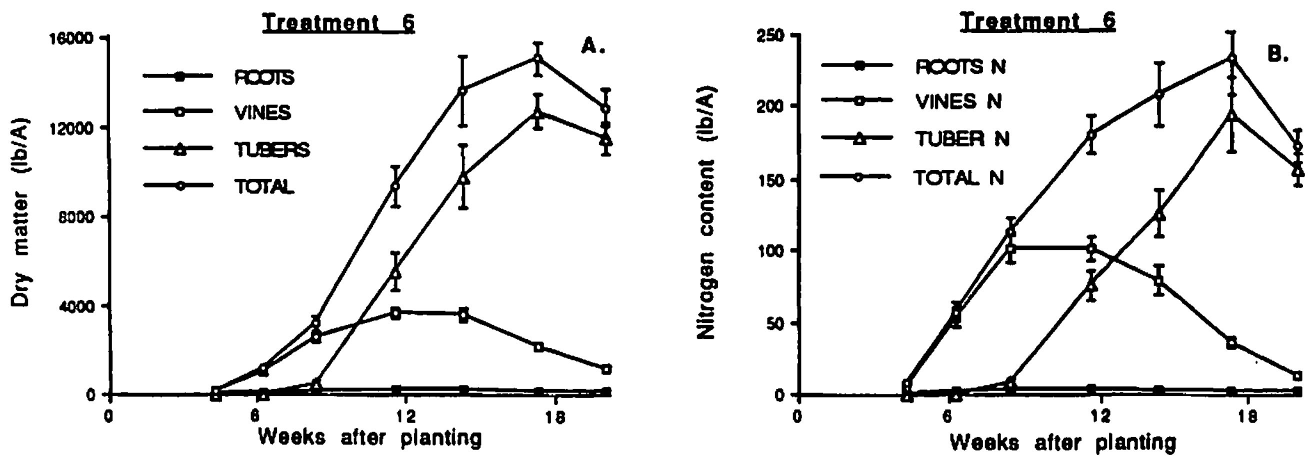


Figure 17. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting and emergence (34-0-0).

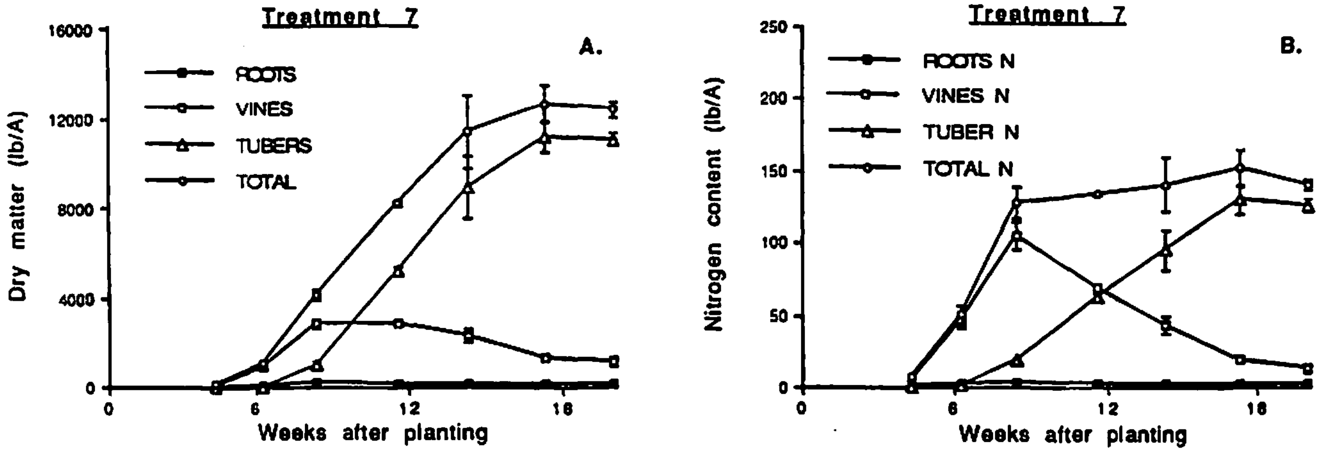


Figure 18. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting and emergence (slow release).

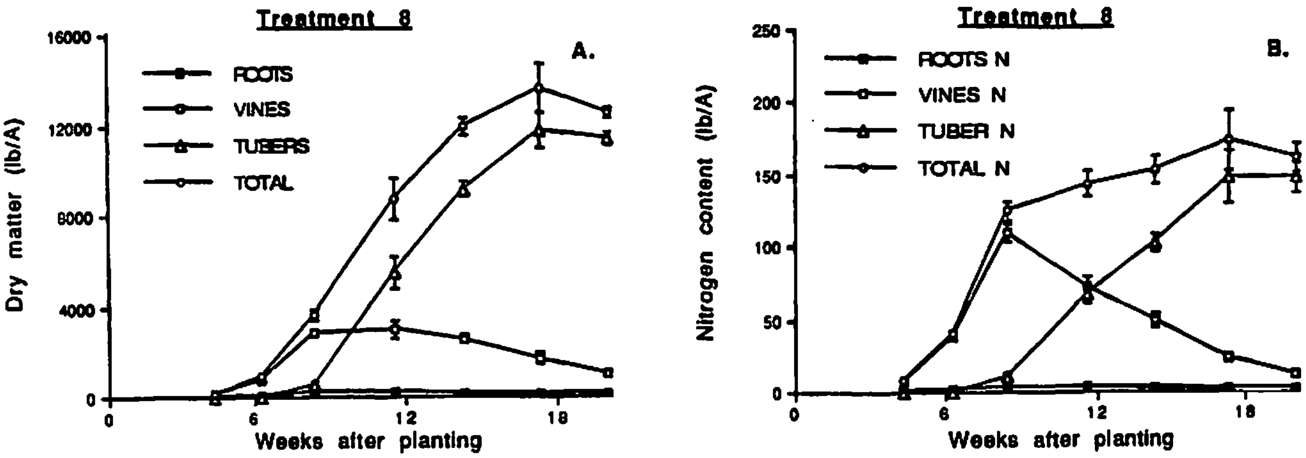


Figure 19. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling (34-0-0).

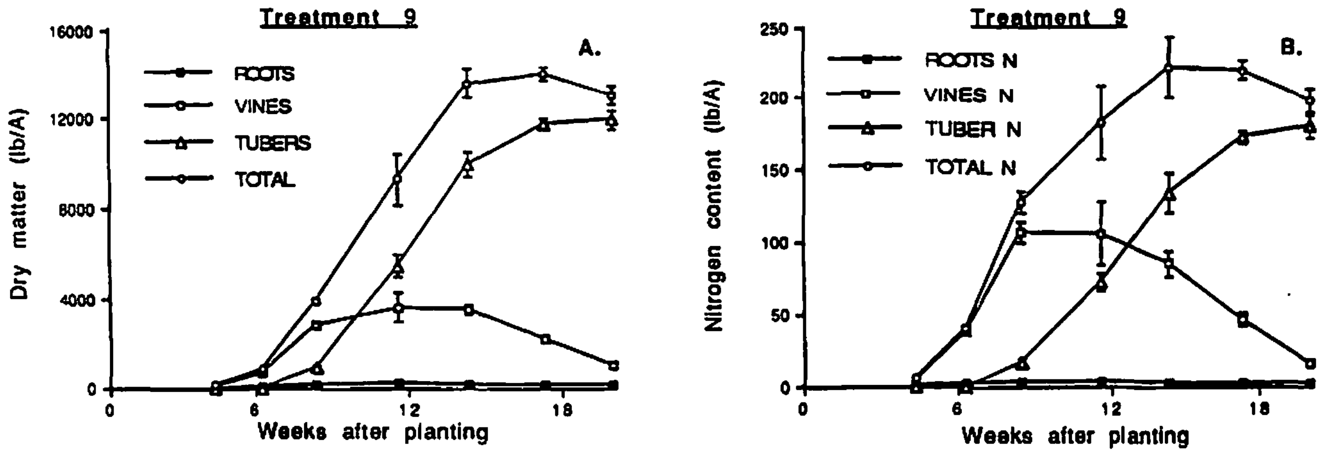


Figure 20. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence hilling and two post-hillings (34-0-0).

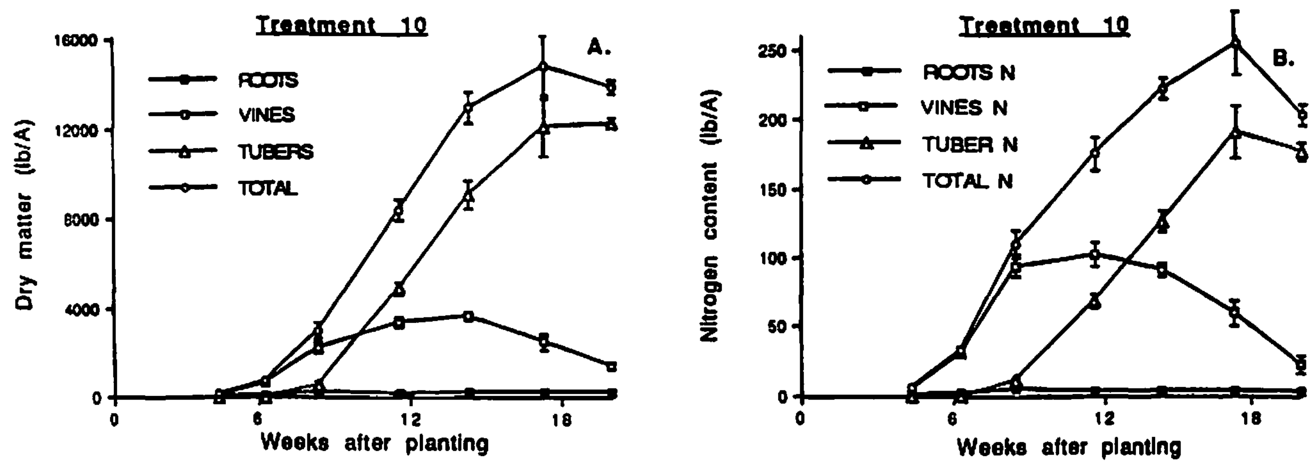


Figure 21. Dry matter (A) and nitrogen accumulation (B) in potato roots, vines and tubers during the 1992 growing season. Nitrogen application rate: 80 lb N/A at planting, emergence and hilling (46-0-0).

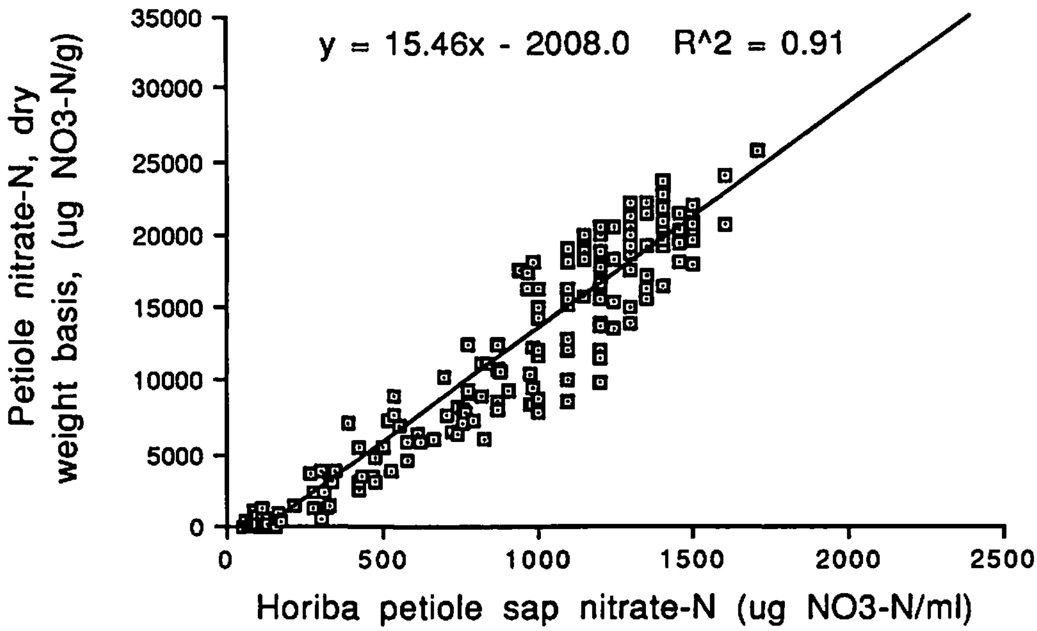


Figure 22. Correlation of petiole nitrate-N (dry weight basis) with petiole sap nitrate-N measured by Horiba electrode.

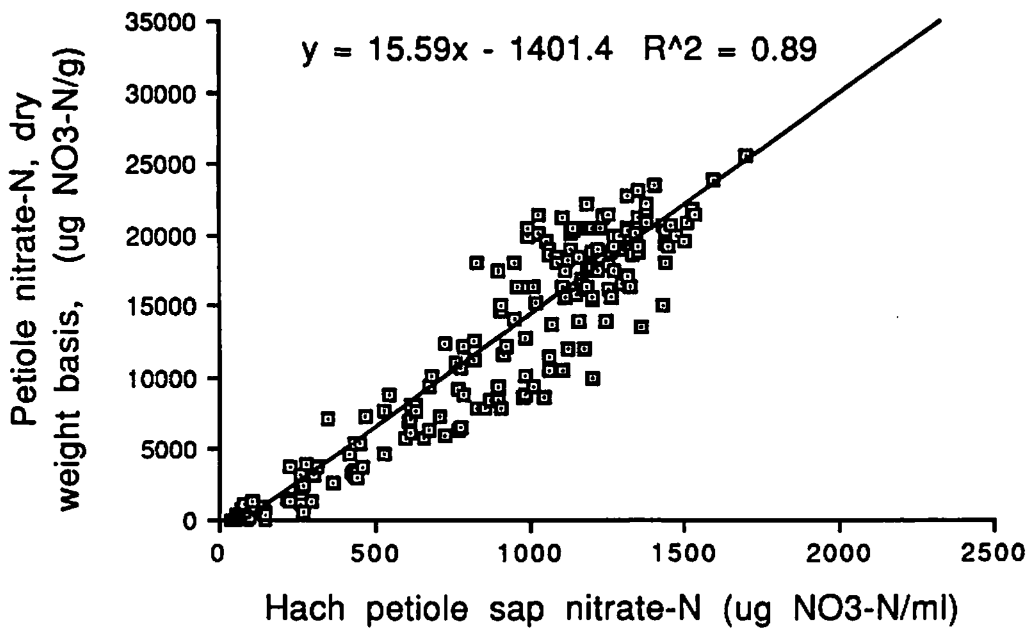


Figure 23. Correlation of petiole nitrate-N (dry weight basis) with petiole sap nitrate-N measured by Hach electrode.

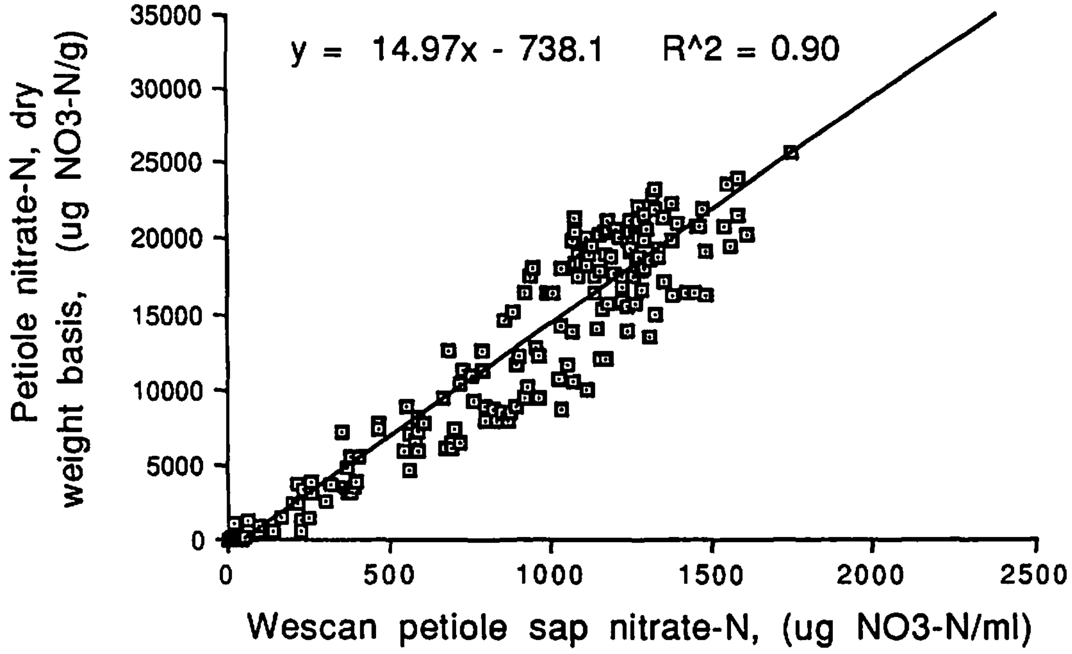


Figure 24. Correlation of petiole nitrate-N (dry weight basis) with petiole sap nitrate-N measured by Wescan electrode.

PHOSPHORUS REQUIREMENTS FOR IRRIGATED POTATOES - 1992

Carl Rosen, Dave Birong, and Glenn Titrud

ABSTRACT: Response of irrigated potatoes to phosphate fertilizer on low and high P testing sites was evaluated. Total and marketable yield increased with phosphate fertilizer application in both sites with most of the increase coming from increases in the 7-14 oz potatoes. The major response to phosphate fertilizer occurred between the 0 to 50 lb P_2O_5 application rate; however, economic increases were still recorded with applications of 150-250 lb P_2O_5/A. The cool season of 1992 may have played a role in these phosphate fertilizer responses. 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, magnesium, and zinc, but decrease tissue copper and boron.

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 irrigated potatoes to phosphate fertilizer on both high and low P testing soils. The results presented here are from the third year of a four year study.

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
Soil pH (1:1 - soil:water)	5.5	6.1
Bray P1	60 ppm	22 ppm
K - NH4OAc	200 ppm	168 ppm

Prior to planting, 250 lb sul-po-mag and 100 lb K_2O (as 0-0-60) were broadcast and incorporated at both sites. Russet Burbank "B" size potatoes were planted on April 23, 1992 at a spacing of 36" between rows and 10" within the row. Each plot consisted of six, 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 80 lb N/A at emergence (May 28) and 80 lb N/A at hilling (June 10). 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 July 1. 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 (five plants per plot) were also collected on June 26 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.

RESULTS

Dry weight of vines, roots, and tubers sampled in June are presented in Tables 1 and 2. For the high P testing site, phosphate fertilizer increased dry weight of vines, but not roots or tubers. 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. Dry weight of tubers and number of tubers also tended to increase with phosphate fertilizer, although some inconsistency occurred at the higher rates.

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

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

Tuber yield and size distribution are presented in Tables 3 and 4. For the low and high P testing sites, phosphate fertilizer tended to increase total tuber yield, primarily due to an increase in the 7-14 oz potatoes and to a lesser extent 3-7 oz potatoes. At rates higher than 150 lb P_2O_5/A, total yield tended to level off in the high P testing site. In the low P testing site highest total yields were recorded at 200 lb P_2O_5/A. For both low and high P testing sites, the greatest yield increase due to phosphate fertilizer occurred between the 0 and 50 lb/A rate. Assuming the price of potatoes is $5.00/cwt, economic increases due to phosphate fertilizer were realized up to 200 lb P_2O_5/A in the low testing site and 150 lb P_2O_5/A in the high testing site. For 7-14 oz potatoes, economic increases in yield were obtained when 50 lb P_2O_5/A were applied in the low testing site, and 250 lb P_2O_5/A were applied in the high testing site. This is the first year where yield increases at these high rates of phosphate fertilizer were recorded and may have been due to the abnormally cool growing season of 1992.

Elemental concentrations were determined in petiole and leaf (leaflets plus petioles) samples to ascertain whether the type of tissue sampled affected diagnostic interpretations (Tables 5-8). Concentrations of phosphorus 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. Based on this years data, a critical level of P in petioles would be about 0.3%, whereas in leaf tissue the critical level would be 0.4%. These critical levels are higher than those reported in previous years and therefore need further validation. Total N in leaf tissue tended to increase with increasing P rate in both high and low P sites. In contrast, petiole nitrate was not affected by P treatment. Concentrations of nitrogen in leaves and nitrate in petioles were generally higher when alfalfa was the previous crop compared to rye. Potassium concentrations in petioles were approximately twice as high as those in leaf tissue. Phosphate fertilizer had no effect on potassium concentrations in the tissues sampled. Calcium and magnesium concentrations were similar in petiole and leaf tissue. Both calcium and magnesium increased with increasing phosphate fertilizer in the low P site, but this trend was not apparent in the high P site. Iron concentrations were approximately twice as high in leaf tissue compared to petiole tissue. Phosphate fertilizer increased leaf iron in the low P site, but had no effect on iron concentrations in the petiole tissue or in any tissue sampled in the high P site. Manganese concentrations were higher in leaf tissue than in petiole tissue. Phosphate fertilizer had inconsistent effects on tissue manganese concentrations. Concentrations of zinc were higher in petiole tissue compared to leaf tissue. However, leaf zinc concentrations tended to increase with increasing phosphate fertilizer rate in both high and low P sites, while petiole 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. Boron concentrations were twice as high in petiole tissue compared to leaf tissue. Increasing phosphate fertilizer tended to decrease petiole and leaf 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 vines, roots, tubers, and number of tubers sampled June 26, 1992. Previous crop - Rye; initial soil test P - 60 ppm.

Phosphate Treatment lb P_2O_5	Plant Part vines	roots	tubers	number of tubers
	grams/plant			per plant
0	48.50	5.97	19.42	8.40
50	62.20	6.88	26.89	12.15
100	65.46	6.46	20.65	10.45
150	60.16	6.14	21.60	10.55
200	62.43	6.52	19.81	10.85
250	56.84	6.07	22.96	10.35
Pr>F	0.13	0.13	0.67	0.28
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 5%.

Table 2. Effect of phosphate fertilizer on dry matter of vines, roots, tubers, and number of tubers sampled June 26, 1992. Previous crop - alfalfa; initial soil test P - 22 ppm.

Phosphate Treatment	Plant Part			
lb P_2O_5	vines	roots	tubers	number of tubers
	grams/plant			per plant
0	43.36	6.43	12.49	7.35
50	59.66	6.77	15.22	9.95
100	66.49	6.47	16.18	9.05
150	62.91	6.78	15.29	8.60
200	67.47	7.12	10.82	7.45
250	65.98	6.95	20.77	9.55
Pr>F	0.02	0.53	0.27	0.45
Lin P_2O_5	**	NS	NS	NS
Quad P_2O_5	*	NS	NS	NS
Cubic P_2O_5	NS	NS	++	++

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

Table 3. Effect of phosphate fertilizer on yield and specific gravity of Russet Burbank potatoes. Previous crop - Rye; initial soil test P - 54 ppm.

Phosphate Treatment	Tuber Yield						
		Tuber Size					Specific
lb P_2O_5	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total	Gravity
	cwt/A						
0	24.7	62.0	264.1	78.7	5.0	434.5	1.0840
50	29.9	71.4	314.8	110.0	6.9	533.0	1.0837
100	37.3	68.1	313.3	106.9	11.1	536.8	1.0843
150	39.9	65.1	293.5	150.3	10.2	559.0	1.0829
200	26.0	76.1	323.4	115.4	1.9	542.8	1.0843
250	36.0	63.9	278.6	173.8	11.2	563.5	1.0833
Pr>F	0.74	0.27	0.37	0.05	0.35	0.01	0.90
Lin P_2O_5	NS	NS	NS	**	NS	**	NS
Quad P_2O_5	NS	NS	++	NS	NS	*	NS
Cubic P_2O_5	NS	NS	NS	NS	NS	NS	NS

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

Table 4. Effect of phosphate fertilizer on yield and specific gravity of Russet Burbank potatoes. Previous crop - alfalfa; initial soil test P - 22 ppm.

Phosphate Treatment	Tuber Yield						
		Tuber Size					Specific
lb P_2O_5	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total	Gravity
	cwt/A						
0	22.4	32.1	263.3	131.6	10.7	460.1	1.0861
50	39.9	34.5	277.8	194.5	23.0	569.6	1.0837
100	34.1	51.3	311.9	158.9	21.6	577.8	1.0817
150	23.2	44.4	317.8	173.1	31.0	589.5	1.0825
200	51.0	43.3	293.1	190.8	30.5	608.7	1.0848
250	34.6	41.6	288.5	177.1	23.8	565.7	1.0831
Pr>F	0.41	0.08	0.09	0.05	0.18	0.00	0.30
Lin P_2O_5	NS	++	NS	++	++	**	NS
Quad P_2O_5	NS	*	*	NS	++	**	NS
Cubic P_2O_5	NS	NS	NS	NS	NS	NS	NS

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

Table 5. Effect of phosphate fertilizer on elemental composition of recently expanded potato leaves (leaflets + petioles) sampled July 1, 1992. Previous crop - rye; initial soil test P - 60 ppm.

Phosphate Treatment lb P_2O_5	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
0	5.26	0.29	4.98	0.59	0.48	119	162	19	9.9	29
50	5.13	0.31	4.83	0.54	0.45	118	175	18	7.9	29
100	5.35	0.36	4.59	0.59	0.48	167	165	21	9.0	27
150	5.64	0.41	4.74	0.55	0.46	162	195	23	8.6	27
200	5.52	0.44	4.79	0.60	0.48	119	175	23	7.9	25
250	5.51	0.43	4.66	0.57	0.47	112	147	22	7.4	26
Pr>F	0.02	0.00	0.30	0.74	0.87	0.59	0.81	0.00	0.00	0.01
Lin P_2O_5	**	**	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 = nonsignificant; ++,*,** = significant at 10%, 5% and 1%, respectively.

Table 6. Effect of phosphate fertilizer on elemental composition of petioles sampled July 1, 1992. Previous crop - rye; initial soil test P - 60 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	20048	0.22	1.03	0.52	0.39	62	141	28	6.4	56
50	17884	0.25	1.01	0.44	0.36	86	164	22	5.2	44
100	19634	0.25	1.02	0.54	0.42	66	143	23	5.0	46
150	20987	0.32	0.97	0.57	0.44	70	143	29	4.9	45
200	17243	0.33	0.99	0.53	0.44	66	134	26	4.2	43
250	18072	0.31	1.01	0.53	0.41	68	123	24	4.4	48
Pr>F	0.07	0.00	0.87	0.01	0.11	0.71	0.90	0.06	0.29	0.22
Lin P_2O_5	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 = nonsignificant; ++,*,** = significant at 10%, 5% and 1%, respectively.

Table 7. Effect of phosphate fertilizer on elemental composition of recently expanded potato leaves (leaflets + petioles) sampled July 1, 1992. Previous crop - alfalfa; initial soil test P - 22 ppm.

Phosphate Treatment lb P_2O_5	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
0	5.47	0.31	4.61	0.62	0.53	98	95	22	8.5	29
50	5.40	0.33	4.62	0.68	0.54	103	100	21	7.4	26
100	5.74	0.38	4.81	0.71	0.58	107	99	22	7.0	26
150	5.78	0.40	4.52	0.76	0.61	109	92	23	7.1	26
200	5.80	0.43	4.51	0.73	0.59	107	94	23	6.6	26
250	6.00	0.47	4.42	0.73	0.61	107	109	26	7.2	26
Pr>F	0.02	0.00	0.38	0.06	0.01	0.02	0.33	0.02	0.01	0.10
Lin P_2O_5	**	**	NS	**	**	**	NS	**	**	++
Quad P_2O_5	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 8. Effect of phosphate fertilizer on elemental composition of petioles sampled July 1, 1992. Previous crop - alfalfa; initial soil test P - 22 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	21347	0.23	9.90	0.57	0.48	55	61	28	6.2	48
50	21209	0.28	10.01	0.63	0.57	56	72	29	5.1	40
100	21697	0.28	9.85	0.67	0.57	59	68	27	4.6	41
150	22255	0.31	9.70	0.69	0.61	60	58	29	4.8	40
200	20429	0.33	9.81	0.70	0.62	55	62	27	4.6	42
250	23404	0.39	9.55	0.72	0.64	54	68	31	5.0	42
Pr>F	0.33	0.00	0.77	0.11	0.01	0.88	0.05	0.48	0.09	0.22
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 = nonsignificant; ++,*,** = significant at 10%, 5% and 1%, respectively.

TILLAGE INDUCED MICRORELIEF IMPACTS ON NITRATE MOVEMENT IN SOILS BECKER MN. AND WESTPORT MN. CORN 1992[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 fertilizer use efficiency and movement through the soil profile. Grain yield were significantly increased at both Becker and Westport when 125 lbs N/A were applied. Tillage had relatively little impact on grain yield except for the chisel treatment at Becker which was adversely effected because the previous rye crop was not adequately controlled. Time of N application had minimal impact on grain yield at Becker while delayed applications were better at Westport. Placement of N at Westport had no impact on grain yield, but yields at Becker were increased with a placement close to the row at the late time of application.

Experimental Procedures

Two experimental locations were selected in 1992: 1. The Sand Plains Research Farm, Becker, MN. and 2. The Herman Rosholt Water Quality Research Farm at Westport, MN. Both experimental sites were irrigated.

Becker: A total of 39 treatments with four replications were established in a split plot design with tillage as the main plot. The 39 treatments consisted of three tillage (chisel, ridge till and plow), a control plot (zero N) plus three nitrogen rates (60, 120 and 180 lbs/A), two method of placement 7.5 or 15 inches from the row and two times of application early (3-leaf) or late (8-leaf). All fertilizer was applied as 28% N solution. The early N application was made on May 21 and the late application on June 22nd. 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 0-2 ft. depth in 6 inch increments from the control and the 180 lbs N/A rate. Soil samples were collected on May 26 (3-leaf), June 15 (8-leaf), June 25 (8-leaf), July 23 (silking) and Sept. 1 (dent). All soil samples were analyzed for nitrate and ammonium N.

Prior to planting 300 #/A 0-0-22 and 165 #/A 0-0-60 were broadcasted and incorporated by the different tillage systems. Corn (DeKalb 485 - 100 day R.M.) was planted on April 30th in 30 inch rows at a population of 30,700 seeds/A. Starter fertilizer was applied at the rate of 10 gal/A as 7-21-7 as a band below the seed. For weed control a tank mix of Dual (2 #/A) + Atrazine (1.5 #/A) was applied on May 1.

Plant samples were collected from the control and all N treated plots on June 15 (8-leaf), July 23 (silking) and October 1 (physiological maturity). Total dry matter production were determined on the first two sampling dates, N concentration and total N uptake. 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 June 26th and continued through August 11th with 8.25 inches of water being applied through irrigation. An additional 17.64 inches of water was obtained during the season as rainfall.

---

1. Funding provided by Cooperative State Research Service (CSRS). Appreciation is also expressed to DEKALB Plant Genetics and Pioneer Hi-Bred International for supplying seed.
2. Professor and Assistant Scientist respectively, Dept. of Soil Science, University of MN.

Westport: The experiment at Westport was identical to Becker except that the 180 lbs N/A was not included (27 treatments). Soil samples were collected to 18 inches in 6 inch increments on June 2nd (3-leaf), 25th (8-leaf), July 6th (8-leaf), August 4th (silking) and Sept. 2nd (denting). All soil samples were analyzed for nitrate and ammonium N.

Corn (Pioneer 3787 - 95 day R.M.) was planted on May 6th at a population of 30,700 seeds/A. Starter fertilizer was applied at the rate of 10 gal/A as 7-21-7 as a band below the seed and Counter 8 lbs/a was banded in the row at planting. A tank mix of Lasso (1.75 #/A) + Bladex (1.75 #/A) was applied May 23th for weed control. Nitrogen application took place on May 28th (3-leaf) and June 29th (8-leaf). Ridges were built on June 25th. Plant samples were taken June 25th (8-leaf), August 4th (silking), October 6th (physiological maturity). Plant samples were collected and analyzed simular to the Becker location.

General Results

Grain yields at Becker were excellent in 1992 considering the cool growing season. Grain yields were increased approximately 70 bu/A at Becker and 50 bu/A at Westpotr with 125 lbs N/A. Tillage systems had relatively little influecec on grain yield except at Becker where the chisel treatments was inferior to both the plow and ridge systems. During the fall of 1991 a rye cover crop was planted into this area. The chisel plow system did not allow for adequet control of the rye the following spring, and additional chemical control was required. The delayed kill is belived to be responsible for the lower yields obtained. Time of N application had relativeily little influence at Becker while the yields at Westport were higher with delayed application. The magnituted of early season N loss due to leaching are usually reflected with decreased yields with early N applications. Placement of fertilizer N had relatively little influence on yield, although at Becker increased yields were optained when N was placed close to the row with the late applications.

The results from Becker location are presentd in tables 1-4,and a summary of the results from Westport are presented in tables 5-6.

Table 1. Influence of N-rate, tillage, placement and time of application on grain yields and dry matter production at harvest. Becker, MN 10/1/1992.

N-Rate	Placement	Time	Tillage	Grain Yields	Dry Matter Production Stover	Grain	Total
#/A				Bu/A	---------T/A-----------		
Control	---	-	Chisel	85.6	2.95	2.03	4.98
60	1	1		143.4	4.03	3.39	7.42
60	1	2		146.4	3.79	3.46	7.25
60	2	1		144.6	3.84	3.42	7.26
60	2	2		138.2	3.81	3.27	7.08
120	1	1		165.9	4.30	3.92	8.22
120	1	2		169.7	4.08	4.02	8.10
120	2	1		169.4	4.29	4.01	8.30
120	2	2		150.5	3.65	3.56	7.21
180	1	1		166.9	4.45	3.95	8.40
180	1	2		157.4	3.89	3.72	7.61
180	2	1		177.5	4.31	4.20	8.51
180	2	2		157.5	3.88	3.73	7.61
Control	---	-	Ridge	115.5	3.70	2.73	6.43
60	1	1		170.2	4.39	4.03	8.42
60	1	2		158.8	3.58	3.76	7.34
60	2	1		148.0	3.98	3.50	7.48
60	2	2		166.8	3.77	3.95	7.72
120	1	1		161.7	3.82	3.83	7.65
120	1	2		178.9	3.95	4.23	8.18
120	2	1		178.6	4.18	4.23	8.41
120	2	2		196.3	4.06	4.65	8.71
180	1	1		167.6	3.88	3.97	7.85
180	1	2		172.4	3.87	4.08	7.95
180	2	1		180.0	4.43	4.42	8.85
180	2	2		170.8	3.77	4.04	7.81
Control	---	-	Plow	108.4	3.49	2.56	6.05
60	1	1		158.0	4.39	3.74	8.13
60	1	2		150.0	4.21	3.55	7.76
60	2	1		158.1	4.31	3.74	8.05
60	2	2		167.8	4.31	3.97	8.28
120	1	1		183.3	4.90	4.34	9.24
120	1	2		181.1	4.31	4.29	8.60
120	2	1		178.2	4.45	4.22	8.67
120	2	2		167.6	4.03	3.96	7.99
180	1	1		173.1	4.42	4.10	8.52
180	1	2		181.1	4.38	4.28	8.66
180	2	1		184.1	4.50	4.35	8.85
180	2	2		183.4	4.29	4.34	8.63

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 10/1/1992.

N-Rate	Placement	Time	Tillage	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
#/A				-------%------		---------#/A-----------		
Control	---	-	Chisel	0.36	0.92	21.7	37.3	58.9
60	1	1		0.45	1.11	36.1	75.6	111.7
60	1	2		0.52	1.09	39.6	75.4	115.0
60	2	1		0.44	1.03	34.1	70.7	104.8
60	2	2		0.52	1.02	39.6	66.7	106.3
120	1	1		0.60	1.26	51.5	98.5	150.0
120	1	2		0.61	1.23	49.5	99.3	148.8
120	2	1		0.47	1.22	40.8	98.4	139.2
120	2	2		0.60	1.32	43.8	93.7	137.5
180	1	1		0.70	1.33	61.6	105.1	166.8
180	1	2		0.64	1.42	49.2	105.9	155.1
180	2	1		0.67	1.31	58.0	109.8	167.8
180	2	2		0.72	1.35	56.0	100.4	156.3
Control	---	-	Ridge	0.49	1.02	36.5	55.6	92.1
60	1	1		0.52	1.09	45.5	88.0	133.5
60	1	2		0.49	1.13	35.1	85.1	120.2
60	2	1		0.50	1.15	39.4	80.2	119.6
60	2	2		0.63	1.05	47.1	83.1	130.2
120	1	1		0.62	1.05	47.5	93.8	141.3
120	1	2		0.66	1.22	52.1	101.4	153.5
120	2	1		0.58	1.33	48.8	112.5	161.2
120	2	2		0.53	1.24	43.4	114.9	158.3
180	1	1		0.59	1.20	46.3	95.4	141.6
180	1	2		0.67	1.26	51.4	102.9	154.3
180	2	1		0.63	1.32	55.8	116.5	172.3
180	2	2		0.67	1.25	50.6	101.0	151.7
Control	---	-	Plow	0.43	0.97	29.9	49.8	79.6
60	1	1		0.41	1.00	35.8	75.4	111.2
60	1	2		0.46	0.98	39.2	70.4	109.6
60	2	1		0.45	1.01	39.2	75.8	114.9
60	2	2		0.53	1.01	46.5	80.7	127.2
120	1	1		0.68	1.24	66.6	107.5	174.1
120	1	2		0.58	1.23	50.7	105.5	156.1
120	2	1		0.76	1.30	67.3	109.5	176.8
120	2	2		0.63	1.30	51.5	102.9	154.4
180	1	1		0.73	1.30	64.6	106.2	170.8
180	1	2		0.64	1.32	55.8	113.5	169.3
180	2	1		0.71	1.42	64.0	123.7	180.7
180	2	2		0.76	1.36	65.9	117.9	183.8

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 Analalysis

N-Rate X Tillage X Placement	Grain Yields	Dry Matter Production Stover	Grain	Total
	Bu/A	---------T/A------------		
N-Rate #/A				
60	154.2	4.03	3.65	7.68
120	173.4	4.17	4.10	8.27
180	173.2	4.17	4.10	8.27
P-Value	99	90	99	99
BLSD (.05)	5.0		0.12	0.22
Tillage				
Chisel	157.2	4.02	3.72	7.74
Ridge Till	171.4	3.97	4.05	8.02
Plow	172.1	4.37	4.07	8.44
P-Value	99	94	99	96
BLSD (.05)	5.1		0.12	0.22
Placement				
1. 7.5 inches	165.8	4.14	3.92	8.07
2. 15 inches	168.0	4.10	3.97	8.07
P-Value	65	54	65	6
Tillage X Placement	66	84	66	81
N-Rate X Tillage	30	21	30	23
N-Rate X Placement	67	49	67	64
N-Rate X Tillage X Placement	96	64	96	91
N-Rate X Tillage X Placement X Time				
Time				
1. 3 leaf	167.5	4.27	3.96	8.23
2. 8 leaf	166.4	3.98	3.94	7.91
P-Value	38	99	38	99
Tillage X Time	93	27	93	71
Placement X Time	57	14	57	40
Tillage X Placement X Time	74	15	74	34
N-Rate X Time	60	15	60	38
N-Rate X Tillage X Time	84	95	84	95
N-Rate X Placement X Time	96	90	96	96
N-Rate X Tillage X Placement X Time	52	64	52	64

Table 4. Continued from table 2: Split Plot Statistical Analalysis

N-Rate X Tillage X Placement	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
	--------%------		---------#/A----------		
N-Rate #/A					
60	0.49	1.05	.39.7	77.2	117.0
120	0.61	1.25	51.1	103.1	154.2
180	0.67	1.31	56.6	108.2	164.8
P-Value	99	99	99	99	99
BLSD (.05)	0.02	0.03	2.7	3.8	5.5
Tillage					
Chisel	0.57	1.22	46.6	91.6	138.2
Ridge Till	0.59	1.20	46.9	97.8	144.8
Plow	0.61	1.20	53.9	99.0	152.9
P-Value	85	90	99	99	99
BLSD (.05)			2.8	4.2	5.8
Placement					
1. 7.5 inches	0.58	1.20	48.7	94.7	143.4
2. 15 inches	0.60	1.22	49.5	97.6	147.2
P-Value	82	88	46	90	85
Tillage X Placement	98	99	87	96	97
N-Rate X Tillage	99	99	99	99	99
N-Rate X Placement	98	96	96	89	80
N-Rate X Tillage X Placement	84	81	4	84	39
N-Rate X Tillage X Placement X Time					
Time					
1. 3 leaf	0.58	1.21	50.1	96.8	146.9
2. 8 leaf	0.60	1.20	48.1	95.5	143.7
P-Value	92	30	89	51	79
Tillage X Time	97	80	67	23	33
Placement X Time	94	83	81	88	33
Tillage X Placement X Time	51	91	48	17	31
N-Rate X Time	99	53	98	13	66
N-Rate X Tillage X Time	97	37	99	23	79
N-Rate X Placement X Time	55	81	70	91	86
N-Rate X Tillage X Placement X Time	97	11	92	15	60

Table 5. Influence of N-rate, tillage, placement and time of application on grain yields and dry matter production at harvest. Westport, MN 10/6/1992.

N-Rate	Placement	Time	Tillage	Grain Yields	Dry Matter Production Stover	Grain	Total
#/A				Bu/A	-----------T/A----------		
Control	---	-	Chisel	43.5	2.60	1.03	3.63
60	1	1		86.8	3.59	2.05	5.64
60	1	2		87.6	3.07	2.07	5.14
60	2	1		84.9	3.67	2.01	5.68
60	2	2		85.2	3.13	2.02	5.15
120	1	1		88.6	3.57	2.10	5.67
120	1	2		93.2	3.36	2.21	5.57
120	2	1		91.1	3.48	2.16	5.64
120	2	2		101.3	3.31	2.40	5.71
Control	---	-	Ridge	48.8	2.61	1.15	3.76
60	1	1		82.3	3.54	1.95	5.49
60	1	2		81.8	3.06	1.94	5.00
60	2	1		81.3	3.54	1.92	5.46
60	2	2		94.0	3.54	2.22	5.76
120	1	1		91.9	4.09	2.17	6.26
120	1	2		99.1	3.71	2.34	6.05
120	2	1		91.0	4.18	2.15	6.33
120	2	2		94.1	3.50	2.23	5.73
Control	---	-	Plow	54.8	2.76	1.30	4.06
60	1	1		79.0	3.68	1.87	5.55
60	1	2		103.4	3.59	2.45	6.04
60	2	1		92.8	3.74	2.20	5.94
60	2	2		92.2	3.42	2.18	5.60
120	1	1		93.0	3.85	2.20	6.05
120	1	2		104.1	3.23	2.46	5.69
120	2	1		102.3	3.97	2.42	6.39
120	2	2		109.8	3.51	2.60	6.11

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

Split Plot Statistical Analalysis

	Grain Yields	Stover	Grain	Total
N-Rate X Tillage X Placement				
N-Rate #/A				
60	87.6	3.46	2.07	5.53
120	96.6	3.64	2.28	5.93
P-Value	99	99	99	99
Tillage				
Chisel	89.9	3.39	2.12	5.52
Ridge Till	89.4	3.64	2.11	5.76
Plow	97.0	3.62	2.29	5.92
P-Value	88	78	88	82
BLSD (.05)				
Placement				
1. 7.5 inches	90.8	3.52	2.15	5.67
2. 15 inches	93.3	3.58	2.20	5.79
P-Value	84	59	84	76
Tillage X Placement	28	18	28	18
N-Rate X Tillage	23	99	23	87
N-Rate X Placement	38	36	38	8
N-Rate X Tillage X Placement	89	79	89	84
N-Rate X Tillage X Placement X Time				
Time				
1. 3 leaf	88.7	3.74	2.09	5.84
2. 8 leaf	95.4	3.37	2.25	5.62
P-Value	99	99	99	98
Tillage X Time	74	2	74	20
Placement X Time	53	13	53	15
Tillage X Placement X Time	47	8	47	56
N-Rate X Time	26	54	26	29
N-Rate X Tillage X Time	51	94	51	89
N-Rate X Placement X Time	38	31	38	7
N-Rate X Tillage X Placement X Time	93	83	93	92

Table 6. Influence of N-rate, tillage, placement and time of application on stover and grain N content and total N removal at harvest. Westport, MN 10/6/1992.

				N-Concentration		N-Removal		
N-Rate	Placement	Time	Tillage	Stover	Grain	Stover	Grain	Total
#/A				-------%------		-----------#/A----------		
Control	---	-	Chisel	0.50	1.17	26.0	24.1	50.1
60	1	1		0.55	1.31	39.3	53.6	92.9
60	1	2		0.58	1.36	35.7	56.1	91.8
60	2	1		0.57	1.16	41.6	46.5	88.1
60	2	2		0.55	1.29	34.0	52.1	86.1
120	1	1		0.60	1.36	42.6	57.1	99.7
120	1	2		0.81	1.49	54.6	65.6	120.2
120	2	1		0.73	1.48	50.6	63.4	114.0
120	2	2		0.73	1.62	48.0	77.6	125.6
Control	---	-	Ridge	0.48	1.05	25.2	24.2	49.4
60	1	1		0.58	1.22	41.5	47.6	89.1
60	1	2		0.56	1.31	34.5	50.8	85.3
60	2	1		0.57	1.33	40.2	51.2	91.4
60	2	2		0.62	1.39	43.9	61.9	105.7
120	1	1		0.74	1.53	60.2	66.4	126.6
120	1	2		0.77	1.48	57.6	69.4	127.0
120	2	1		0.74	1.60	61.9	68.9	130.8
120	2	2		0.77	1.54	54.1	68.7	122.8
Control	---	-	Plow	0.43	1.03	23.5	26.7	50.2
60	1	1		0.55	1.35	40.0	50.6	90.6
60	1	2		0.61	1.29	43.7	63.3	107.1
60	2	1		0.48	1.20	35.7	52.7	88.4
60	2	2		0.60	1.28	40.8	55.8	96.6
120	1	1		0.62	1.53	47.8	67.7	115.5
120	1	2		0.73	1.44	47.1	70.9	118.0
120	2	1		0.70	1.49	55.5	72.5	128.0
120	2	2		0.68	1.49	47.8	77.4	125.2

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

Split Plot Statistical Analalysis

	Stover	Grain	Stover	Grain	Total
N-Rate X Tillage X Placement					
N-Rate #/A					
60	0.56	1.29	39.2	53.5	92.7
120	0.71	1.50	52.3	68.8	121.1
P-Value	99	99	99	99	99
Tillage					
Chisel	0.63	1.38	43.2	59.0	102.2
Ridge Till	0.66	1.42	49.2	60.6	109.8
Plow	0.61	1.38	44.8	63.9	108.7
P-Value	67	91	76	86	81
BLSD (.05)					
Placement					
1. 7.5 inches	0.64	1.39	45.3	59.9	105.3
2. 15 inches	0.64	1.40	46.1	62.3	108.5
P-Value	21	61	48	93	89
Tillage X Placement	29	99	10	33	31
N-Rate X Tillage	66	8	99	29	84
N-Rate X Placement	65	99	35	96	90
N-Rate X Tillage X Placement	54	99	88	99	99
N-Rate X Tillage X Placement X Time					
Time					
1. 3 leaf	0.61	1.38	46.4	58.2	104.6
2. 8 leaf	0.66	1.41	45.1	64.1	109.2
P-Value	99	96	68	99	98
Tillage X Time	66	99	53	44	62
Placement X Time	93	85	79	26	43
Tillage X Placement X Time	96	72	84	58	54
N-Rate X Time	68	86	21	20	26
N-Rate X Tillage X Time	90	92	99	89	99
N-Rate X Placement X Time	99	35	98	17	80
N-Rate X Tillage X Placement X Time	33	27	18	76	67

LONG-TERM N MANAGEMENT EFFECTS ON CORN PRODUCTION AND NITRATE LEACHING POTENTIAL AT THE SOUTHWEST EXPERIMENT STATION, LAMBERTON, MN

D. R Huggins, D. J. Fuchs, J. A. Staricka, and G. L. Malzer[1]

Improved N management can increase N use efficiency and minimize N leakage from production systems. A field study was initiated in 1960 to determine if continuous corn yields are affected by N form (urea or ammonium nitrate), amount (14 to 174 lbs N/ac), time of application (fall, spring or sidedressed), and placement (surface, moldboard plow incorporation or sidedress). In addition, crop and soil nitrate data collected in 1969 and 1989 were used with a computer model (NLEAP) to assess nitrate leaching potential. Long-term corn yields responded primarily to N rate, however, significantly greater yields were also obtained with spring and sidedress applied N as compared to treatments with fall applied N. Despite greater yields with sidedressed N, soil nitrate levels in the rooting zone (0 to 5 ft) after harvest in 1969 were significantly greater in treatments with sidedressed as compared to fall applied N. Similar results were obtained in 1989 but at only the greatest N rate. Nitrate levels below the root zone (5 to 10 ft) were significantly greater for fall and sidedressed applied N than for spring applied N. The N available for leaching calculated with the screening process of the NLEAP model indicated moderate to high values across all treatments in 1969 and 1989. However, despite high levels of N available for leaching, a low leaching index resulted in low leaching risk potentials for most treatments. The exceptions were treatments with high N rates (174 lbs N/ac) which had high annual leaching risk potentials. These results indicate that excessive N rates present the greatest risk for nitrate-N leaching under the environmental conditions of the this long-term study.

MATERIALS AND METHODS

The continuous corn study is a nitrogen fertilization experiment involving various rates (0, 40, 80, 160 lbs N/ac) and application times (fall, spring, sidedress) of ammonium nitrate and urea. The experiment has been conducted since 1960 on tiled Normania loam/Webster clay loam soils. The fertilizer treatments have been applied annually to the same plot area (20 x 77.5 ft) for 33 years. The experimental design is a randomized incomplete block with four replications. After ear corn removal and stalk cutting, plots with treatments of fall applied N receive either broadcast N followed by moldboard plowing or moldboard plowing followed by surface applied N. All other treatments are also fall moldboard plowed to a depth of 12 inches. Spring treatments of applied N are broadcast before seedbed preparations in late April or early May. The corn is planted in 30-inch rows, and 100 lbs/ac starter fertilizer (14-41-15) is banded in all treatments. Sidedress treatments of applied N are broadcast in June and incorporated during cultivation. Additional management information is provided in Table 1. In 1969 and 1989, soil samples were collected at one foot increments to a depth of 7 and 10 ft, respectively, and analysed for nitrate-N. These data were combined with N budget estimates in a screening procedure using the NLEAP model to assess potentially leachable nitrate-N below the root zone.

RESULTS AND DISCUSSION

Corn yield in 1992 responded significantly to increased N rate but showed no response to timing or N form (Table 2). Long-term corn yields (1960-1992) revealed a significant response to N rate and timing (Table 3). Yields with spring and sidedress applied N were up to 18% greater than yields with fall N applications (Table 3). Soil nitrate-N depth distributions were similar for the control and 80 lb N/ac rates across all N timings (Fig. 1). Over-application of N was indicated by increased levels of soil nitrate-N in treatments receiving 160 lb N/ac (Fig. 1). In 1989, accumulations of soil nitrate-N within the rooting zone (0-5 ft) were very high at the greatest N rate (Fig. 2). Nitrate-N levels below the rooting zone (5-10 ft) also increased with increasing N rate to a high of 100 lb N/ac for the sidedressed treatment (Fig. 3). In general, soil nitrate levels within and below the rooting zone were greater for sidedressed and fall applied N than for spring applied N.

The NLEAP model contains a screening procedure to assess the risk of nitrate-N leaching below the rooting zone. Inputs include: (1) precipitation data and soil hydrologic group to calculate a leaching index (LI); (2) estimates of the nitrate-N available for leaching (NAL) based on an estimated N balance; (3) estimates of the nitrate-N leached from the root zone (NLy) calculated from LI and NAL; and (4) the annual leaching risk potential (ALRP) based on NLy and qualitative aquifer data. Leaching indices (LI) during 1961-

[1] Soil Scientist and Scientist, respectively, U of MN, Southwest Experiment Station, Lamberton, MN; Soil Scientist, USDA-ARS, Morris, MN; Soil Scientist, U of MN St. Paul, MN.

1991 were low (< 5 in) in all years with the exception of 1985 and 1986 where they were moderate (Fig. 4). The estimated nitrate-N available for leaching (NAL) was generally high (>80 lb N/ac) across all N rates and timings in 1969 and 1989 (Fig. 5). However, despite a high NAL, the estimated nitrate-N leached (NLy) was low (<40 lb N/ac) for most treatments (Fig. 6). The exceptions were treatments with the highest N rates which had moderate or high NLy. The annual leaching risk potential (ALRP) was low for 1989 across all N rates and timings (Table 4). Using the highest LI in the past 32 years, the ALRP was still low for intermediate rates of applied N, however, high rates of applied N had a high ALRP rating. This analysis indicates that excessive N rates present the largest risk for groundwater contamination with nitrate-N under the environmental conditions of the study.

Table 1. 1992 Management Information.

Item	Type	Rate	Date
Secondary Tillage	Disc	1 pass	4/26
	Digger	1 pass	5/8
Seed	Pioneer	27,700 seeds/ac	5/9
Fertilizer	Starter	14-41-15 lbs/ac ($N-P_2O_5-K_2O$)	5/9
Herbicides	Lasso	3.0 lbs/ac (ai)	4/26
	Bladex	2.0 lbs/ac (ai)	
Insecticides	Counter	1.0 lbs/ac (ai)	5/9
	Pounce 3.2E	6.0 oz/ac (ai)	6/27
Cultivation		1 pass	6/18

Table 2. Corn yields (bu/ac) in 1992.

Application Time	Ammonium Nitrate (lbs/ac)			Urea (lbs/ac)		
	40	80	160	40	80	160
Fall Incorporated	89	110	120	97	111	122
Fall Plowed Surface	87	---	---	89	---	---
Spring Pre-plant	97	111	---	106	122	---
Side Dress	107	115	135	106	122	---
Check: 54						

$LSD_{0.05}$ = 17 bu/ac

Table 3. Long-term average yields (bu/ac) from 1960-1992.

Application Time	Ammonium Nitrate (lbs/ac)			Urea (lbs/ac)		
	40	80	160	40	80	160
Fall Incorporated	83	104	114	91	105	114
Fall Plowed Surface	87	---	---	88	---	---
Spring Pre-plant	93	108	---	93	110	---
Side Dress	98	105	119	98	113	---
Check: 62						

$LSD_{0.05}$ = 4 bu/ac

Table 4. NLEAP screening procedure for assessing nitrate-N leaching risk potential (Pierce et al., 1991).

NLy (lb/ac)	NLy Score	TT	TT Score	PA	PA Score	VA	VA Score	ALRP	ALRP Rating
<40	1	>15 yr	1	deep/conf	1	Cls III	1	0-2	vlow
40-<80	2	5-15 yr	2	medium	2	CLS IIB	2	3	low
>80	4	<5 yr	4	shallow	4	Clsl, IIA	4	4	mod
								5	high
								6	vhigh
								7	extreme
								8	vextreme

Abbreviations: NLy, nitrate-N leached; TT, travel time; PA, position of aquifer; VA, vulnerability of aquifer; ALRP, annual leaching risk potential.

Table 5. Estimate of nitrate-N leaching risk potential, 1989.

Treatment	--- NLy Score --- High LI	1989 LI	TT Score	PA Score	VA Score	Score Product	-------- ALRP -------- High LI	1989 LI
Control	1	1	2	2	2	8	3 (LOW)	3 (LOW)
Fall N								
94 lb/ac	1	1	2	2	2	8	3 (LOW)	3 (LOW)
174 lb/ac	4	1	2	2	2	32	5 (HIGH)	3 (LOW)
Spring N								
94 lb/ac	1	1	2	2	2	8	3 (LOW)	3 (LOW)
Sidedress N								
94 lb/ac	1	1	2	2	2	8	3 (LOW)	3 (LOW)
174 lb/ac	4	1	2	2	2	32	5 (HIGH)	3 (LOW)

Abbreviations: NLy, nitrate-N leached; TT, travel time; PA, position of aquifer; VA, vulnerability of aquifer; ALRP, annual leaching risk potential; LI, leaching index.

Fig. 1. Influence of N timing and rate on soil nitrate-N distribution.

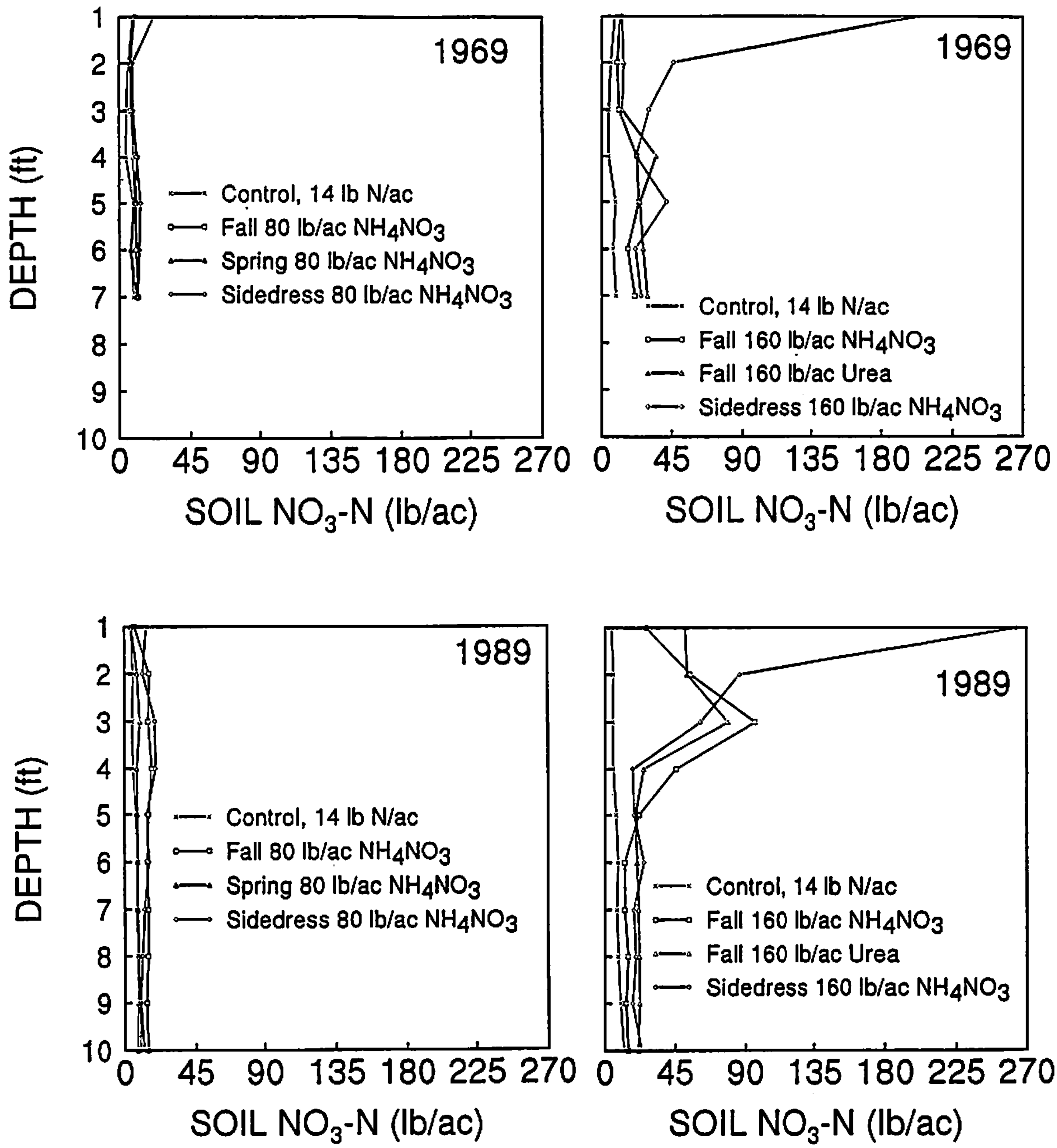


Figure 2. Soil nitrate-N in the root zone, fall 1989.

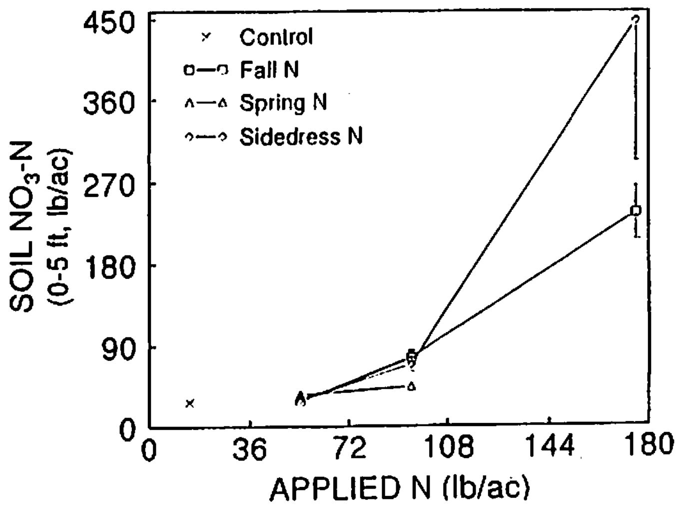


Figure 3. Soil nitrate-N below the root zone, fall 1[illegible]

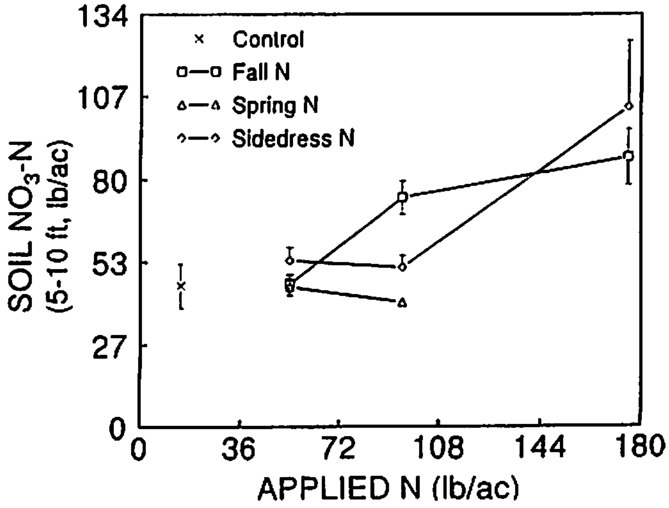


Fig. 4. Leaching index (LI)
SWES, Lamberton, MN

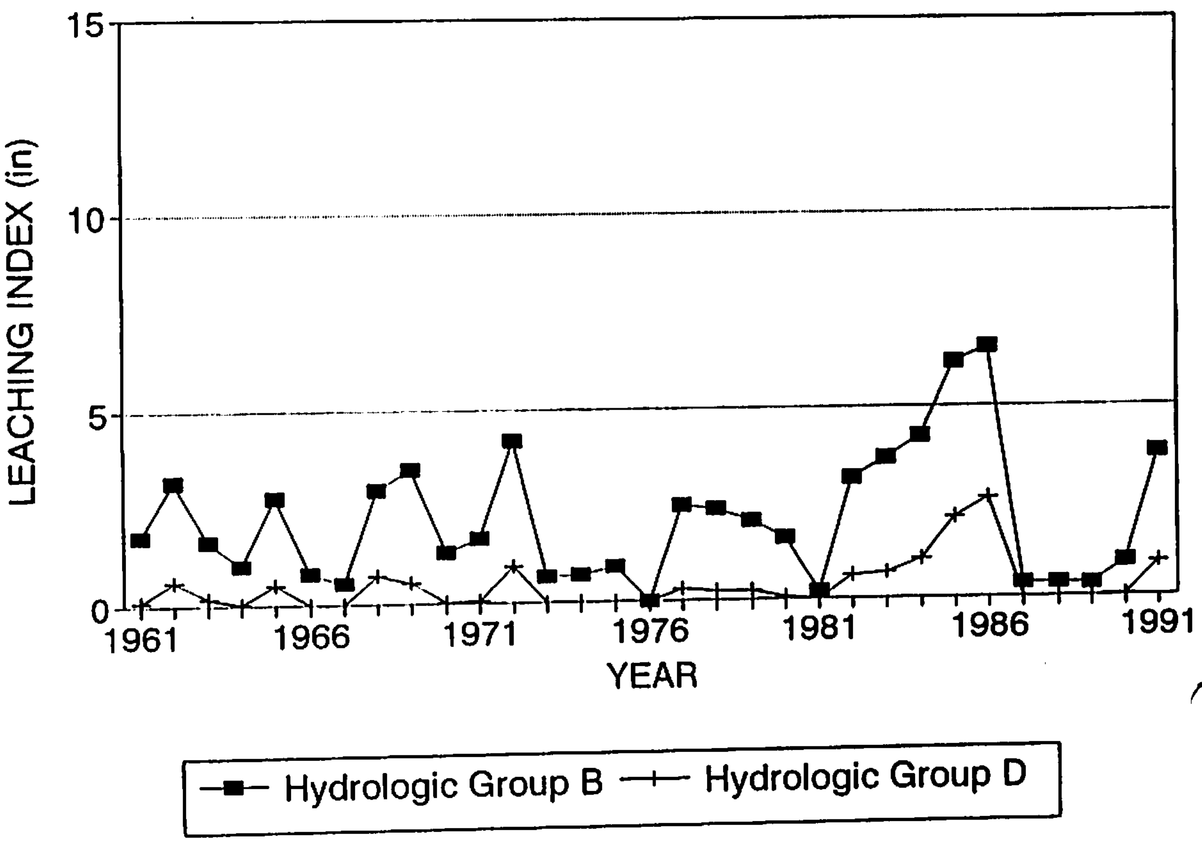


Fig. 5. Estimated nitrate-N available for leaching.

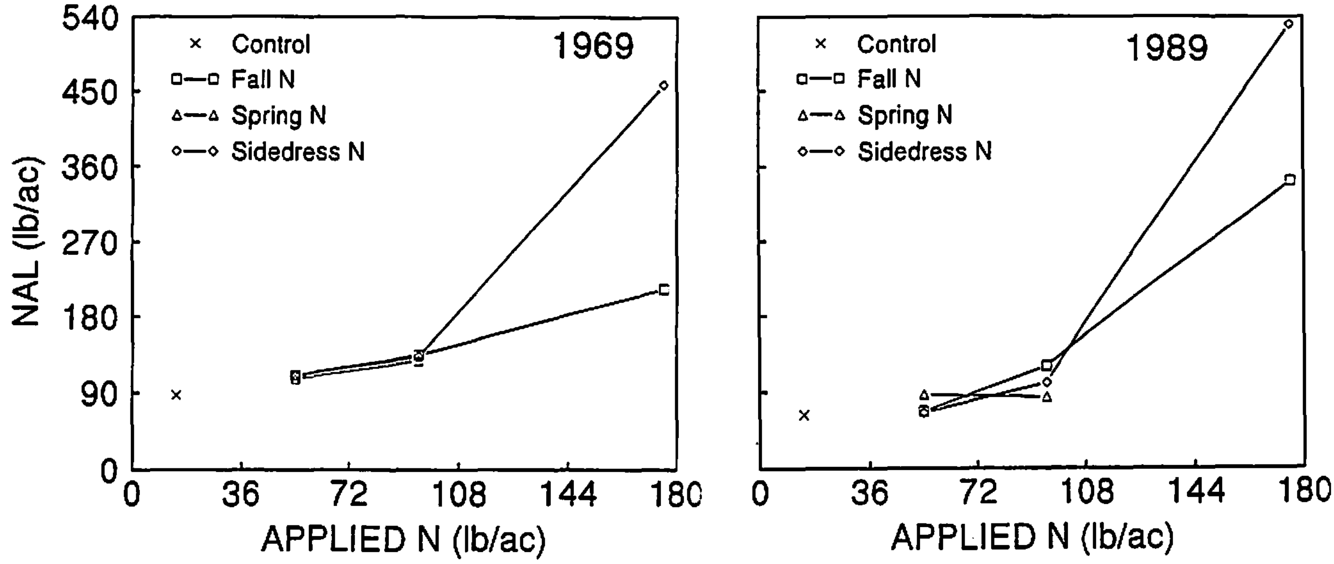
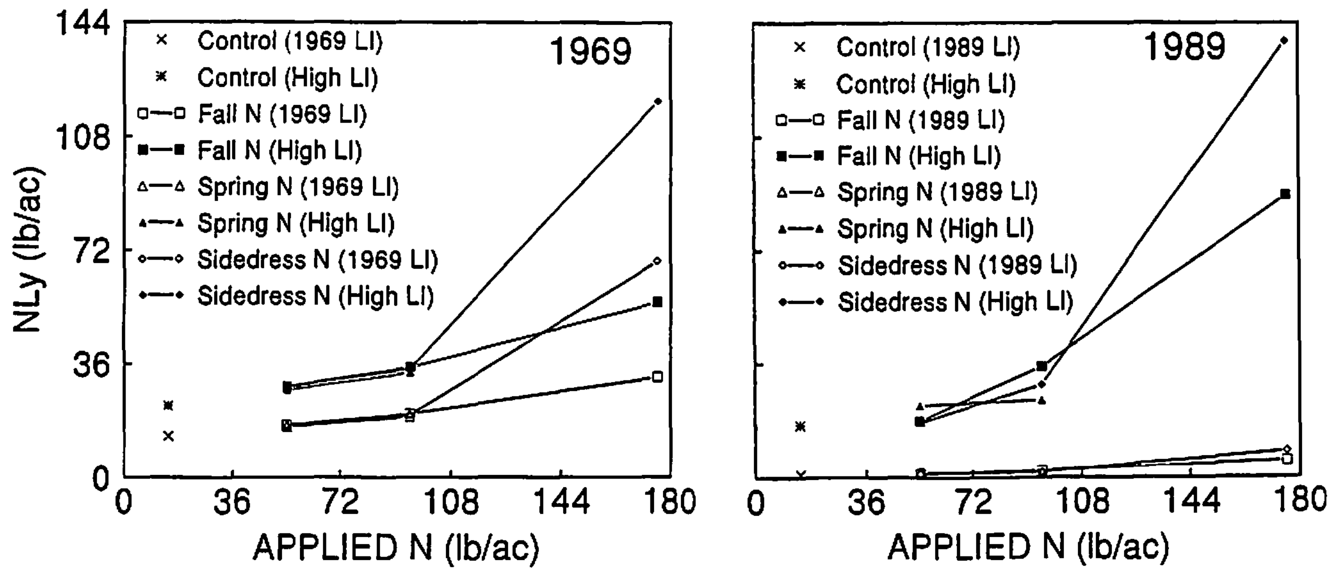


Fig. 6. Estimated nitrate-N leached from the root zone.



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

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

Field data is needed to evaluate crop growth simulation models. The objective of this study is to determine the interactive effect of tillage and soil erosion level on corn yields. A field study was initiated in 1984 where continuous corn is grown with conventional tillage (fall moldboard plow) or ridge tillage on sites where soil types are slightly, moderately, or severely eroded. In 1992, tillage and erosion levels had a significant effect on corn yields. Corn yields with conventional tillage yielded 12 percent more than with ridge tillage. Corn on the severely eroded soil yielded 13 percent less and on the moderately eroded soil 9 percent less than corn grown on soil that was only slightly eroded. Over the course of the experiment, the effect of erosion class on corn yields has been consistent with the higher yields occurring on the less eroded treatments. Tillage effects on corn yields have been inconsistent over the course of the experiment.

METHODS AND MATERIALS

Field plots were established in 1984 with continuous corn and two tillage regimes in areas which had been slightly, moderately, and severely eroded. The soil type for the slight and moderately eroded areas is a Ves (fine-silty, mixed mesic Typic Hapludalf). The soil type on the severely eroded area is a Storden (fine-loamy, mixed (calcareous), mesic Typic Udorthent). The two tillage systems used on each erosion class were fall moldboard plow and ridge tillage.

The entire study was moldboard plowed in the fall of 1989 because of the visual and measured potassium deficiency symptoms that occurred in the ridge tillage treatment. Ridges were re-established during the 1990 growing season. In 1991, the ridge tillage plots were row cultivated with a conventional row cultivator, but because of wet field conditions, they were not ridged with the ridge cultivator. In the fall of 1991, the ridge area was paraplowed. Additional management information is given in Table 1. Analysis of variance, using a split plot design (tillage = whole plot, erosion class = split plots) is given in Table 2. If treatments were significantly different (0.05 level), means were separated using Fisher's $LSD_{(0.05)}$.

RESULTS and DISCUSSION

The objectives of this study are to asses the effect of erosion on soil characteristics and potential productivity of selected soils with emphasis on evaluation of physically-based simulation models. In 1992, corn yields on the severely eroded soil yielded 13 percent less and on the moderately eroded soil 9 percent less than corn grown on soil that was only slightly eroded (Table 2 and 3). Over the past eight years, erosion levels have affected corn yields with the greatest yields occurring on the least eroded soil. In 1992, corn in moldboard plow treatments yielded 12 percent more than the ridge tillage system (Table 2 and 3). In the past, tillage effects on corn yields have been inconsistent. More information may be obtained from Dr. Mike Lindstrom, USDA-ARS, Morris, Minnesota 56267, ph. 612-589-3411.

ACKNOWLEDGEMENTS

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

---

[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; Soil Scientist - U of MN, Southwest Experiment Station, respectively.

Table 1. 1992 Management Information.

Item	Type	Rate	Date
Primary Tillage (MP)	Moldboard Plow	1	Fall 1991
Secondary Tillage	Disc Digger	1 pass 1 pass	4/29 4/30
Seed	Dekalb 535	29,000 seeds/ac	4/30
Fertilizer	Urea	150-0-0 lbs/ac ($N-P_2O_5-K_2O$)	4/29
Herbicides	Eradicane Bladex	2.5 lbs/ac 1.5 lbs/ac	4/29
Insecticides	Furadan	1.0 lbs/ac	4/30
Row Cultivation Ridging		once once	5/20 5/29

Table 2. Analysis of Variance.
Randomized block with split plot restriction
Number of: Cases = 24 Blocks = 4
Tillage Levels = 2 Erosion Levels = 3

Source	DF	SS	MS	F	P
Block	3	385.99	128.66	1.02	0.42
Tillage	1	1821.78	1821.78	14.48	**0.00
Whole plot error	3	204.48	68.16	0.54	0.66
Erosion Class	2	1487.76	743.88	5.91	*0.02
Tillage*Erosion	2	831.73	415.87	3.30	0.07

* significant at alpha = 0.05, ** significant at alpha = 0.01

Table 3. Mean yields (bu/ac) of tillage, erosion class and interactions.

	Erosion Class[1]			Overall average
Tillage[2]	Slight	Moderate	Severe	
Moldboard plow	158.4	149.8	130.0	146.0
Ridge area	137.6	119.0	128.4	128.6
Overall average	148.0	134.8	129.2	137.3

1/ $LSD_{0.05}$ = 12.2 (bu/ac) for comparing erosion classes (averaged over both tillage treatments)
2/ $LSD_{0.05}$ = 10.7 (bu/ac) for comparing tillage systems (averaged over erosion classes)

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 1992, tillage treatments had a significant effect on corn 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 corn 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. Soil movement will be assessed at the conclusion of the study 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 $LSD_{0.05}$.

RESULTS AND DISCUSSION

In 1992, corn yields for the various tillage treatments were significantly different for each slope percentage. The moldboard plow and chisel plow treatments significantly yielded more than the ridge tillage in all cases (Table 2-8). Yields with moldboard plowing were 2.0 percent greater than yields with the chisel plowing on the 8 percent slope (Table 2 and 3). In addition, corn yields with moldboard plowing were 12.8 percent and chisel plowing 10.6 percent greater than ridge tillage (Table 3). No significant yield differences occurred on the 8 percent slope between row direction or position (Table 2 and 4).

On the 4 percent slope area, moldboard plow corn yielded 15.7 percent and chisel plow 12.8 percent more than the ridge tillage treatment (Table 6). There was no significant effect of row direction on corn yield on the site with 4 percent slope (Table 5). On the 1 percent slope area, moldboard plow corn yielded 6.6 percent and chisel plow 10.5 percent more than the ridge tillage treatment (Table 8). The different slope percentages (8, 4 & 1%) were not compared with an analysis of variance, however, the overall average corn yield on the 8, 4, and 1 percent slopes were 153.1 (bu/ac), 164.0 (bu/ac), and 162.6 (bu/ac), respectively. In 1992, there was little difference between corn yields on the 1 and 4 percent slopes (Table 6 and 8). In the past, there has been a trend of decreasing yield with increasing slope percentage.

---

[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; Soil Scientist - U of MN, Southwest Experiment Station, respectively.

Table 1. 1992 Management Information.

Item	Type	Rate	Date
Primary Tillage[1]	CP and MP	Once	Fall 1991
Secondary Tillage[1]	Field Cultivator	2 passes	4/29
Seed	Pioneer 3615	29,000 seeds/ac	4/30
Fertilizer	Urea	125 lbs N/ac	6/10
	Starter	7-20-7 lbs $N-P_2O_5-K_2O$/ac	4/30
Herbicides	Lasso	3.0 lbs/ac (ai)	5/1
	Bladex	1.5 lbs/ac (ai)	5/1
Row Cultivation		Once	6/10

1/ No primary or secondary tillage on ridge tillage plots.

Table 2. Analysis of Variance for the 8 Percent Slope.
Variable: Corn grain yield (bu/ac)
Randomized block with split - split plot restriction
Number of: Cases = 54 Blocks = 3
Row Directions = 2 Tillage Levels = 3 Slope Positions = 3

Source	DF	SS	MS	F	P
Block	2	328.75	164.37	0.90	0.41
Row Direction	1	81.47	81.47	0.45	0.51
Whole Plot Error	2	296.34	148.17		
Tillage	2	6743.60	3371.80	18.47	** 0.00
Row*Tillage	2	3.11	1.55	0.01	0.99
Sub-Plot Error	8	1053.80	131.73		
Position	2	136.93	68.47	0.38	0.69
Row*Position	2	1417.20	708.60	3.88	0.02
Tillage*Position	4	688.52	172.13	0.94	0.44
Row*Tillage*Position	4	524.73	131.18	0.72	0.58

** significant at alpha = 0.01

Table 3. Corn Yields on the 8 Percent Slope by Tillage.

Tillage	Average yield[1]	Standard deviation
	------------------- bu/ac ------------------	
Moldboard Plow	160.2 a	11.2
Chisel	157.0 b	12.7
Ridge Tillage	142.0 c	15.8

1/ $LSD_{0.05}$ = 1.3 bu/ac
Means in a column with the same letter do not differ significantly using Fischer's LSD (0.05 probability level).

Table 4a. Corn Yields on the 8 Percent Slope by Tillage-Row Dir.-Slope Position Interaction.

Row direction	Tillage	Slope Position	Average yield	Standard deviation
			-------- bu/ac	-------
Up & Down	Moldboard Plow	Top	161.3	12.2
		Middle	159.8	9.5
		Bottom	161.7	13.1
	Chisel Plow	Top	149.3	10.5
		Middle	160.9	6.9
		Bottom	163.1	6.3
	Ridge Tillage	Top	136.2	11.7
		Middle	140.8	11.2
		Bottom	152.5	6.1
Contour	Moldboard Plow	Top	163.1	14.7
		Middle	157.3	8.8
		Bottom	157.8	11.7
	Chisel Plow	Top	156.1	13.6
		Middle	157.9	19.0
		Bottom	154.8	15.5
	Ridge Tillage	Top	151.8	16.5
		Middle	133.8	12.1
		Bottom	137.2	25.3

Table 4b. Corn Yields on the 8 Percent Slope by Row Direction-Slope Position Interaction (sig. at alpha = 0.05).

Row direction	Slope Position	Average yield	Standard deviation
		----------- bu/ac	-----------
Up & Down[1]	Top	148.9 b	3.6
	Middle	153.8 ab	3.0
	Bottom	159.1 a	2.3
Contour[2]	Top	157.0 a	3.5
	Middle	149.7 a	4.1
	Bottom	149.9 a	4.6

1/ $LSD_{0.05}$ = 8.6 (bu/ac)
2/ $LSD_{0.05}$ = 11.8 (bu/ac)

Table 5. Analysis of Variance for the 4 Percent Slope.
Variable: Corn grain yield (bu/ac)
Randomized block with split plot restriction
Number of: Cases = 12 Blocks = 2
Tillage Levels = 3 Row Directions = 2

Source	DF	SS	MS	F	P
Block	1	115.28	115.28	0.51	0.48
Row direction	1	9.88	9.88	0.04	0.84
Whole plot error	1	170.67	170.67		
Tillage	2	2490.09	1245.04	5.55	** 0.01
Row*Tillage Interaction	2	68.40	34.20	0.15	0.86

** significant at alpha = 0.01

Table 6. Corn 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	173.3 a	Up & Down	173.6	14.2
		Contour	173.0	6.9
Chisel Plow	169.0 a	Up & Down	169.8	15.0
		Contour	168.2	14.7
Ridge Tillage	149.8 b	Up & Down	146.8	23.1
		Contour	152.9	8.2

1/ $LSD_{0.05}$ = 15.9 (bu/ac) averaged over row directions
Means in a column with the same letter do not differ significantly using Fischer's LSD (0.05 probability level).

Table 7. Analysis of Variance for the 1 Percent Slope.
Variable: Corn grain yield (bu/ac)
Randomized block
Number of: Cases = 6 Blocks = 2
Tillage Levels = 3

Source	DF	SS	MS	F	P
Block	1	155.5	155.5	5.99	0.04
Tillage	2	531.1	265.6	10.23	** 0.01

** significant at alpha = 0.01

Table 8. Corn Yields on the 1 Percent Slope by Tillage.

Tillage	Average yield[1]	Standard deviation
	--------------- bu/ac ---------------	
Moldboard Plow	163.9 a	3.5
Chisel Plow	170.0 a	1.9
Ridge Tillage	153.8 b	10.3

1/ $LSD_{0.05}$ = 8.3 (bu/ac)
Means in a column with the same letter do not differ significantly using Fischer's LSD (0.05 probability level).

PESTICIDE RUNOFF AND LEACHING UNDER CONVENTIONAL AND SOIL-SPECIFIC MANAGEMENT[1]

B.R. Khakural, P.C. Robert, D.R. Huggins, D.J. Fuchs and W.C. Koskinen[2]

ABSTRACT: Leaching and runoff loss of alachlor was studied on a soil catena with varied slope and drainage characteristics under conventional and soil-specific management. Alachlor concentration of runoff (water, water+sediment) was lower for soil-specific than for uniform rate in both Ves soils. Alachlor was not detected in soil samples obtained from greater than 6 in depths in any soil or treatment after the first sampling. During the first sampling (7 days after application), alachlor was detected to deeper depths in treatments receiving higher alachlor rates. Detectable amount of alachlor was observed in soil water samples from all three soils during some sampling dates. There was no particular trend in soil water alachlor concentration due to soil or alachlor rates.

Introduction:

Growing concerns about crop management sustainability and surface and ground water pollution by agricultural chemicals have initiated soil-specific management system (SSMS). Effects of SSMS on runoff and leaching of chemicals were studied on landscape plots (runoff, micro-plots) at the Southwestern Experiment Station, Lamberton, MN.

Materials and Methods:

A landscape comprised of two soil series with varied drainage characteristics was selected for this study. Two soil series used in this study were a well drained Ves (fine-loamy, mixed, mesic Udic Haplustoll) and a poorly drained Webster (fine-loamy, mixed, mesic Typic Haplaquoll). They represent a catena with the Ves soils on the backslope (1-4%) and sideslope (6-12%) and the Webster soil on the toeslope (0-3%) positions. Selected properties of the three soil types studied were presented in a 1992 report.

Runoff plots were arranged as a split plot design with soil (landscape position) as main plot and herbicide rate as sub-plot (30 ft X 2.5 ft) with three replications. Stainless steel sampling gutters attached to vertically installed nalgene carboys were used to receive runoff samples. Six leaching microplots (7 ft X 7 ft: 2 on each soil type) were established. Each plot was isolated vertically with polyethylene sheets (0.0059 in) to a depth of 5 ft. Suction cups were installed in duplicates at 2- and 4 ft depths. Three plots across the landscape received a uniform rate of alachlor (Lasso) herbicide (UR) and the remaining half received soil-specific rates (SSR).

Plot Management

Crop: soybean variety: Kato — Planting Date: 5-13-1992
Herbicide used: alachlor — Date application: 5-13-92
Herbicide rate:

Uniform rate: 3 lb/A

Soil-specific rate

	lb/A
Ves (1-4%)	: 2.50
Ves (6-12%)	: 2.00
Webster (0-3%)	: 3.25

Sampling and Laboratory Procedure:

Soil samples (0-4 ft) were collected using a soil probe with a plastic liner. Runoff samples were obtained by placing the stainless steel sampler at the end of a 30 ft crop row (30 ft X 30 in). Soil water suction samples were collected after each significant rainfall. Soil, soil water and runoff (water and sediment) samples were analyzed for alachlor concentration in the laboratory using gas chromatographic procedures.

[1]Funding for this project was provided by a USDA-CSRS grant.
[2]B.R. Khakural and P.C. Robert are Post Doctoral Research Associate and Associate Professor respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN 55108. D.R. Huggins and D.J. Fuchs are Assistant Professor and Scientist, Southwest Experiment Station, University of Minnesota. W.C. Koskinen is a Soil Scientist, USDA-ARS, St. Paul, MN.

Results and Discussion

Runoff

Three runoff events occurred during the 1992 cropping season. The second runoff event (34 days after application) had a higher concentration of alachlor in runoff water in the Ves soil than the first event. The second event occurred on the same day, 19 hours after the first event.

Alachlor concentration of the runoff water and runoff (water+sediment) was consistently lower for soil-specific rate (SSR) than for uniform rate (UR) in both Ves soil conditions and were statistically significant during the second and third runoff events (Table 1). A similar trend was observed in sediment alachlor concentration except in the Ves (6 to 12%) soil in event 2. The differences in concentrations between SSR and UR however, were not statistically significant. No significant difference in concentration was observed in the Webster soil due to alachlor rates.

Alachlor concentration was very high in the runoff sediment (0.7 to 22 ppm) compared to its concentration in runoff water (6 to 110 ppb). Runoff water contributed 88% (71 to 98%) of the bulk concentration. The contribution from the sediment phase increased as slope gradient increased. On an average, runoff sediment of the Ves (1 to 4%), Ves (6 to 12%) and Webster soils contributed 12.5, 14.5, and 9% to the bulk concentration, respectively.
Soil-specific rates, compared to the uniform rate, reduced alachlor concentration in runoff sediment, water, and water+sediment by 10, 24, and 22% (average of events 1 and 2), respectively. The reduction in runoff water and bulk (water+sediment) concentration was statistically significant at the p= 0.1 level.

Leaching and Soil Alachlor Concentration

At the first sampling (7 days of alachlor application), alachlor was found in soil samples taken from deeper depths in treatments receiving higher rates (Table 2). Maximum depths of detections were 1.5 and 3 ft in the Ves and Webster soils, respectively. Alachlor was not detected in soil samples obtained from greater than 6-in depths in any soils or treatments after the first sampling.

Alachlor was detected in soil water samples from all three soils during some sampling dates except Ves (6 to 12%) at 2-ft depth (Table 3). Alachlor concentration varied from 0.2 to 9.4, and 0.1 to 2.4 ppb at 2- and 4-ft depths, respectively. No particular trend was observed with alachlor rates.

Surface soil alachlor concentration was significantly lower for SSR compared to UR in the Ves (6-12%) soil during the second and third samplings and in the Ves (1-4%) soil only during the second sampling (Figure 1).

Table 1. Average alachlor concentration in runoff sediment and water from Ves and Webster soils.

Event (Date)	Soil	Sediment		Water		Sediment+Water	
		UR	SSR	UR	SSR	UR	SSR
		----- ppm ----		---------------- ppb		--------------	
1 (5-16-92)	Ves (1-4%)	7.32	5.05	33.8	24.0	40.1	30.3
	Ves (6-12%)	5.40	2.81	35.1	28.8	37.7	34.1
	Webster (0-3%)	2.27	1.91	34.3	43.5	36.1	48.5
2 (5-16-92)	Ves (1-4%)	6.23	5.23	84.9a	65.9b	90.4a	72.3b
	Ves (6-12%)	3.47	6.57	104.8a	63.5b	110.1a	64.6b
	Webster (0-3%)	2.69	3.06	26.7	16.2	29.5	19.0
3 (7-2-92)	Ves (1-4%)	6.61	2.67	29.1a	14.0b	33.3a	17.2b
	Ves (6-12%)	22.17	12.35	33.5a	12.4b	47.1a	17.5b
	Webster (0-3%)	-	0.66	-	6.0	-	6.4
Management (UR, SSR) Ave†		4.56	4.11	53.3	40.31	57.32	44.8

Within a soil and runoff phase (water, water+sediment), means followed by different letters are significantly different at the p= 0.05 level. An absence of letters indicates no significant difference.
†Averaged across soils and events (1 and 2).
UR= Uniform rate SSR= Soil-specific rate

Table 2. Soil alachlor concentration of the first sampling (7 days after application).

Soil	Depth	Uniform rate		Soil-specific rate	
		Mean†	Sd‡	Mean	Sd
	in	ppb			
Ves (1-4%)	00-06	411	182	424	188
	06-12	16	28(2)	-	-
	12-18	9	22(1)	-	-
Ves (6-12%)	00-06	434	299	294	53
	06-12	18	29(2)	21	32(2)
	12-18	8	19(1)	-	-
Webster (0-3%)	00-06	422	228	469	674
	06-12	11	27(1)	71	121(3)
	12-18	-	-	12	28(1)
	18-24	-	-	18	45(1)
	24-36	-	-	35	85(1)

†Six observations were used to calculate mean and Sd.
‡Numbers in parenthesis indicate number of observations with a detectable amount of alachlor out of six observations. - Alachlor not detected.

Table 3. Alachlor concentration in soil water at 2 and 4 feet depths.

Soil Date:	7-2-92		7-14-92	
	UR	SSR	UR	SSR
	ppb			
	2 feet			
Ves (1-4%)	ND	9.4	ND	2.0
Ves (6-12%)	ND	ND	ND	ND
Webster (0-3%)	ND	2.6	ND	ND
	4 feet			
Ves (1-4%)	ND	ND	ND	2.4
Ves (6-12%)	ND	ND	0.9	0.8
Webster (0-3%)	2.2	-	0.8	0.9

†ND = Not detected - Unable to get samples

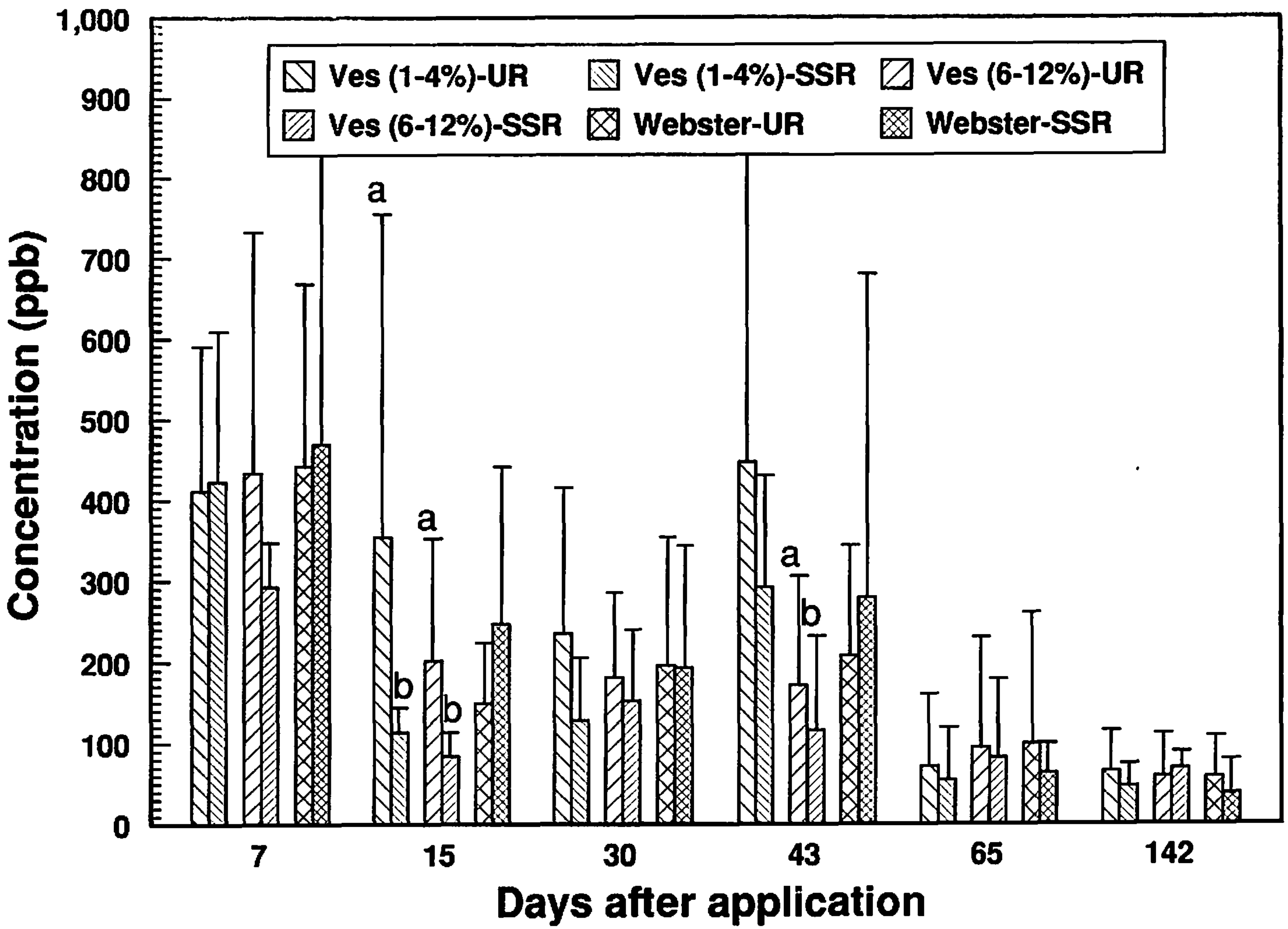


Figure 1. Surface (0-6 in.) soil alachlor concentration under uniform and soil-specific rates during the 1992 growing season. Means within a soil condition and sampling date followed by different letters are significantly different at the p= 0.05 level. An absence of letters indicate no statistical difference. UR= Uniform rate SSR= Soil-specific rate

THE MOVEMENT OF SURFACE APPLIED TRACERS BY SECONDARY, RIDGE, CHISEL, AND MOLDBOARD PLOW TILLAGE SYSTEMS

D. J. Fuchs, J. A. Staricka and D. R. Huggins[1]

Broadcasted phosphorus and potassium fertilizers may be positionally limiting to plants in reduced tillage systems. This study was conducted to determine the placement of broadcasted granular fertilizers by using ceramic spheres as tracers. The ceramic spheres ranged in diameter from 1 to 3 mm and were similar in size to fertilizer granules. The area chosen had three different primary tillage systems moldboard plow (MP), chisel plow (CP), and ridge tillage (RT) in a corn soybean rotation. Spheres were applied at a rate of 2.7 spheres/cm^2 in the spring of 1990 and 1991 after primary tillage and before any secondary tillage. Soil samples were collected after the last row cultivation. Two transects of 40 cores each (4-cm spacing, 160 cm total transect) were collected perpendicular to the corn rows (75-cm spacing) to a depth of 30 cm in each plot. Cores were then sectioned into 2-cm increments. Measurements on individual samples included tracer count, plant residue mass, and bulk density. The RT treatment had the greatest concentration of tracers near the surface with an average tracer depth of 3 cm. The CP and secondary tillage (2 passes with a field cultivator or disc) had similar tracer depths. The MP treatment had an average tracer depth of tracer depth of 14 cm. There was not a visual difference in horizontal distribution of the tracers between tillages. RT treatment had higher bulk densities throughout the measured soil profile in comparison to MP and CP. Little vertical movement of surface applied materials occurred with RT.

Introduction

Tillage systems used for crop production in southwest Minnesota can effect corn and soybean yield. Corn and soybean yields may be reduced by several factors, including soil compaction, weed pressure, and disease pressure. Another factor that may limit crop yield in reduced tillage systems is decreased nutrient uptake induced by poor fertilizer placement. Corn growing in ridge tillage systems showed visual K deficiency symptoms during the drought of 1988 in southwestern Minnesota, whereas the conventional tillage systems displayed no K deficiency symptoms.

The objectives of this study were to: (i) evaluate placement of fertilizer in reduced and conventional tillage systems using ceramic spheres as a tracer, (ii) estimate bulk density differences between tillage systems.

Materials and Methods

This study was conducted in 1990 and 1991 at the University of Minnesota Southwest Experiment Station. Plots were established in April 1990 on a Ves loam (fine-loamy, mixed, mesic Udic Haplustolls) with 4 percent slope. The site has been alternately planted with corn and soybean since 1985 with corn being the crop for 1990 and soybean in 1991. The chosen area had three different tillages: fall moldboard plow with spring secondary tillage (MP), fall chisel plow with spring secondary tillage following (CP), and ridge tillage (RT). All tillage was performed across the slope.

Tillage areas were 24.32 m by 15.20 m. Located within the tillage areas, plots 6.08 by 6.08 m were established for application of tracers. Ceramic spheres, 1 to 3 mm in diameter with a density of 0.42 g cm^{-3}, were used as tracers to simulate surface applied material. The spheres applied in 1990 were painted with fluorescent red paint, and spheres applied in 1991 were painted with fluorescent green. This aided in tracer recovery, and in 1991, the separation of each year's movement. The tracers were applied in the spring of 1990 and 1991 at a rate of 2.7 per cm^2 before any secondary tillage.

In the fall of 1989, primary tillage was performed after harvest on the MP and CP plots. The MP area was moldboard plowed to a depth of 10 inches, with an 18-inch cutting width. The CP area was chisel plowed to a depth of 8 inches, with 3.25-inch wide twisted shovels.

On 23 April 1990, secondary tillage was performed twice on the chisel and moldboard treatments with a field cultivator, working depth of 6 in. No secondary tillage was performed on the ridge tillage plots. Corn was planted in 30-in. rows. The MP and CP area was planted with a four-row John Deere 7000

Scientist - U of MN, Southwest Experiment Station; Soil Scientist - USDA-ARS, Morris MN 56267; Soil Scientist - U of MN, Southwest Exp. Stn., P.O. Box 428, Lamberton, MN 56152

planter with 16-in. dia. fluted residue-cutting coulters. The ridge tillage plot was planted using a four-row John Deere 7000 Conservation planter with 14-in. dia. horizontal disk, attached in front of the planting unit to removed the previous year's crop residue and to clear the ridge.

In 1990, on 6 June all treatments were cultivated with a John Deere 875 4-row cultivator with 3 shanks per row. The middle shank is a 12-in. wide sweep. The outer two shanks were sweeps with a 6-in. width. On 22 June 1990 the MP and CP treatments were cultivated with John Deere 885 for the second time, and the RT treatment was ridged with a John Deere 875 4-row cultivator with 1 12-in. sweep in the middle of the row, and two outer 14-in. vertical concave discs for ridging soil into the row, creating 6-in. ridges.

Primary tillage was performed in the fall of 1990 after chopping corn stalks on the MP, CP and RT plots. The MP area was moldboard plowed to a depth of 10 inches, with an 18-inch cutting width. The CP area was chisel plowed to a depth of 8 inches, using 4-inch wide twisted shovels. RT received no primary tillage.

In 1991, secondary tillage was performed once using a disk with a working depth of 6 in. On 22 May 1991, soybeans were planted with the same planters as in 1990. In 1991, all tillage treatments were row cultivated on 17 June and 1 July with same cultivation method as in 1990.

In both July 1990 and September 1991, soil samples were collected, with two transects per tillage treatment, perpendicular to crop rows (75-cm spacing), using a straight template with 40 holes at a 4-cm spacing. Microrelief measurements were taken at time of sampling for each hole in the template. A soil core (1.8-cm diam.) was taken from each hole to a depth of 30 cm, and then sectioned into 2-cm increments. Each 2-cm increment was stored in coin envelope air dried and weighed. Measurements on individual samples included tracer count, residue mass, root mass, and bulk density.

Figures 1, 2, and 3 are from data collected in 1991. Data collected in 1990 was very similar to the tracer distribution seen for tracers applied in 1991 tracer application. Figures 4 and 5 are average bulk density measurements for 1990 and 1991.

Table 1. Management information.

Tillage System	Primary Tillage	Apply Tracers	Secondary Tillage	Plant	Row Cultivate	Collect Samples
	----------Date----------					
1990						
Secondary Tillage (following CP and MP)	Fall 1989	4/23/90 (AM)	4/23/90 (PM)[1]	4/24/90	6/6/90, 6/22/90	7/13/90
Ridge Tillage	None					
1991						
Chisel Plow & Moldboard Plow	Fall 1990	5/21/91 (AM)	5/21/91 (PM)[2]	5/22/91	6/17/91, 7/1/91	9/25/91
Ridge Tillage	None					

1. Field cultivator two passes.
2. Disc one pass.

Results and Discussion

Tracers

In 1990 and 1991, there was no visual horizontal distribution differences of the tracers between tillage systems (Fig 1-3). In 1990 and 1991, there was significant vertical distribution differences between tillage treatments. In the ridge tillage system depth of tracers for the year of application was 2.3 cm (Table 2). After one year, the tracers applied in 1990 in the ridge tillage area had an average tracer depth of 4.1 cm, resulting in less than 2 cm incorporation. The average depth of tracers was 6.4 cm in 1990 after secondary tillage (two passes with a field cultivator) and 2 passes with a row cultivator in the MP and CP area (Table 2). The average depth of tracers was 5.3 cm in 1991 after one pass with a disc and two passes with a row cultivator in the MP and CP area. The surface roughness differences between the moldboard plow and chisel plow treatment at time of tracer application did not effect resultant vertical position (Fig. 1, 2, and Table 2). The average depth of tracers was 5.8 cm in 1991 for the chisel plowing treatment (Table 2). The chisel plow placed the tracers at about the same depth as the

secondary tillage treatments. The average depth of tracers was 14.0 cm in 1991 for the moldboard plow treatment, resulting in the deepest tracer placement.
Recovery of the tracers ranged from 56.7 percent to 128.8 percent with the greatest recovery occurring in 1990 in the ridge tillage system.

Bulk density

The ridge tillage system had higher bulk densities in the upper 30 cm than the chisel plow and moldboard plow treatments (Fig. 4 and 5). The ridge tillage treatment had the highest bulk density measurements occurring where a majority of the tracers were located (Fig. 3 and 4). The differences in bulk density measurements between tillages systems decreased with depth (Fig. 4). Wheel track areas had higher bulk densities than non-wheel track areas in all tillage systems (Fig. 5).

Microrelief

There was no difference in microrelief between tillages at time of sampling in 1990. In 1991, the ridge tillage system showed more relief at time of sampling than the moldboard plow and chisel plow treatments (Fig. 1-3).

Little movement of surface applied materials occurred with the ridge tillage treatment. Moldboard plowing resulted in the deepest placement of tracers. Chisel plowing did not incorporate the tracers deeper than secondary tillage. In ridge tillage systems, broadcast fertilizer availability may be limited because of poor resultant position and higher soil bulk densities, reducing root interception and uptake of fertilizer.

Table 2. Tracer average placement and percent recovery.

			Tracers (year = year of application)			
			Mean Depth		Recovery All depths	
Tillage System	Rep	Year	1990	1991	1990	1991
			------ cm-----		------- % -------	
Field Cult.-2X (following CP)	1	1990	6.6	--	87.2	--
	2		6.3	--	62.8	--
Field Cult.-2X (following MP)	1		5.9	--	79.3	--
	2		6.7	--	74.2	--
Ridge Tillage	1		1.7	--	128.8	--
	2		2.2	--	112.3	--
Chisel (or Disc 1X)	1	1991	6.0	5.8	69.9	76.4
	2		5.6	5.2	68.5	68.1
M. Plow (or Disc 1X)	1		13.5	4.6	71.7	62.4
	2		14.4	5.7	98.3	68.9
Ridge Tillage	1		2.7	2.8	90.0	75.3
	2		5.4	2.6	76.4	56.7

Fig. 1. Location of Tracers in Chisel Plow (rep. 1)

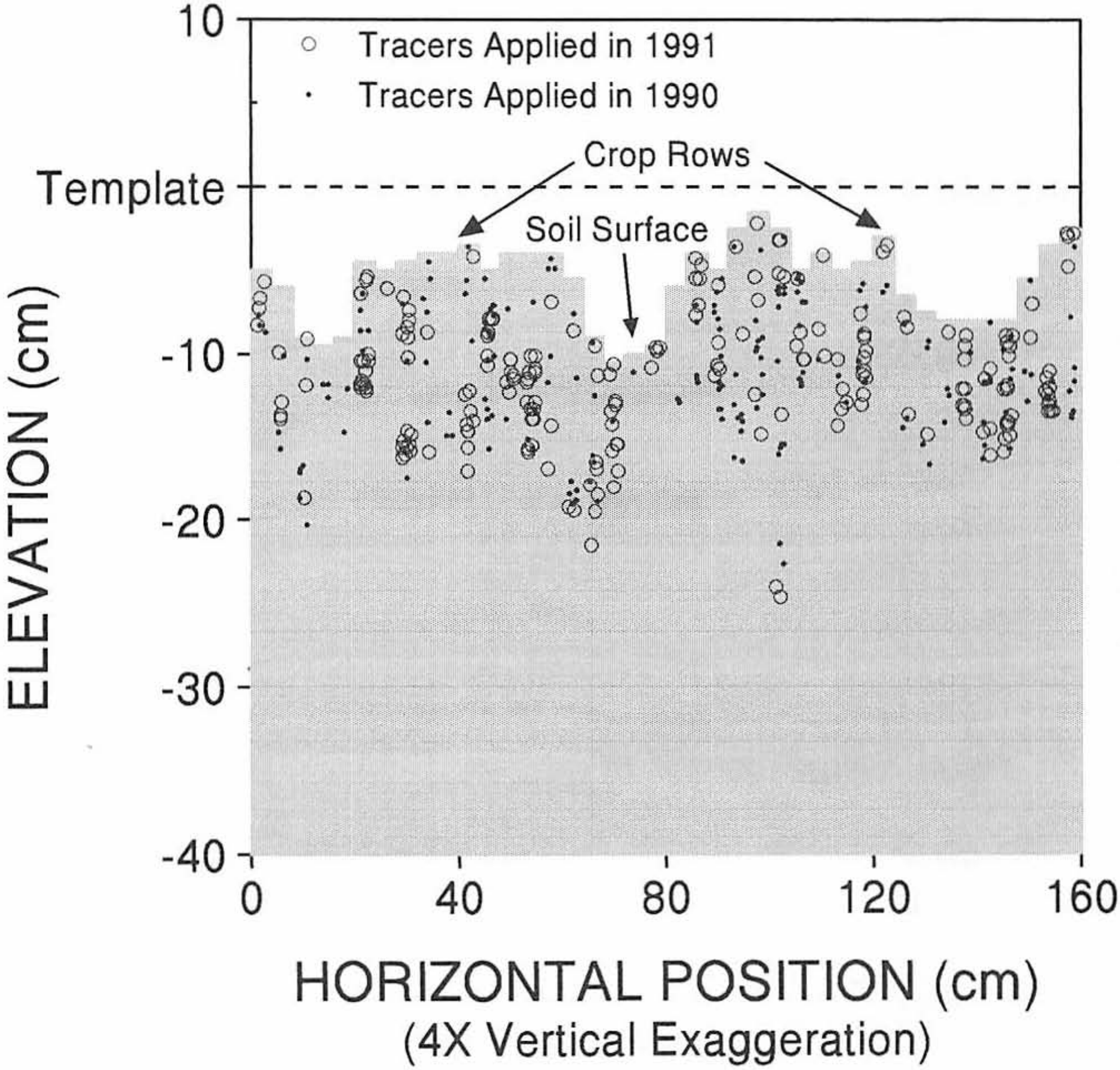


Fig. 2. Location of Tracers in Mlbrd. Plow (rep. 1)

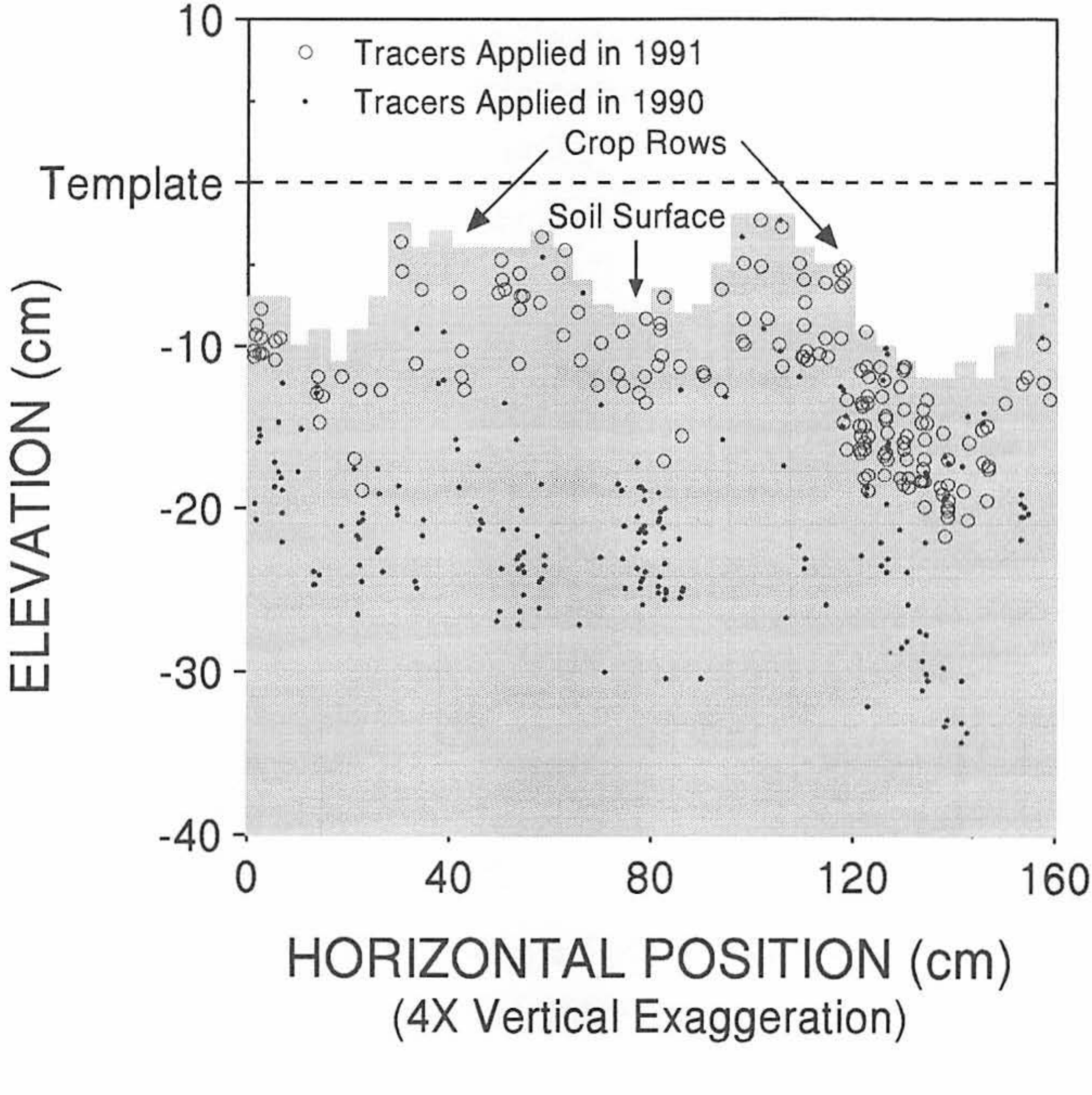


Fig. 3. Location of Tracers in Ridge Tillage (rep. 1)

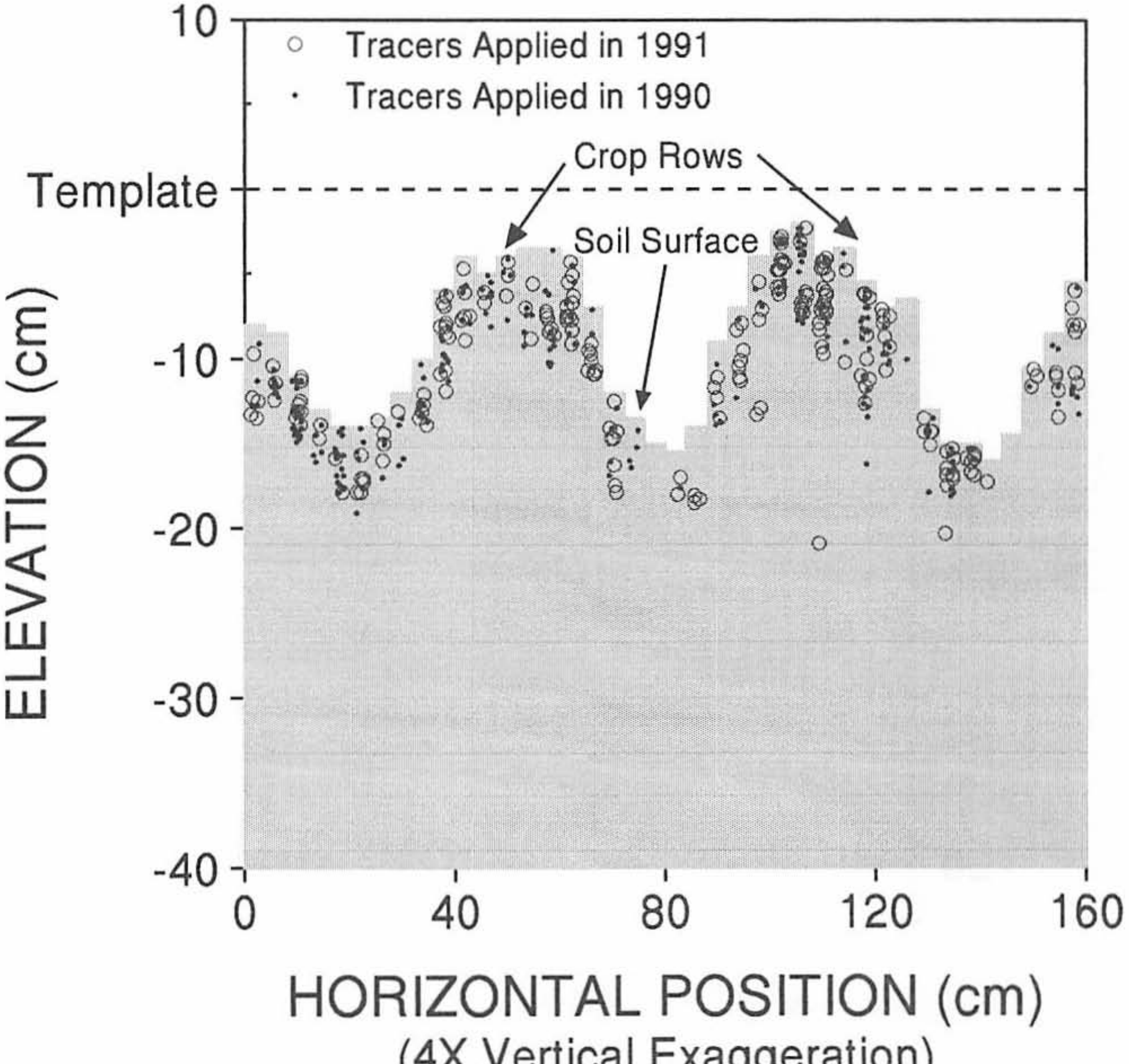


Figure 4. Bulk Density - Vertical Trends

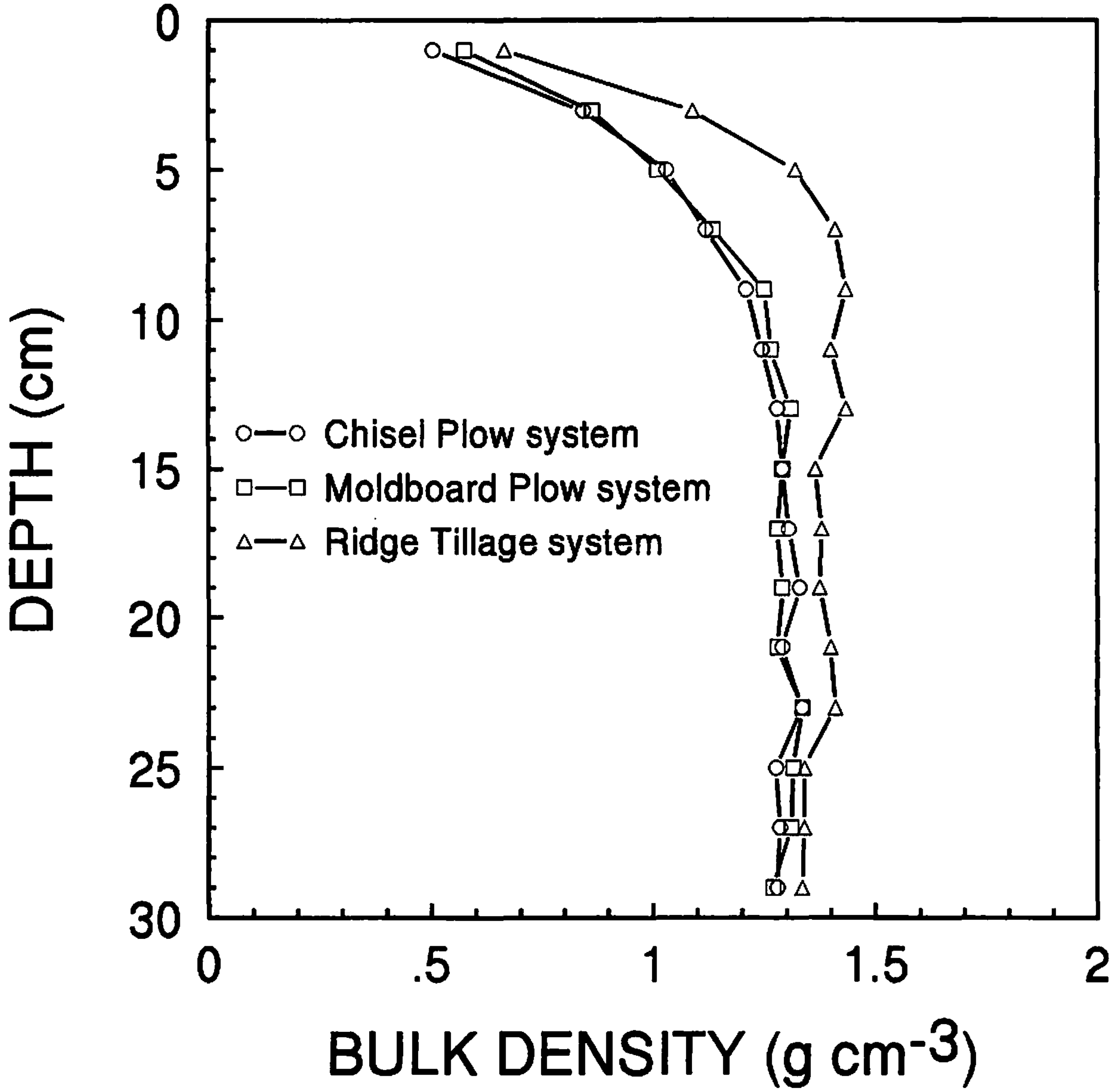
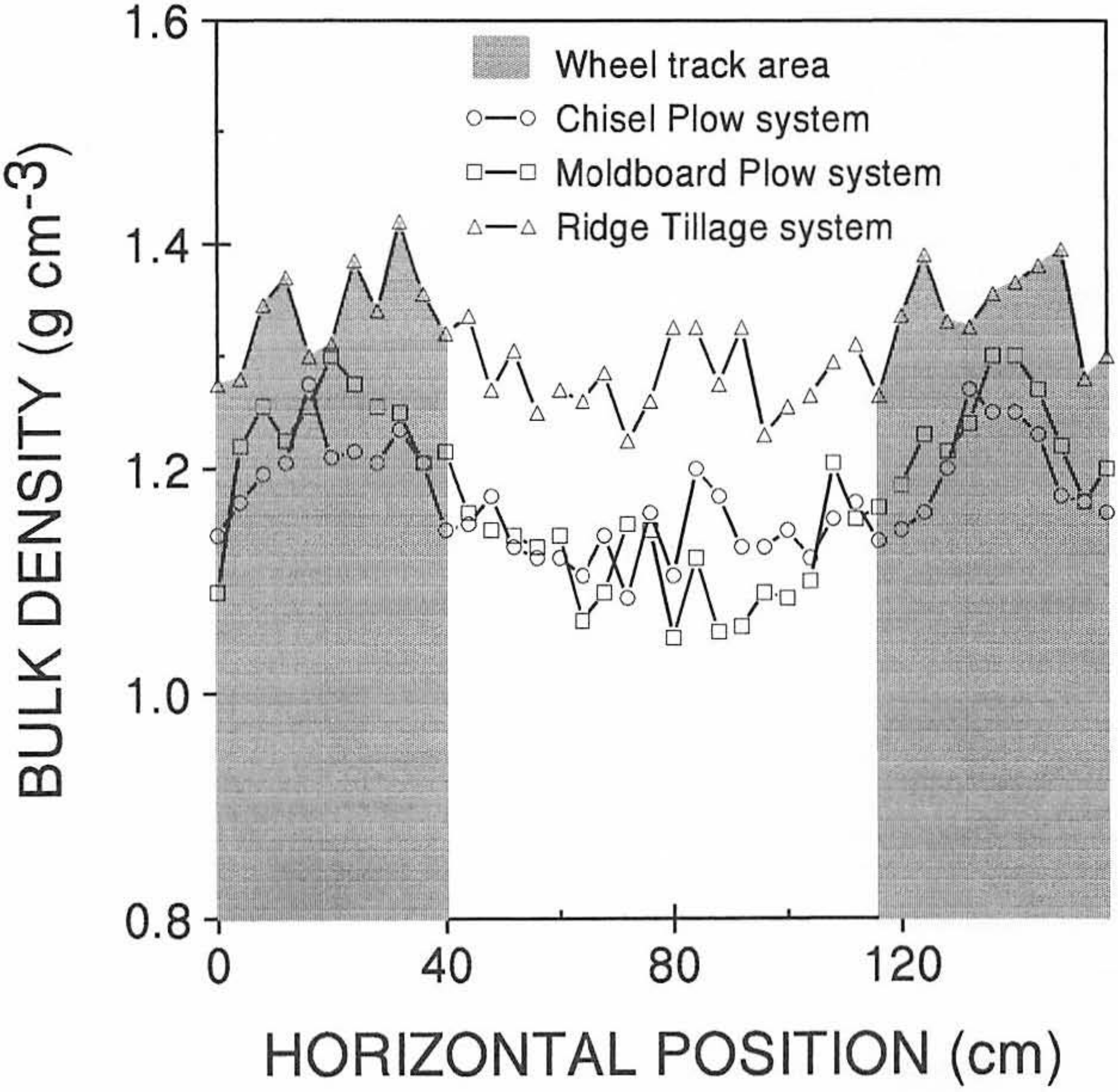


Figure 5. Bulk Density - Horizontal Trends



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

Lamberton, 1992

G. W. Randall, D. Fuchs, W. W. Nelson, D. D. Buhler,
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. Corn and alfalfa yields in this fifth year of the study were very good while soybean yields were average. Nitrogen removed by the continuous corn, corn-Sb, soybean, and alfalfa crops totaled 140, 109, 167 and 307 lb/A, respectively. Residual soil NO_3-N remaining in the 0-5' profile in October totaled 95, 59, 44, 16 and 10 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 5.6 and 6.1 inches while the perennial crops had 5.1" (alfalfa) and 4.7" (CRP). Tile water drainage from the row-crop systems ranged from 4.9 to 7.0 acre-inches while only 2.1 to 3.4 acre-inches drained from the perennial crops. Flow-weighted NO_3-N concentrations ranged from 26 to 40 mg/L for the 6-month drainage period with the corn and soybean systems but averaged <3 mg/L with the alfalfa and CRP systems. Nitrate-N losses ranged from only 1.5 lb/A with the alfalfa and CRP systems to 46 lb/A with continuous corn. Alachlor was detected in 17 of 69 tile water samples, but cyanazine was not found in any.

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 and pesticide 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 indicate 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 155-lb N rate used for continuous corn and the 120-lb N rate for corn after soybeans was based on the NO_3 concentration in the 0 to 24" and 24 to 48" layers and a yield goal of 140 bu/A.

Results and Discussion

Weather

Climatic conditions during the 1992 growing season were cooler than normal (Table 2). Rainfall over the 7-month growing season was 2.1" above normal with greatest departure from normal in August. Monthly temperature averages were markedly below normal in July and August while the 7-month seasonal average was 3° F below normal. These conditions resulted in good corn and alfalfa yields and average soybean yield.

Spring Soil Nitrate

Residual NO_3 in the 0 to 5-foot soil profile in late-April was moderately 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 throughout the profile in the corn-Sb system,

[1] Funding provided by the North Central Regional Research Comm. (NC-201), Southwest Experiment Station, Southern Experiment Station, and Center for Agricultural Impacts on Water Quality.

showed increased concentrations below one foot in the soybean-c system, and highest concentrations below two feet in the continuous corn system. This is in contrast to 1991 when NO_3 concentrations were uniform throughout the profile and in 1990 when most of the NO_3 was in the top two feet. Residual soil NO_3 in the cropping systems did not change by more than 22% between the October '91 sampling and the April '92 sampling. These changes between fall and spring sampling suggest little over-winter "losses" of NO_3 in this year.

Crop Yields

Crop yields shown in Table 4 were above the yield goal for continuous corn, slightly below for corn after soybean, and were very good for alfalfa. Yield and N uptake by continuous corn were 17 and 28% higher than for corn after soybean. In addition, N concentration in corn after soybean was less than for continuous corn. These data suggest sufficient N may not have been present in the corn-soybean system. Yet, N deficiency symptoms were not noted (in fact, the corn after soybean looked more green than the continous corn in mid-September) and soil NO_3 in the top three feet at the end of the season was not different between the two systems. This unexpected difference between the two corn systems may be explained on the basis of grain moisture at harvest and plant maturity at the time of the first fall frost (September 28). Grain moisture on October 9 was 30.3% for continuous corn and 34.5% for corn after soybean. Perhaps the cooler growing season delayed maturity of corn after soybean greater than continuous corn, and the full yield potential was not reached by the time of the first fall frost. Nitrogen removal by alfalfa far exceeded that by corn. The CRP plots were essentially all grass at the end of 1992 after being dominated by alfalfa in 1989, showing a 50:50 split between grass and alfalfa in 1990, and a 90:10 ratio between grass and alfalfa in 1991. The wetter conditions in the last three years apparently led to the reestablishment of the grass species.

Fall Soil Nitrate and Ammonium

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 > C-Sb>Sb-C>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 3' was very uniform for the CC and C-Sb systems but declined below 5' with the Sb-C system. Nitrate-N concentrations between 4' and 8' were uniformly quite high for the CC system. The alfalfa and CRP systems exhibited very low NO_3-N concentrations down to 8 feet. From 8 to 10 feet, NO_3-N concentrations, although still low, more than doubled. Amounts of soil NO_3 in the top five feet in October ranged from 5% (continuous corn) to 34% (Sb-C) lower than in April. Absolute differences between the dates of sampling were 5 - 8, and -23 lb NO_3-N/A for the CC, C-Sb and Sb-C systems, respectively. Application of 155 and 120 lb N/A to the CC and C-Sb systems did not influence soil NO_3-N levels compared to the pre-application levels. Soil NH_4-N was not affected by cropping system (Table 6).

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 7). Available soil water was lowest for the perennial crops (alfalfa and CRP), intermediate where corn was grown in 1992, and highest following soybean.

Tile Flow

Tile line discharge occurred from early March through mid-October (except September) for the corn and soybean systems and from early March through early May for CRP and alfalfa. Discharge averaged 5.6" for the systems containing corn and soybean; this was 2x higher than the 2.8" for the alfalfa and CRP systems (Table 8). Flow-weighted NO_3-N concentrations for the season were highest for the CC system and was approximately 16x higher than the alfalfa and CRP systems. Nitrate-N concentrations from the C-Sb and Sb-c systems averaged about 13 mg/L less than from the CC system. Temporal changes in NO_3-N concentration did not occur over the flow period. Losses of NO_3-N in the tile drainage for the 1992 season ranged from 20 and 32 times higher for the corn-soybean sequences and CC systems compared to the two perennial crop systems. Losses averaged 36 lb/A for the two corn-soybean sequences, 46 lb/A for the CC system and only 1.5 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.

Water samples were collected periodically throughout the flow period from the corn and soybean systems and were submitted for pesticide analyses. Alachlor (Lasso) was found in 17 of the 69 samples collected. Alachlor concentration in the 17 samples averaged 0.46 ppb with a range from 0.09 to 1.88 ppb. Cyanazine (Bladex) was not found in the 51 samples collected from the CC and Sb-C systems that received cyanazine in 1991 or in the 18 samples collected after May 2 (date Bladex applied) from the C-Sb system that received cyanazine in 1992. Detection limits were 0.05 ppb for both herbicides. These data indicate little need for concern regarding the leaching of these herbicides to tile discharge water in these high organic matter, fine-textured soils in southern Minnesota.

Conclusions

The slightly wetter than normal conditions in 1992 resulted in good corn and alfalfa yields and average soybean yield in this fifth year of the study. Nitrogen removal by soybean and alfalfa was 1.2x and 2.2x as high, respectively, as with continuous corn. After three 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 5x higher with the row crop systems compared to the perennial crop systems. Tile flow occurred over a 6-month period for the corn and soybean systems and a 2-month period for the perennial crops. Drainage averaged 5.6 acre-inches from the row crop systems and 2.8 acre-inches from the perennial crop systems. Nitrate-N concentrations also were 11 to 16x higher with the row-crop systems. Nitrate-N losses to the drainage water totaled 46 lb/A from the continuous corn system and 29 lb/A from the corn-soybean rotation that received fertilizer N in 1992. Nitrate-N losses from the soybean-corn system were higher (43 lb/A) due primarily to higher tile flow. Less than 2 lb NO_3-N/A were lost in the drainage water from the alfalfa and CRP systems. Tile water samples analyzed for alachlor and cyanazine showed 25% of the samples to contain detectable levels of alachlor with an average concentration of 0.46 ppb in the 17 positive samples. No cyanazine was detected in any of the 69 samples.

Table 1. Experimental procedures used in 1992 for the nitrate-pesticide movement study at Lamberton.

Cropping System	Procedures
Cont. Corn and Corn-"Sb"	
Hybrid	Pioneer 3615
Planting rate and date	29000 ppA on 5/4
Insecticide	Furadan (1 lb/A)
Herbicides	Lasso (4 lb/A) + Bladex (3 lb/A)
Date	Both applied on 5/2 and incorporated 1X with field cultivator; previous field cultivation on 4/30
N rate (Cont. corn only)	155 lb N/A as urea
Date	6/5 and cultivated in the same day
Cultivation date(s)	6/5 and 6/22
Harvest date	10/9
Fall tillage (kind and date)	Moldboard plow 10/30
Corn - "Sb"	
N rate	120 lb N/A as urea on 6/5
Soybeans	
Secondary tillage	Field cultivated 2X (4/30 and 5/2)
Variety	Hardin
Planting rate and date	150,000 seeds/A on 5/5
Row width	30"
Herbicides	
Lasso: Rate and date	4.0 lb/A on 5/2, incorporated with a field cultivator
Pursuit: Rate and date	0.063 lb/A plus surfactant + UAN on 5/27
Cultivation date(s)	6/22
Harvest date	10/13
Fall Tillage	None
Alfalfa	
Harvest date(s)	6/4, 7/7 and 9/1
Harvest area	3' x 20'
CRP	
Harvest date	9/25

Table 2. Growing season monthly air temperature averages and precipitation amounts during 1992 and the long-term normals for Lamberton.

Month	Avg. Temperature 1992	Avg. Temperature Normal	Precipitation 1992	Precipitation Normal
	°F		inches	
April	41	46	2.50	2.73
May	62	59	1.62	3.16
June	66	68	4.08	3.55
July	65	73	4.80	3.88
Aug.	64	70	5.13	2.73
Sept.	59	60	2.10	3.34
Oct.	46	49	3.41	2.17
7-mo avg.	58	61	-	
Total	-	-	23.64	21.56

Table 3. Residual NO_3-N in the 0 to 5' soil profile of the cropping systems in April, 1992.

Depth	Cropping System in 1992: Cont. Corn	Corn-Sb	Soybean-C
feet	lb NO_3-N/A		
0 - 1	8.1	15.7	9.1
1 - 2	17.6	14.5	15.9
2 - 3	22.6	12.4	17.3
3 - 4	28.4	11.9	14.0
4 - 5	23.6	12.4	10.5
Total (0-5')			
Apr.'92	100.3	66.9	66.8
Oct. '91	83.9	85.7	55.9
% Change over winter	+20	-22	+19

Table 4. Crop yields, N concentration, and N uptake at Lamberton in 1992.

Cropping System	Yield	N Concentration	N Uptake
		%	lb/A
Cont. Corn			
Grain (bu/A)	156.1	1.25	109.2
Stover (lb DM/A)	5798.	0.54	31.1
Total			140.3
Corn-Sb			
Grain (bu/A)	133.6	1.07	80.2
Stover (lb DM/A)	5582.	0.52	29.0
Total			109.2
Soybean-C			
Seed (bu/A)	36.2	6.39	139.0
Stover (lb DM/A)	2258.	1.21	27.9
Total			166.9
Alfalfa			
1st Cut Forage (lb DM/A)	4372	2.83	124.1
2nd Cut Forage (lb DM/A)	3452	3.00	103.6
3rd Cut Forage (lb DM/A)	2426	3.28	79.6
Total	5.12 T/A		307.3
CRP			
Grass (lb DM/A)	4686	1.00	46.5

Table 5. Soil profile NO_3-N concentrations and amounts in October, 1992 as influenced by cropping system at Lamberton.

Depth	Cont. Corn Avg.	Cont. Corn SE	Cont. Corn Avg.	Corn-Sb Avg.	Corn-Sb SE	Corn-Sb Avg.
feet	ppm	ppm	lb/A	ppm	ppm	lb/A
0 - 1	3.6	0.61	14.5	3.9	0.34	15.7
1 - 2	1.8	0.07	7.3	1.5	0.23	6.0
2 - 3	2.9	0.92	11.7	1.8	0.35	7.2
3 - 4	7.1	2.15	28.5	3.8	0.55	15.2
4 - 5	8.3	3.70	33.2	3.8	0.58	15.1
5 - 6	7.9	3.61	31.6	3.4	0.09	13.7
6 - 7	7.0	3.52	28.0	3.2	0.47	12.9
7 - 8	5.8	3.21	23.3	3.3	0.52	13.1
8 - 9	5.0	2.47	19.9	3.3	0.37	13.3
9 - 10	4.2	1.81	16.8	2.9	0.35	11.5
Totals						
0 - 5			95.3			59.2
5 - 8			82.9			39.7
8 - 10			36.7			24.8
0 - 10			214.9			123.7

Depth	Soybean-C Avg.	Soybean-C SE	Soybean-C Avg.	Alfalfa Avg.	Alfalfa SE	Alfalfa Avg.
feet	ppm	ppm	lb/A	ppm	ppm	lb/A
0 - 1	3.3	0.64	13.1	1.3	0.96	5.3
1 - 2	0.9	0.44	3.6	0.9	0.38	3.5
2 - 3	1.7	0.69	6.9	0.6	0.38	2.5
3 - 4	2.8	1.07	11.3	0.5	0.27	1.9
4 - 5	2.3	0.61	9.2	0.6	0.31	2.4
5 - 6	1.9	0.65	7.7	0.5	0.32	1.9
6 - 7	1.6	0.35	6.5	0.5	0.30	2.1
7 - 8	1.7	0.26	6.7	0.7	0.41	2.9
8 - 9	1.6	0.26	6.4	1.5	0.35	6.0
9 - 10	1.2	0.56	4.8	1.6	0.12	6.5
Totals						
0 - 5			44.1			15.6
5 - 8			20.9			6.9
8 - 10			11.2			12.5
0 - 10			76.3			35.1

Depth	CRP Avg.	CRP SE	CRP Avg.
feet	ppm	ppm	lb/A
0 - 1	1.0	0.43	4.1
1 - 2	0.3	0.19	1.3
2 - 3	0.4	0.18	1.5
3 - 4	0.4	0.21	1.6
4 - 5	0.3	0.12	1.2
5 - 6	0.3	0.15	1.2
6 - 7	0.4	0.18	1.5
7 - 8	0.7	0.33	3.1
8 - 9	1.4	0.47	5.6
9 - 10	1.7	0.48	6.7
Totals			
0 - 5			9.7
5 - 8			5.8
8 - 10			12.3
0 - 10			27.7

Table 6. Soil profile NH_4-N concentrations and amounts in October, 1992 as influenced by cropping system at Lamberton.

Depth	Cont. Corn Avg.	Cont. Corn SE	Cont. Corn Avg.	Corn-Sb Avg.	Corn-Sb SE	Corn-Sb Avg.
feet	ppm	ppm	lb/A	ppm	ppm	lb/A
0 - 1	8.8	0.28	35.2	8.1	0.15	32.4
1 - 2	3.4	0.17	13.6	3.5	0.03	13.9
2 - 3	2.5	0.17	10.1	2.9	0.19	11.7
3 - 4	3.0	0.20	12.1	3.2	0.09	12.7
4 - 5	3.7	0.22	14.9	4.0	0.32	15.9
5 - 6	4.0	0.19	15.9	4.4	0.46	17.5
6 - 7	4.3	0.21	17.2	4.7	0.44	18.7
7 - 8	4.9	0.21	19.6	4.9	0.36	19.6
8 - 9	5.0	0.15	19.9	5.0	0.51	20.0
9 - 10	5.3	0.25	21.2	5.2	0.33	20.7
Totals						
0 - 5			86.0			86.5
5 - 8			52.7			55.8
8 - 10			41.1			40.7
0 - 10			179.7			182.9

Depth	Soybean-C Avg.	Soybean-C SE	Soybean-C Avg.	Alfalfa Avg.	Alfalfa SE	Alfalfa Avg.
feet	ppm	ppm	lb/A	ppm	ppm	lb/A
0 - 1	6.6	1.13	26.5	5.4	0.90	21.7
1 - 2	4.1	0.33	16.5	3.5	0.29	14.0
2 - 3	3.8	0.41	15.1	3.2	0.29	12.9
3 - 4	4.2	0.20	16.9	3.3	0.20	13.3
4 - 5	4.9	0.45	19.6	3.8	0.35	15.3
5 - 6	5.5	0.57	22.1	4.6	0.31	18.4
6 - 7	5.4	0.50	21.5	5.0	0.23	20.0
7 - 8	5.4	0.50	21.7	5.3	0.35	21.2
8 - 9	5.3	0.53	21.2	5.2	0.37	20.9
9 - 10	5.3	0.58	21.2	5.4	0.52	21.5
Totals						
0 - 5			94.7			77.3
5 - 8			65.3			59.6
8 - 10			42.4			42.4
0 - 10			202.4			179.3

Depth	CRP Avg.	CRP SE	CRP Avg.
feet	ppm	ppm	lb/A
0 - 1	4.0	1.42	16.1
1 - 2	3.6	0.50	14.5
2 - 3	2.9	0.31	11.6
3 - 4	3.1	0.15	12.3
4 - 5	3.6	0.09	14.5
5 - 6	4.6	0.31	18.4
6 - 7	5.1	0.12	20.3
7 - 8	5.1	0.32	20.5
8 - 9	5.3	0.35	21.3
9 - 10	5.4	0.41	21.5
Totals			
0 - 5			69.1
5 - 8			59.2
8 - 10			42.8
0 - 10			171.1

Table 7. Gravimetric water content of the 0-10' profile and "available" water in the 0-5' profile as influenced by cropping system in October, 1992.

Profile depth	Cropping system: Cont. Corn	Corn-Sb	Soybean-C	Alfalfa	CRP
feet	Water Content (%)				
0 - 1	24.5	23.2	23.5	21.6	23.8
1 - 2	22.4	21.9	22.0	21.8	21.4
2 - 3	20.1	20.3	21.8	20.4	18.8
3 - 4	19.4	20.1	20.6	18.9	18.3
4 - 5	20.1	20.2	20.5	19.1	19.6
5 - 6	20.6	20.0	22.5	19.9	19.5
6 - 7	23.2	20.5	20.7	20.7	19.8
7 - 8	22.4	20.3	20.7	20.1	20.0
8 - 9	20.9	19.7	20.2	19.4	20.2
9 - 10	19.8	19.8	21.0	19.7	21.5
"Available" Water 0-5' (inches)	5.58	5.67	6.11	5.06	4.68

Table 8. 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	1.19	0.95	2.17	0.61	1.58
April	1.43	1.70	2.13	1.40	1.69
May	0.44	0.52	0.50	0.10	0.12
June	1.16	1.03	1.08	0.00	0.00
July	0.40	0.30	0.38	0.00	0.00
August	0.06	0.02	0.01	0.04	0.00
October	0.48	0.34	0.68	0.00	0.00
Total	5.16	4.86	6.95	2.15	3.39
	Flow-weighted NO_3-N Conc. (ppm)				
March	38.3	28.0	25.2	1.4	1.3
April	39.2	25.1	27.8	5.6	1.4
May	37.1	26.5	28.2	3.9	1.1
June	41.0	25.3	30.3	0.0	0.0
July	37.8	25.5	29.7	0.0	0.0
August	40.0	26.8	33.4	2.9	0.0
October	36.4	22.3	28.0	0.0	0.0
Season Avg.	39.8	26.1	27.1	3.8	1.3
	NO_3-N Loss (lb/A)				
March	10.4	6.1	12.0	0.18	0.47
April	12.9	9.7	13.2	1.59	0.53
May	3.8	3.2	3.3	0.08	0.03
June	11.1	6.0	7.3	0.00	0.00
July	3.6	1.7	2.6	0.00	0.00
August	0.5	0.1	0.1	0.02	0.00
October	4.2	2.0	4.2	0.00	0.00
Total	46.5	28.8	42.7	1.87	1.03

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1992

Month	Period	Precipitation 1992	Precipitation 100-yr. av.	Precipitation Dev. from av.	Temperature 1992	Temperature 100-yr. av.	Temperature Dev. from av.	Soil Temperature (10 cm depth) 1992	Soil Temperature (10 cm depth) 10 yr. av.
January	1-31	0.56	0.68	-0.12	18.8	8.0	+10.8	28.2	20.7
February	1-28	0.29	0.67	-0.38	24.7	12.8	+11.9	29.6	23.9
March	1-31	1.66	1.13	+0.53	32.5	26.7	+ 5.8	36.5	29.2
April	1-10	0.67	0.57	+0.10	39.2	38.0	+ 1.2	40.8	
	11-20	0.70	0.64	+0.06	37.9	44.4	- 6.5	41.8	
	21-30	0.61	1.05	-0.44	41.9	48.3	- 6.4	44.6	
Total or av.		1.98	2.26	-0.28	39.7	43.6	- 3.9	42.4	41.4
May	1-10	0.01	0.77	-0.76	61.6	52.0	+ 9.6	62.0	
	11-20	0.95	0.95	0.00	61.0	55.8	+ 5.2	62.8	
	21-31	0.49	1.25	-0.76	57.4	60.0	- 2.6	62.9	
Total or av.		1.45	2.97	-1.52	59.9	56.1	+ 3.8	62.6	57.1
June	1-10	1.20	1.29	-0.09	61.8	63.0	- 1.2	66.4	
	11-20	3.35	1.30	+2.05	67.6	66.3	+ 1.3	71.3	
	21-30	0.17	1.37	-1.20	60.6	68.1	- 7.5	69.5	
Total or av.		4.72	3.96	+0.76	63.4	65.8	- 2.4	69.1	69.3
July	1-10	2.05	1.44	+0.61	61.8	70.1	- 8.3	68.4	
	11-20	3.28	1.06	+2.22	63.4	71.4	- 8.0	70.2	
	21-31	0.23	1.01	-0.78	63.8	71.4	- 7.6	73.4	
Total or av.		5.56	3.51	+2.05	63.1	70.9	- 7.8	70.8	76.7
August	1-10	0.16	1.04	-0.88	67.2	70.4	- 3.2	75.6	
	11-20	0.08	0.93	-0.85	61.8	69.0	- 7.2	72.4	
	21-31	1.22	1.04	+0.18	61.6	66.9	- 5.3	67.1	
Total or av.		1.46	3.01	-1.55	63.6	68.7	- 5.1	71.6	73.9
September	1-30	1.62	2.20	-0.58	56.9	59.0	- 2.1	61.9	61.5
October	1-31	0.19	1.74	-1.55	45.0	47.2	- 2.2	49.1	47.8
November	1-30	1.94	0.97	+0.97	27.0	29.7	- 2.7	34.5	33.6
December	1-31	0.62	0.61	-0.01	13.7	15.2	+ 1.5	31.5	23.4
April-Aug. Growing Season		15.17	15.71	-0.54	58.0	61.0	- 3.0	63.4	63.8
January-December Annual		22.05	23.78	-1.73	42.4	42.0	+ 0.4	49.0	46.7

CONTINUOUS CORN SILAGE[1]

MORRIS, 1992

S.D. Evans[2]

ABSTRACT: This long-term study addresses the effects of removal of continuous corn silage and corn grain on soil properties and yield. Results after 27 years show no yield differences due to the removal of silage versus grain. A significant difference in yield exists between the high and low fertilizer rates for the long-term (27 years) and in 1992.

OBJECTIVE

This is the 27th year of a continuing study initiated in 1965 on a McIntosh silt loam soil. The study was initiated to determine the effects of removal of continuous corn silage and fertilizer rate on soil properties and yield. Half the plots receive a fertilizer rate of 74+48+48 ($N+P_2O_5+K_2O$) lbs./acre and the other half a rate of 148+96+96, fall applied. Silage and shelled corn yield samples were collected.

EXPERIMENTAL PROCEDURE

The experiment is set up as a latin square with 4 treatments: (1) silage, low fertility (2) silage, high fertility (3) grain, low fertility (4) grain, high fertility. The 1991 corn stalks were chopped and fall fertilizer was spread on October 17, 1991. The experimental area was moldboard plowed on October 21, 1991. The study was field cultivated on May 4, 1992 for seedbed preparation. The study was then seeded to Pioneer 3751 corn at 27,500 seeds per acre. Lorsban 15G was applied in the row at seeding at 10 lbs/acre (1.5 lbs./acre a.i.). Lasso @ 3 lbs./acre a.i. + Bladex @ 2.2 lbs./acre a.i. were applied pre-emergence broadcast on May 6. The study was cultivated on June 23 and date of tasseling and silking was recorded. Silage yields were chopped from 3-10 foot rows on September 28 and grain yields were calculated from 2-45 foot rows harvested with a plot combine on October 16, 1992. Yields were also taken, as in past years, on an adjacent unfertilized (check) area where only the grain is removed.

RESULTS AND DISCUSSION

Silage yields are given in Table 1. Silage yields for 1992 and the 27-year average are not significantly different for silage versus grain plots, but do show sifnificant differences between high and low fertility treatments. Grain yields, including the grain yield from the unfertilized check area adjacent to the treatment plots, are given in Table 2. Grain yields for 1992 and the 27-year average show a significant difference between the high and low fertility treatments.

This study will be continued in 1993.

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

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

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

Treatment	1992 Yield	1966-1992 Yield
	- - - - dry matter, tons/acre	- - - - - - - - -
Silage, low fertility	6.73	5.59
Silage, high fertility	7.75	6.12
Grain, low fertility	6.83	5.67
Grain, high fertility	8.16	6.04
Signif. Levels (%)		
Treatment	93	>99
Year	--	>99
Treatment x Year	--	>99
LSD, treatment (.05)	.78	0.15

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

Treatment	1991 Yield	1966-1991 Yield
	- - - - - - - - Bu/ac @ 15.5% M.	- - - - - - - - -
Grain, low fertility	118.8	90.0
Grain, high fertility	130.5	95.3
Signif. Levels (%)		
Treatment	98	>99
Year	--	>99
Treatment x Year	--	>99
LSD, Treatment (.05)	8.6	2.9
Grain, check (Bu/Ac)	37.8	48.3

MATCHING PRECISION PLACEMENT OF POTASH FERTILIZER TO ROOT GROWTH IN A RIDGE-TILL PLANTING SYSTEM[1/]

D. Allan, S. Evans, G. Rehm, J. Johnson, L. Oldham, G. Nelson, A. Scobbie, and D. Schmitz[2/]

ABSTRACT: Early growth, K concentration and uptake, and grain moisture and yield were compared for two tillage treatments (fall chisel and ridge tillage planting systems), two hybrids (Pioneer 3732 and 3737), and three fertilizer treatments (control and 40 lb/A banded or broadcast K_2O). Early growth, K uptake, and grain yields were greater in the fall chisel system and for the Pioneer 3737 hybrid. Banded application of K also improved early growth and yield especially in the ridge tillage system. Potassium uptake was always highest from the banded K_2O application, with little difference between the broadcast and control treatments. Root measurements indicate that Hybrid 3732 has higher root length density than 3737, especially in the ridge-till planting system, despite its lower K uptake rate.

Introduction

Potassium (K) deficiency is a common problem in ridge-till corn production in Minnesota as well as Iowa and South Dakota, and can result in reduced corn yields. The deficiency occurs even on soils with high to very high soil test K values. Severity of the deficiency varies with hybrid. Band application of 40-50 lb K_2O/acre in the previous fall or as a starter fertilizer at planting can correct the problem.

Recent research at the West-Central Experiment Station at Morris has shown that the K deficiency problem is limited to ridge-till and no-till planting systems. The early growth and response to applied K_2O is the same for both tillage systems.

The purpose of this research is to identify the physiological basis for this problem by examining the development and morphology of root systems for a sensitive and tolerant hybrid in a ridge-tillage planting system.

Objectives

The research described in this study 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. Quantify root growth in both ridge-till and fall chisel planting systems as affected by corn hybrid.

Methods and Materials

This study was initiated in the fall of 1991 at the West-Central Experiment Station at Morris, Minnesota. Three factors (tillage system, hybrid, K_2O treatment) were combined in a complete factorial with 4 replications. A split-plot arrangement was used. Tillage system (fall chisel, ridge-till) was the main plot. The sub-plots were hybrids (Pioneer 3732, Pioneer 3737) and potash fertilizer treatment. The three potash fertilizer treatments were: 1) control, 2) 40 lb. K_2O/acre in a band, 3) 40 lb. K_2O/acre broadcast.

The potash was applied in late October, 1991. When applied in a band, the K_2O was placed at a depth of 3-4 inches below the soil surface directly beneath the existing row. The previous crop was soybeans. The banded and broadcast application of K_2O was made before the chisel plow operation. All treatments received 10-34-0 as a starter at planting and ample N as anhydrous ammonia in the fall of 1991. Corn was planted in early May and a recommended herbicide program was used for weed control.

One major objective of this study is to quantify root growth as affected by tillage system and corn hybrid. To do this, non-essential nutrients (strontium, rubidium, lithium) were hand injected to various depths at a distance of 4 inches perpendicular to the row. These non-essential nutrients were injected shortly after emergence.

[1/] Support for this project was provided by Pioneer Hi-breds International and the Minnesota Agricultural Experiment Station.

[2/] D. Allan, G. Rehm, J. Johnson, L. Oldham, A. Scobbie, and D. Schmitz are Assistant Professor, Professor, Scientist, Graduate Research Assistant and Technical Field Crew in the Soil Science Department of the University of Minnesota, St. Paul, MN 55108. S. Evans, and G. Nelson are Professor and Assistant Scientist at the West Central Experiment Station, Morris, MN.

Plant and soil samples were collected at approximately 30, 40, and 60 days after emergence. The plant samples were dried, weighed, ground and analyzed for potassium, strontium, rubidium, and lithium. The analysis for potassium provides a measure of potassium uptake. Analysis for strontium, rubidium, and lithium provides some measure of root growth and development.

Soil samples were also collected at approximately 30 and 40 days after emergence. Roots were separated from the soil and root length was measured. Root density was calculated from the root length and soil volume measurements. Soil samples for root measurement were collected from the control treatment for both hybrids in both tillage systems.

Grain yields were measured in late October. Moisture samples were collected and grain yields were corrected to 15.5% moisture.

Results and Discussion

Plant growth at all samplings was significantly affected by both tillage system and the application of potash (Table 1 and 2). When averaged over hybrid and potash treatment, plant growth was greater for the fall chisel planting system. Hybrid had a significant effect on growth for the samples collected at 60 days after emergence. For this sampling, there was better growth for Pioneer 3737. The hybrid used had no significant effect on early growth for the samples collected at 30 and 40 days after planting.

Table 1. Combined statistical analysis for plant growth at 30, 40, and 60 DAP, grain moisture content and grain yield at the West Central Experiment Station, Morris site, 1992.

Source of Variation	df	Early Plant Growth 30 DAP	40 DAP	60 DAP	Percent K 40 DAP	60 DAP	K Uptake 40 DAP	60 DAP	Grain Moisture	Grain Yield
Tillage	1	**	**	*	NS	NS	+	+	*	*
Hybrid	1	NS	NS	*	**	**	*	**	**	**
Till x Hyb	1	NS	NS	NS	NS	NS	NS	NS	NS	NS
K rate	2	**	**	**	**	NS	**	**	**	**
Till x K	2	*	NS	NS	NS	NS	NS	NS	**	**
Hyb x K	2	*	*	NS	NS	+	NS	NS	NS	NS
Till x Hyb x K	2	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV		24.4	24.8	18.7	23.8	23.4	39.3	33.4	9.1	12.8

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

Table 2. The effect of tillage system, hybrid and potash fertilizer treatment on the weight of young corn plants.

Tillage System	Hybrid	K_2O Treatment	Days After Planting 30	40	60
		lb./acre	gm/8 plants	gm/6 plants	gm/4 plants
Fall Chisel	3732	0	3.9	31.4	137.7
		40 (band)	5.4	49.5	194.6
		40 (bdcst)	2.8	28.3	128.3
Fall Chisel	3737	0	3.9	35.8	163.9
		40 (band)	4.5	45.1	220.9
		40 (bdcst)	4.3	38.7	159.3
Ridge Till	3732	0	1.7	17.9	73.6
		40 (band)	5.2	47.2	202.1
		40 (bdcst)	2.5	21.8	92.5
Ridge Till	3737	0	2.0	20.4	106.5
		40 (band)	4.3	37.4	161.8
		40 (bdcst)	3.0	29.4	117.0

There were no significant interactions between tillage system and hybrid for any sampling date (Table 1). However, there was a highly significant interaction between hybrid and potash treatment when the corn was sampled at both 30 and 40 days after planting. These results are consistent with grower reports that the potassium deficiency condition is more severe with Pioneer 3732 when compared with Pioneer 3737.

For plant samples collected at 40 and 60 days after planting, potassium concentrations are summarized in Table 3. As expected, K concentration decreases with time due to the increase in dry matter production. Treatment can influence the K concentration in plant tissue, with lower K concentrations in tall plants when compared to short plants because of plant dilution.

Table 3. Potassium concentration in whole corn plants as affected by tillage system, hybrid, and potash fertilizer treatment.

Tillage System	Hybrid	K_2O Treatment	Days After Planting 40	60
		lb./acre	--- % K ---	
Fall Chisel	3732	0	.401	.371
		40 (band)	.644	.517
		40 (bdcst)	.384	.460
Fall Chisel	3737	0	.507	.598
		40 (band)	.859	.590
		40 (bdcst)	.588	.506
Ridge-Till	3732	0	.312	.334
		40 (band)	.670	.431
		40 (bdcst)	.374	.447
Ridge-Till	3737	0	.417	.536
		40 (band)	.877	.557
		40 (bdcst)	.560	.459

Hybrid had a significant effect on K concentration when the corn was sampled at both 40 and 60 days after planting. The concentration was higher for Pioneer 3737. The higher plant weights and higher plant concentration of K indicate that this hybrid is better equipped to absorb K from the soil system.

Potash application affected K concentration when samples were collected 40 days after planting. Concentrations were higher when the potash was applied in a band for both tillage systems and both hybrids.

The K uptake at both 40 and 60 days after planting was significantly affected by tillage system, hybrid, and potash application (Tables 1 and 4). There were no significant interactions between any of the variables. When averaged over hybrid and potash treatment, K uptake was higher in the fall chisel system. Uptake by Pioneer 3737 was higher than uptake by Pioneer 3732 when averaged over tillage system and potash treatment. Potassium uptake was highest for both hybrids and both tillage systems when the potash fertilizer was applied in the band. Potassium uptake from broadcast applications was nearly equal to uptake from the controls receiving no potash fertilizer.

Because of the abnormally cool growing season, grain moisture at harvest was exceptionally high (Table 5). Moisture content was significantly affected by tillage system, hybrid, and potash treatment (Table 1). There was also a highly significant interaction between tillage system and K treatment.

Grain moisture was lower in the fall chisel planting system and Pioneer 3737 had a lower moisture content than Pioneer 3732. The banded application of potash also reduced the moisture content at harvest to a greater extent for ridge tillage than for the fall chisel treatment. The moisture content of the grain at harvest is a consequence of differences in early growth. Taller plants, early in the growing season, were more mature at frost. If more mature, the moisture content of the grain was reduced.

Grain yields were substantially below potential because of the extremely cool growing season. Yields were higher for the chisel plow planting system. Pioneer 3737 produced statistically higher yields than Pioneer 3732. These differences can be traced to differences in early growth (Table 2). Effect of potash treatment on yield varied with tillage system. Potash use increased yields of Pioneer 3732 in both tillage systems. However, larger increases were measured in the ridge-till planting system. Potash use increased the yield of Pioneer 3737 only in the ridge-till planting system. These conclusions are consistent with observations of growers who use the ridge-till planting system.

Table 4. Potassium uptake by corn plants as affected by tillage system, hybrid, and potash fertilizer treatment.

Tillage System	Hybrid	K_2O Treatment	Days After Planting 40	60
		lb./acre	- - - mg/plant	- - -
Fall Chisel	3732	0	22.1	128.4
		40 (band)	54.8	262.9
		40 (bdcst)	18.9	152.1
Fall Chisel	3737	0	30.3	253.0
		40 (band)	63.7	335.2
		40 (bdcst)	38.9	212.7
Ridge-Till	3732	0	9.1	64.4
		40 (band)	53.9	219.0
		40 (bdcst)	15.0	102.0
Ridge-Till	3737	0	15.6	147.9
		40 (band)	54.8	228.6
		40 (bdcst)	29.0	133.7

Table 5. Moisture content of grain at harvest and grain yield as affected by tillage system, hybrid, and potash fertilizer treatment.

Tillage System	Hybrid	K_2O Treatment	Grain Moisture	Yield
		lb./acre	%	bu./acre
Fall Chisel	3732	0	41.7	79.3
		40 (band)	35.4	102.0
		40 (bdcst)	37.1	97.5
Fall Chisel	3737	0	33.1	100.6
		40 (band)	29.5	111.2
		40 (bdcst)	33.6	101.2
Ridge-Till	3732	0	47.1	53.6
		40 (band)	37.3	93.3
		40 (bdcst)	47.0	57.8
Ridge-Till	3737	0	45.2	58.4
		40 (band)	29.3	101.6
		40 (bdcst)	43.8	68.7

These results demonstrate the positive effect of the banded application of potash. They support the recommendation that potash fertilizer should be banded instead of broadcast in a ridge-till planting system.

Analysis of plant samples for strontium, rubidium, and lithium is not yet completed. Root length density for the second sampling time is presented in Table 6. When averaged over all positions and depths, there was no difference between the ridge-till and fall chisel planting systems (.38 cm/cm^3). Hybrid 3732 had a higher mean root density (0.48 cm/cm^3) than 3737 (0.28 cm/cm^3), with the biggest differences between hybrids in the ridge-till planting system (3732 - 0.55 cm/cm^3, 3737 - 0.20 cm/cm^3). Hybrid differences were much less in the chisel system (3732-0.41 cm/cm^3, 3732 - 0.35 cm/cm^3). It appears that the roots of Hybrid 3732 are considerably less efficient at K uptake than 3737, since these plants have higher root densities and lower uptake rates. Physiological studies of K uptake rates by roots of both hybrids will be conducted to confirm this observation.

Table 6. Root length density at 40 days after emergence.

		Tillage		Hybrid		Ridge		Chisel	
Position	Depth	Ridge-Till	Fall Chisel	3732	3737	3732	3737	3732	3737
		cm/cm³							
in row	0-6"	0.52	0.81	0.65	0.68	0.68	0.37	0.62	0.99
	6-12"	0.29	0.36	0.48	0.17	0.54	0.04	0.42	0.31
	12-24"	0.28	0.29	0.32	0.25	0.46	0.09	0.17	0.41
3" from row	0-6"	0.60	0.40	0.72	0.28	0.95	0.24	0.49	0.31
	6-12"	0.29	0.45	0.58	0.17	0.53	0.06	0.62	0.28
	12-24"	0.36	0.23	0.44	0.19	0.55	0.17	0.27	0.21
6" from row	0-6"	1.00	0.42	0.97	0.45	0.14	0.60	0.55	0.22
	6-12"	0.29	0.67	0.51	0.45	0.30	0.28	0.73	0.62
	12-24"	0.24	0.22	0.14	0.33	0.07	0.42	0.21	0.24
12" from row	0-6"	0.06	0.43	0.33	0.16	0.04	0.07	0.62	0.24
	6-12"	0.36	0.20	0.42	0.13	0.66	0.05	0.18	0.21
	12-24"	0.25	0.10	0.25	0.10	0.46	0.02	0.03	0.18

INTERACTIONS OF HARD RED SPRING WHEAT (TRITICUM AESTIVUM L.) CULTIVARS WITH TILLAGE SYSTEMS, NITROGEN RATES, AND CHLORIDE APPLICATION.

Dennis D. Warnes, Robert H. Busch, Samuel D. Evans, George A. Nelson, and Roy D. Wilcoxson[1/]

Increased concern for soil conservation and further compliance with government programs, that have targeted reductions in soil erosion, will dictate further adoption of conservation tillage systems. In addition to reduction in soil erosion, conservation tillage systems can increase soil water retention which is a benefit in short drouth periods. However, the extra water retained in excessive soil water conditions can contribute to denitrification losses (Blevins 1983). As tillage practices are changed to leave more residue on the soil surface, other management practices must be re-evaluated to determine if different management strategies are required with conservation tillage. Generally, plant growth and grain yield responses to various seedbed preparation methods are the result of such factors as changes in soil moisture, soil temperature, and diseases and insects associated with increased crop residue left on the surface.

No-till seedbeds tend to have lower spring soil temperatures and higher soil moisture and may have more problems with insect and diseases that overwinter on residue on or near the soil surface (Wall & Stobbe, 1984; VanDoren, 1978; MacLean & Donovan, 1973). Crop residue associated with no-till seedbeds also has been shown to have an allelopathic effect on the newly seeded crop of certain species (Elliot, 1978). Cox et al. (1986) evaluated the effect of three tillages on the winter survival of two hard red winter wheat cultivars and found that percentage winter survival was greatest for no-till wheat planted into tall stubble for snow catch. Type of tillage was more important than cultivar selection in determining percentage winter survival. Wilhelm et al. (1982) reported that nitrogen fertilization did not significantly change rooting pattern of hard red winter wheat, however, root weight was greatest for the no-tillage and least for the subtillage. Ditsch et al. (1991), using two red winter wheat cultivars and two tillage systems, found that the incidence of powdery mildew was higher under no-till but septoria glume blotch was not affected by tillage.

Literature on the effects of various tillage systems on spring wheat cultivars is very limited. Ciha (1982) compared four spring wheat cultivars and three tillage systems. He found cultivar x tillage interactions for yield and test weight which indicates a need to evaluate individual spring wheat cultivars for specific tillage conditions. Hall and Cholick (1989) compared 18 spring wheat cultivars and two tillage systems and reported a significant cultivar x tillage interaction for grain yield. Cultivars ranged from a 9.8% increase to 11.6 decrease in grain yield depending on tillage.

Fixen et al. (1986) studied the influence of soil and applied chloride on hard red spring wheat. They found that chloride did not influence root rot but did suppress leaf rust and a complex of leafspot diseases at one location. However, the beneficial effect of chloride was more general than disease reduction and contributed to grain yield. Goos (1987) summarized the roles of chloride in plant nutrition and concluded that apart from its direct role as an essential nutrient, chloride fertilization also can restrict nitrate uptake by plants, lower leaf water potential, and inhibit nitrification by soil microorganisms. South Dakota chloride recommendations (Fixen, 1987) are calculated from the equation: Fertilizer chloride in kg/ha = 67.2 - soil chloride in a 0-.61 meter soil profile. Windels et a.l (1992) found that application of chloride tended to increase forage yield, decrease grain protein, and significantly increased test weight. However, soil supplemented with chloride was not effective in decreasing common root rot or in increasing hard red spring wheat grain yield in Northwest Minnesota. Breeding and selection programs for spring wheat are generally conducted on conventional seedbeds. Therefore, factors associated with non-conventional tillage are not considered until released cultivars are used with various tillage systems in farmers' fields.

The objective of this study was to determine: 1) the reaction of eight spring wheat cultivars reacted uniformly to nitrogen application in three tillage systems and, 2) the response of two cultivars to chloride application.

Materials and Methods

Field plot studies were conducted for four years (1987-1990) at the West Central Experiment Station at Morris, Minnesota. However, data from the severe drought year, 1988, were not included in the combined analysis. A split-split plot with four replications was employed with main plots as tillages, subplots as

[1/] Agronomist, Agronomist, Soil Scientist, Assistant Scientist, and Plant Pathologist, repectively. University of Minnesota, West Central Experiment Station, Morris; USDA, ARS; Plant Pathology, respectively.

nitrogen rates, and sub-sub plots as cultivars. A companion study was used to evaluate the effect of chloride on yield and leaf diseases using the same experimental design. Each year the experiment was planted in a different location after a bulk planting of wheat the previous year, but each year was on a Barnes loam soil. Soil samples were taken to evaluate for nitrogen, phosphorous, potassium, and chloride. Phosphorous and potassium were applied each fall prior to fall tillages according to soil test recommendations.

Fall plow, fall chisel and no-till were the three primary tillages. Fall tillages were performed in the October. Each spring the fall plow and fall chisel treatments were field cultivated to prepare a seedbed. No tillage was performed on the no-till plots but glyphosate, (N-(phosphono-methyl) glycine, was applied prior to seeding wheat to kill emerged weeds. Immediately after seeding, ammonium nitrate (34-0-0) was applied broadcast over the soil surface at nitrogen rates of soil (0-0.61 m depth) plus applied nitrogen equal to 67.2, 134.4 and 201.6 kg/ha. Individual cultivar plots consisted of eight rows (1.42 m.) 17.8 cm apart and 9.12 m. long. The plots were seeded using an ALMACO plot drill with a fluted coulter in front of each planter unit in all seedbeds. The cultivars were seeded at 101 kg/ha on April 17, 1987, May 11, 1989, and April 25, 1990.

The origin and traits of hard red spring wheat cultivars used are as follows:

Cultivar	Release Origin	Release Year	Plant Height	Maturity
+ Marshall	Minnesota	1982	Semidwarf	Late
Wheaton	Minnesota	1983	Semidwarf	Medium
Len	North Dakota	1979	Semidwarf	Medium
+Guard	South Dakota	1983	Semidwarf	Early
2369	Pioneer	1983	Semidwarf	Medium
Nordic	AgriPro	1986	Semidwarf	Late
Butte 86	North Dakota	1986	Tall	Early
Stoa	North Dakota	1985	Tall	Medium

+ Cultivars used in chloride companion study

Just after wheat tillering, diclofop + COC was applied at 0.84 kg/ha to control grass weeds and three days later (bromoxynil (3,5- Dibromo-4-hydroxybenzonitrile) + MCPA [(4-chloro-2-methylphenoxy)acetic acid] was applied at 0.28 kg/ha to control broadleaf weeds. Grain yield was measured by harvesting 1.4 or 3.2 m² of each plot. Date of emergence was determined in 1987 and 1990 and converted to days after planting. Leaf spotting diseases in 1990 were tan spot and septoria and were visually rated from 1-5 with 1=1-5%, 2=6-10%, 3=11-30%, 4=31-70%, and 5=71-100% infection. Scab infection in 1990 was rated on the same rating scale. Analysis of variance was first calculated using individual years and then combined over years.

In the companion study, chloride treatments were applied as potassium chloride with the seed at the rate of 67.2 kg/ha minus the soil test in a 0 to 0.61 meter profile for chloride. Guard and Marshall were the only cultivars used in the chloride study. All other variables were the same as in the primary study.

Results and Discussion

The combined analysis of variance for 1987, 1989, and 1990, nitrogen rates, tillage systems, and cultivars are presented for yield, test weight, grain protein, and date of emergence in 1987 in Table 1. Growing conditions were favorable in 1987 even with minimal precipitation because of adequate moisture carryover from a very wet year in 1986. Severe dought was encountered in 1988 and the data are not included in the combined analysis. Favorable growing conditions occurred during 1989 and 1990 with adequate precipitation during the growing season.

Significant differences in emergence date after planting was observed for cultivars, tillages and the cultivar x tillage interaction. The range of cultivar emergence was from 12.1 to 14.1 days after planting in 1987 from 8.6 to 9.9 days after planting in 1990. Tillage had a similar range in days to emergence in 1987 with conventional at 12.4 and both Chisel and No-Till emerged 13.2 days after planting, but there was no difference in 1990 due to tillage (Table 2). The average soil temperature for 10 days after planting at 5 cm depth was 1.5 °C degree cooler in 1987 than 1990 (nearby weather station) and could explain the greater delay in emergence for reduced tillage treatments in 1987. This delay in emergence in 1987 resulted in a 1 to 2 day delay in heading date for the reduced tillage treatments, similar to Hall and Cholick (1989). Reduced tillage treatments have lower spring soil temperatures and higher soil moisture due to the increased residue (Wall and Stobbe,1984; Van Doren et al. 1978, and MacLean and Donovan,1973). Another possible cause of emergence delay could be due allelopathic effects from the previous crop residue (Elliot,1978), but cooler soil temperatures were probably most responsible for emergence delays in 1987 in this study.

Nitrogen rate and cultivar both differed significantly for grain yield and test weight. The nitrogen x cultivar and tillage x cultivar interactions for yield were significant for grain yield. The cultivar x tillage interaction agrees with Hall and Cholick (1989) who reported a cultivar x tillage interaction from work in South Dakota. A comparison of yield in the different tillages was computed by using the formula Tillage Yield Difference (TYD) = till - no-till (Table 3). Marshall and Guard favored no-till while 2369, Len, and Wheaton favored conventional tillage, very similar to the results of Hall and Cholick (1989).

The cultivar x nitrogen interaction was further investigated using trend analyses to determine the yield response to rate of nitrogen fertilization. Both the linear and quadratic effects of nitrogen rate were significant. Responses were classed as those cultivars that increased yield with each increasing rate of nitrogen, cultivars that increased yield with only the first increment of nitrogen and cultivars which increased yield at the first increment of nitrogen but decreased in yield at the second rate (Chart 1). Wheaton produced the largest increases in yield for each rate of nitrogen, while Stoa and Butte 86 had smaller yield increases for each rate of nitrogen. Guard and Len increased yield only with the first increment of nitrogen. Marshall, 2369, and Nordic produced slight increases of yield with the first nitrogen rate but decreased in yield with the second rate of nitrogen. Cultivars ranged in grain protein from 12.3 to 13.8 %. Increasing the rate of nitrogen increased average protein from 12.3 to 13.5 % (Table 2).

Effects from chloride application were evaluated combined over years. Cultivar and chloride applications differed for grain yield. Grain yield increased with application of chloride on the cultivar Marshall but Guard did not respond. Diseases were severe to rate only in 1990 with Guard move severely affected by leaf spotting diseases (tan spot and septoria) than Marshall. A significant variety x chloride interaction for control of head scab was detected. The application of chloride reduced head scab on Guard but had no benefit on Marshall.

A cultivar x tillage and cultivar x nitrogen interaction indicates cultivar development should include selection and evaluation under various tillage systems and under various nitrogen fertility levels. Tillage systems and nitrogen fertility levels can be viewed as altering the environment for growth and development. They add to the complexity of a genotype x environment interaction which are a major component of nearly all plant breeding programs.. This research was partially funded by grants from the Minnesota Wheat Research and Promotion Council. The assistance of Alfred J. Koehler, Plot Coordinator and Carlos Bright, Senior Research Plot Technician in this research is gratefully acknowledged.

Literature Cited

Blevins, R. L., M. S. Smith, G. W. Thomas, and W. W. Frye. 1983. Influence of conservation tillage on soil properties. J. Soil Water Conserv. 38:301-305.

Ciha, A. J. 1982. Yield and yield components of four spring wheat cultivars grown under three tillage systems. Agron. J. 74:317-320.

Cox, D. J., J. K. Larsen, and L. J. Brun. 1986. Winter survival response of winter wheat: Tillage and cultivar selection. Agron. J. 78:795-801

Ditsch, D. C., and J. H. Grove. 1991. Influence of tillage on plant populations, disease incidence, and grain yield of two soft red winter wheat cultivars. J. Prod. Agric. 4:360-365.

Elliot, L. F., T. M. McCulla, and A. Waiss, Jr. 1978. Phytotoxicity associated with residue management. pp. 131-146. In W. R. Oschwald (ed) Crop Residue Management Systems. ASA, CSSA, and SSSA, Madison, WI.

Fixen, Paul E. 1987. Chloride fertilization? Crops and Soils Magazine March 1987:14-16.

Fixen, P. E., G. W. Buchenau, R. H. Gelderman, T. E. Schumacher, J. R. Gerwig, F. A. Cholick, and B. G. Farber. 1986. Influence of soil and applied chloride on several wheat parameters. Agron. J. 78:736-740.

Goos, R. J. 1987. Chloride fertilization. Crops and Soils Magazine March 1987:12-13.

Hall, E. F., and F. A. Cholick. 1989. Cultivar X tillage interaction of hard red spring wheat cultivars. Agron. J. 81:789-792.

MacLean, A. J., and L. S. Donovan. 1973. Effects of soil temperature on early growth of six single-cross corn hybrids. Canadian J. Soil Science 53:128-129.

Van Doren, D. M. Jr. and R. R. Allmaras. 1978. Effect of residue management practices on the soil physical environment, microclimate, and plant growth. pp.49-84 In W.R. Oschwald (ed) Crop Residue Management Systems. ASA, CSSA, and SSSA, Madison, Wi.

Wall, D. A., and E. H. Stobbe. 1984. The effect of tillage on soil temperature and corn (Zea mays L.) growth in Manitoba. Can. J. Plant Sci. 64:59-67.

Wilhelm. W. W., L. N. Mielke, and C. R. Fenster. 1982. Root development of winter wheat as related to tillage practice in western Nebraska. Agron. J. 74:85-88.

Windels, Carol E., John A. Lamb, and Todd E. Cymbaluk. 1992. Common root rot and yield responses in spring wheat from chloride application to soil in northwestern Minnesota. Plant Disease 76:908-911.

Table 1. A partial list of the sources of variation from analysis of variance of eight cultivars compared for three years with three nitrogen rates and three tillage systems for measured traits at Morris, MN.

		Combined 1987,1989,1990			1987,1990
Source	d.f.	Yield	Test Weight	Protein	Emergence
			P>		
Year (Yr)	2	NS	0.01	-	0.01
Tillage (T)	2	NS	NS	NS	0.01
Nitrogen (N)	2	0.02	0.01	0.01	0.02
Cultivar (C)	7	0.01	0.01	0.01	0.01
Yr x T	4	NS	NS	-	0.01
YR x N	4	NS	0.01	-	NS
YR x C	14	0.01	0.01	-	0.01
T x N	4	NS	NS	NS	0.02
N x C	14	0.05	NS	NS	NS
T x C	14	0.06	0.01	NS	0.01

Table 2. Dates of emergence for eight spring wheat cultivars and three tillage systems at Morris, MN. 1987, 1990.

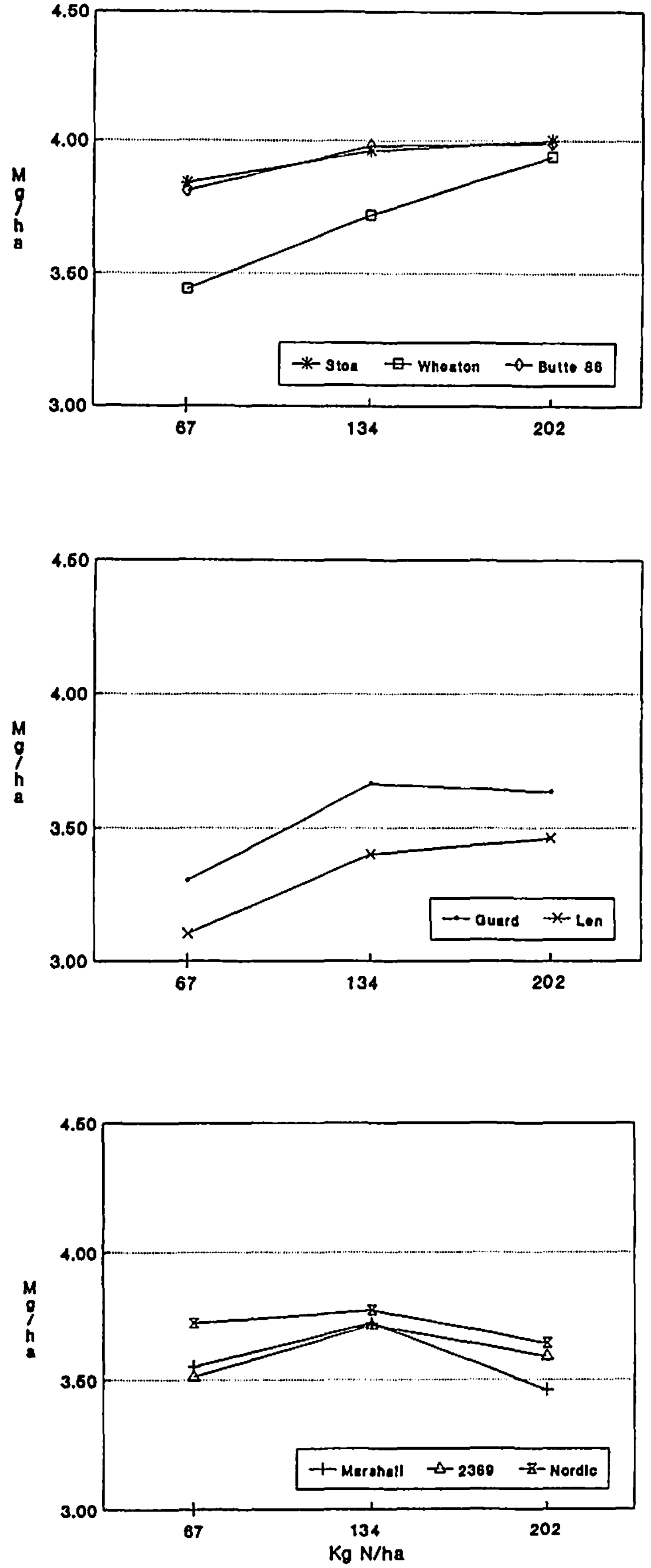
	Tillage System								
Cultivar	Moldboard		Fall Chisel		No-Till		Average		
	1987	1990	1987	1990	1987	1990	1987	1990	Average
	----days after planting----								
Butte 86	11.8	8.8	12.8	9.1	12.4	9.3	12.3 e	9.1 d	10.7 d
Guard	11.5	8.5	12.1	8.7	12.8	8.8	12.1 e	8.6 e	10.4 e
Marshall	12.2	9.6	12.6	9.5	12.5	9.3	12.4 de	9.5 b	11.0 c
Stoa	11.9	9.3	12.9	9.2	13.5	9.6	12.8 c	9.4 bc	11.1 c
Wheaton	12.5	9.0	12.8	9.2	12.8	9.2	12.7 cd	9.2 bcd	10.9 c
Len	13.1	9.1	13.7	9.5	13.4	9.1	13.4 b	9.2 cd	11.3 b
2369	13.6	9.1	14.4	9.5	14.2	9.2	14.1 a	9.3 bcd	11.7 a
Nordic	12.8	9.8	14.2	10.0	13.8	9.8	13.6 b	9.9 a	11.7 a
Average	12.4	9.1	13.2	9.3	13.2 a	9.3	12.9	9.3	

Table 3. Mean grain yields (mg/ha) and TYD (Tillage Yield Differences) for eight spring wheat cultivars using three tillage systems combined across 3 years.at Morris, Mn, 1987, 1989, 1990

		Tillage		TYD (Tillage Yield Difference)		
Cultivar	No-Till	Fall Chisel	Moldboard	Fall Chisel - No-Till	Moldboard - No-Till	Tillage(SD)# - No-Till
Len	3.20	3.31	3.46	+0.11	+0.26	+0.05
2369	3.53	3.52	3.27	-0.01	+0.24	+0.16
Butte 86	3.87	3.94	3.98	+0.07	+0.11	
Wheaton	3.65	3.57	3.89	-0.08	+0.24	+0.03
Stoa	3.91	3.76	4.12	-0.15	+0.21	
Marshall	3.67	3.49	3.60	-0.18	-0.07	-0.10
Guard	3.61	3.40	3.60	-0.21	-0.01	-0.30
Nordic	3.75	3.80	3.59	+0.05	-0.16	

Chisel TYD = Chisel - No-Till
Moldboard TYD= Moldboard - No-Till
#Tillage (SD) TYD = Tillage - No-Till (Hall and Cholick, 1989)

Chart 1. Cultivar x Nitrogen Interaction



EFFECT OF RATE OF APPLIED N ON CORN RESPONSE AND SOIL WATER NITRATE CONCENTRATION ON A COARSE TEXTURED SOIL[1]

J.F. Moncrief, S.D. Evans, D. Ginting, G.N. Nelson, and B.J. Johnson[2]

This is the second year of a study designed to look at the effect of nitrogen rate on soil water nitrate concentration on a coarse textured soil under dry land conditions in west central Minnesota. Corn responded to the highest rate of applied N (150 lbs/acre). There was above average rainfall in June and July. At the beginning of the season there was very little difference in soil water nitrate concentration due to rate. As the season progressed, differences due to N rate were apparent.

Methods and Materials

The experimental design is a randomized complete block design with rates of nitrogen application as treatments (0, 50, 100, 150 lbs/A)and corn as the test crop. The study is being conducted on a LaPrairie loam. This soil series is formed in alluvium underlain by stratified sand and gravel. The surface layer in a typical profile is black loam about 24 inches thick. The subsoil is very dark grayish-brown to dark grayish-brown, friable loam in the upper part and dark-brown to olive-brown loam the lower part. Water moves through these soils at a moderate rate. Prior to establishing the study, test holes were made in the potential plot area. The experiment was established where the depth to fine sand varied from 40 - 60 inches. These soil samples were saved and will be analyzed for NO_3-N. The plot size are 65 feet in length and 30 feet in width (12-30 inches row). The area was in corn in 1990 and was moldboard plowed that fall. In the spring of 1992 the area had no tillage done due to ridges. Urea fertilizer was broadcast with a airflow applicator at rates of 0, 50, 100, and 150 lbs-N/ac on May 5. Corn was planted on May 5 using Pioneer 3788 at 27500 seeds/ac. On 06/12/91 two suction samplers were placed in each plot. The samplers were installed in the corn row and the bottom of the sampler was placed at the loam-fine sand interface. Therefore, the sampling depth varied from 40 to 60 inches, depending on the depth to the fine sand layer. Samples were to be taken on a 7- day interval throughout the growing season. The soil water collected was analyzed for total, nitrate, and ammoniacal nitrogen. The corn was cultivated with a Hiniker 5000 during on 06/12/92 and ridged on 06/29/92. On 10/12/92 two rows were harvested with a 2-row Almaco plot combine. Yields and soil moisture were determined electronically and recorded. A grain sample was saved for nitrogen analysis. On 10/28/92, one row was harvested with a forage chopper to assess total dry matter and total nitrogen uptake. The remainder of the corn was harvested and corn stalks were chopped. The area will be maintained in the future in a ridge-till system.

Results and Discussion

Corn responded to the highest rate of applied N (150 lbs/acre). There was above average rainfall in June and July. At the beginning of the season there was very little difference in soil water nitrate concentration due to rate. As the season progressed, differences due to N rate were apparent.

Table 1.Cultural practices at Morris, MN in 1992.

Tillage
No tillage
Cultivated on June 12
Ridged on June 29

Cropping Pattern
Corn - Soybean rotation from 1991

1991-92 crop
Corn - Pioneer 3788

Planting and harvest dates

Corn - was planted with a two row Hiniker Series 1 EconoTill planter with 30 inches row spacing.

[1]Support for this project was provided by the Agricultural Utilization and Research Institute and the Minnesota Agricultural Experiment Station.

[2] J.F. Moncrief, S.D. Evans, G.W. Nelson, and B.J. Johnson are Extension Soil Scientist, Soil Scientist, Research Assistant, and Assistant Scientists respectively.

Crop	Planting Date	Planter	Rate	Harvest date Grain	Silage
Corn	May 5, 1992	Row	27,500 seeds/ac	October 12	September 28

Weed control

3.0 qt/A (3.0 lb/A) Lasso + 2.2 qts (2.2 l/A) Bladex 90 DF applied preemergence on May 6. Lorsban 15G (10 lbs/A) with planter.

Table 2. Effect of nitrogen application rate on grain nitrogen percent and uptake of corn at Morris, MN, 1992

Nitrogen rate (lbs/A)	Grain N (%)	Grain N uptake (lbs/A)
0	1.16 a	33.9 a
50	1.16 a	48.3 b
100	1.31 a	69.3 b
150	1.29 a	73.2 b

The p value for nitrogen rate on grain nitrogen percent and uptake are 0.448 and < 0.001 respectively. The means within the same column with the same letters are not significantly different (α= 0.10).

Table 3. Monthly precipitation totals (inch) at site of study.

May	1.36
June	4.88
July	5.50
August	1.48
September	1.48
October	0.12

Table 4. Effect of nitrogen application rate on grain and total dry matter of corn at Morris, MN, 1992

Nitrogen rate (lbs/A)	Grain Yield (bu/A)	Total dry matter (tons/A)
0	61.9 a	3.35 a
50	88.2 b	5.38 b
100	112.1 c	6.05 c
150	120.3 c	6.58 d

The p value for nitrogen rate on grain yield and total dry matter are <0.001 and <0.001 respectively.

Table 5. Effect of N rates on plant density and grain moisture at Morris, Mn, 1992

Nitrogen rate (lbs/A)	Population (plts/A x 10^{-3})	Grain moisture (%)
0	25.8	26.1
50	25.6	24.3
100	25.0	23.6
150	25.4	25.1

The p value for nitrogen rate on population and grain moisture are 0.465 and 0.09 respectively.

Table 6. Distribution of total, nitrate and ammoniacal nitrogen concentration in soil water on different dates of sampling in Morris, MN, 1992.

Date	Total N (ppm)	Nitrate N (ppm)	Ammoniacal N (ppm)
06/18/92	63.98	63.89	0.08
07/07/92	63.04	63.00	0.04
07/15/92	49.37	49.23	0.09
08/27/92	42.43	42.41	0.02
09/03/92	45.26	45.13	0.13
10/04/92	59.95	59.88	0.07
10/16/92	56.75	56.54	0.21

1. Mean value averaged over N rates.

Table 7. Effect of nitrogen application rate on total, nitrate and ammoniacal N in soil water over different sampling dates in Morris, MN, 1992.

Dates sampled	Total N(ppm) lbs/ac				Nitrate N (ppm) lbs/ac				Amm.-N (ppm) lbs/ac			
	0	50	100	150	0	50	100	150	0	50	100	150
06/18	72.1	58.5	60.5	64.2	72.0	58.4	60.4	64.1	0.05	0.07	0.07	0.13
07/07	55.6	62.3	67.6	70.2	55.6	62.2	67.5	70.2	0.00	0.07	0.04	0.05
07/15	36.6	33.9	53.9	72.5	36.3	33.8	53.8	72.5	0.12	0.08	0.09	0.05
08/27	20.8	35.2	50.7	62.0	20.8	35.2	50.6	62.0	0.01	0.01	0.02	0.04
09/03	26.9	42.2	58.9	59.6	26.8	42.1	58.8	59.5	0.13	0.12	0.13	0.13
10/04	46.2	73.8	83.3	49.5	46.1	73.7	83.2	49.5	0.09	0.08	0.12	0.01
10/16	42.9	111.1	65.5	48.4	42.7	110.9	65.3	48.2	0.20	0.24	0.24	0.19

FIG. 1 SOIL WATER–N CONCENTRATION OVER TIME IN CORN AT MORRIS, MN. 1992

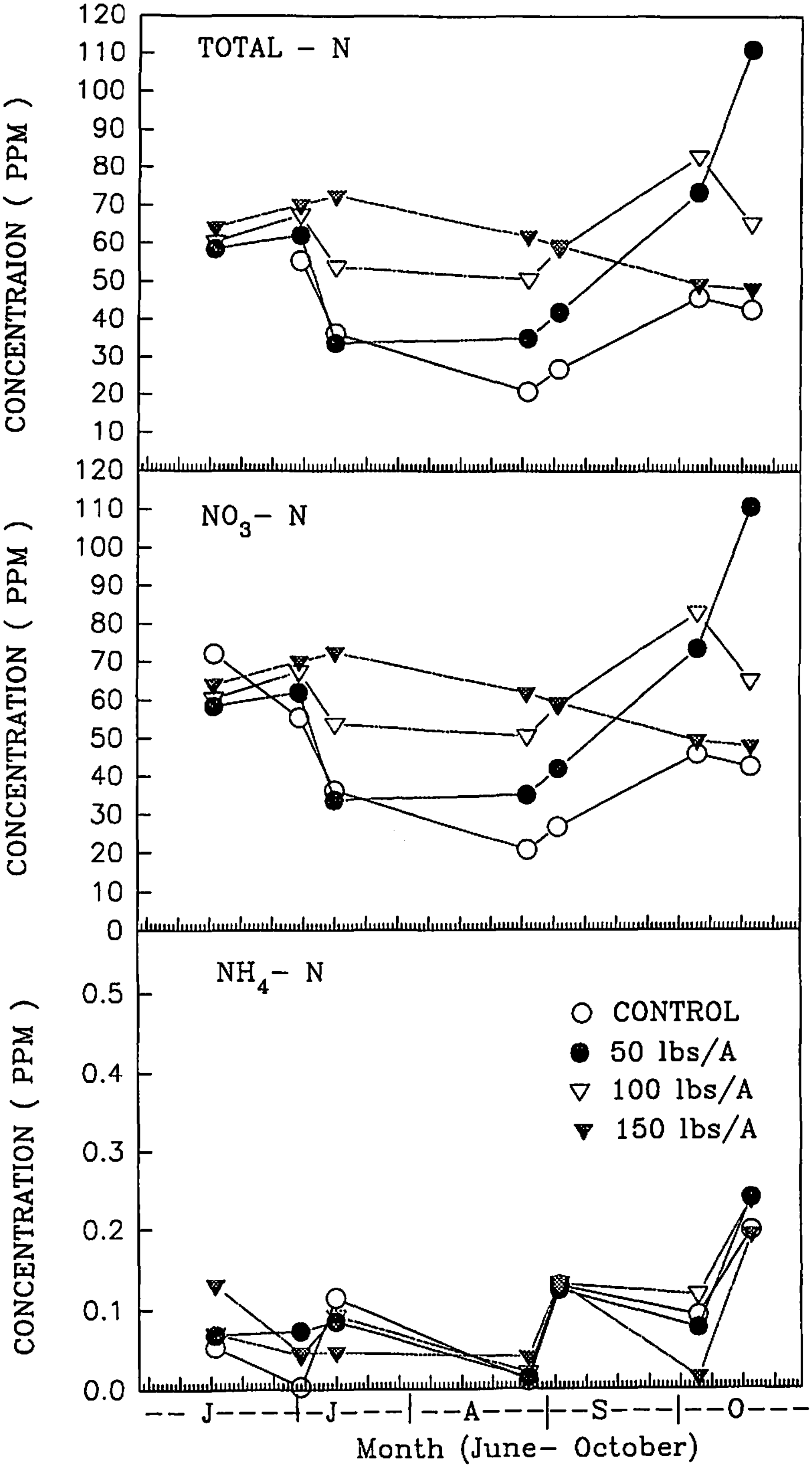
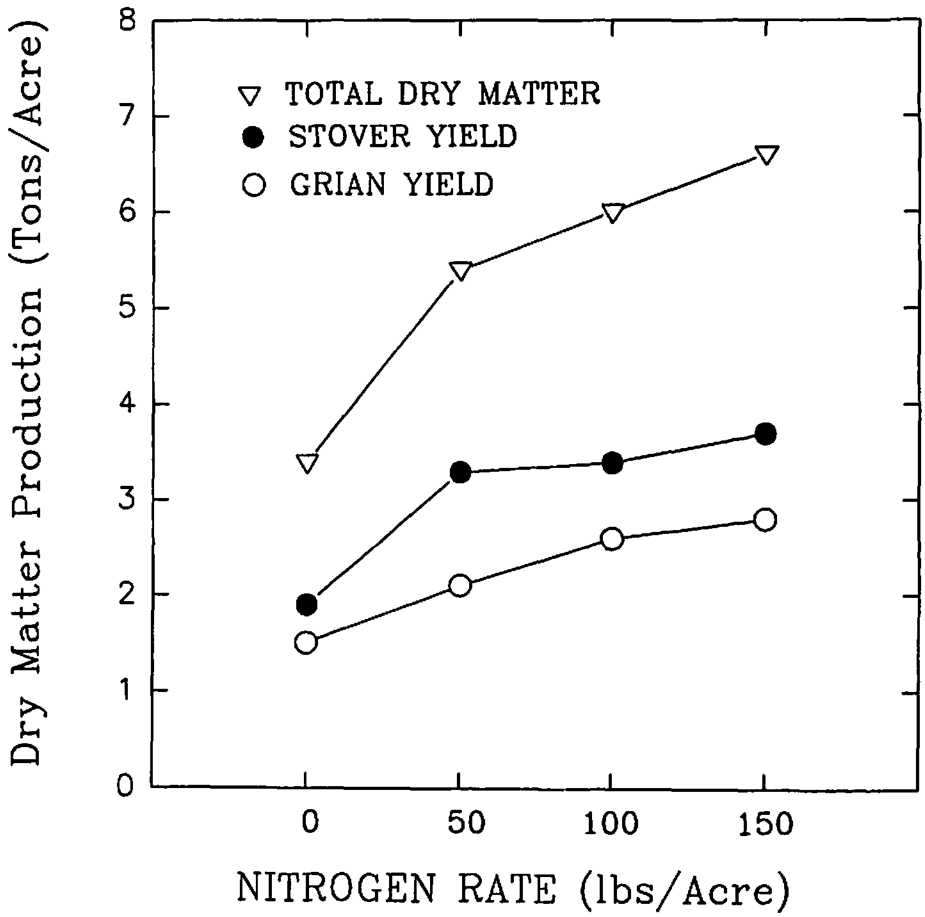


Figure 2.

GRAIN, STOVER AND TOTAL DRY MATTER OF CORN AT DIFFERENT N RATES. MORRIS, MN.



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

Tillage and beef manure application effects on total-P, bioavailable-P and soluble-P were evaluated. Due to greater runoff volume and sediment produced from moldboard plowing, moldboard plowing resulted in significantly greater total-P, bioavailable-P and soluble-P compared to no-till system. Beef manure application resulted in significantly higher total-P. The application of manure in combination with moldboard plowing resulted in 167 % higher total-P compared to the non-manure application.

Introduction

One of the important questions in manure utilization on a steep land is what type of tillage is necessary such that manure is incorporated into the soil. At the same time, the tillage system will not cause excessive erosion. Sound utilization of manure from farming enterprises is imperative. Since beef and livestock operations are an important part of the economy in the West Central Minnesota and since there are several lakes in the area which are subject to contamination from surface runoff, an experiment was conducted at the West Central Agricultural Experiment Station, Morris, MN to evaluate the influence of tillage (Ridge till and moldboard) and beef manure application on surface water quality.

Materials and Methods

Tillage treatment included ridge tillage and moldboard plowing. Since ridging was not done until July 1992 the results reported here applied to no-till conditions. Moldboard plowing was done in the spring of 1992. Prior to plowing beef manure was spread over the plots assigned for manure treatments at a rate of 25 ton/a (May, 6/1992). The erosion plots were established after plowing (5/6/92) and planting (5/7/92). Corn was replanted two times because of plant damage caused by gophers (June 15). Cultural practices are presented in Table 1.

The plot area had 12 % slope and was previously cropped with alfalfa. The experimental design is a randomized complete block with three replications with tillage as main plot and manure treatment as the subplot. Twelve erosion plots, 76 feet by 10 feet (to accomodate four rows of corn) were marked and isolated from the border areas using corrugated steel plates. At the end of each plot the runoff was trapped with a pvc sheet (10 feet by 1 foot) and then channeled through a pvc pipe of 4 and 3 inch diameter to a series of collectors consisting of three barrels of 55 gal. each. Over the PVC trap, corrugated roofing was placed to avoid direct precipitation getting in to the trap. The collector was designed for runoff volume of 550 gallons (25 years return period of excess runoff after considering the curve number of Barnes loam). The first barrel mainly collected very coarse sediments. The overflow from the first barrel was channelled to the second barrel. At the second barrel, 8 adjacent holes of 1.5 inch diameter were drilled near the rim of the barrel. One of the holes was connected to a PVC pipe of 1.5 inch diameter which channelled the excess runoff to the third barrel. This setup allowed 1/8 of the overflow from the second barrel to be collected in the third barrel.

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

Total phosphorus was analyzed using perchloric acid digestion as described in EPA procedure. Twenty 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

[1]Support for this project was provided by the Agricultural Utilization and research Institute, the Minnesota Pollution Control Agency, the Soil Conservation Service, the Clear Water River Watershed District, and the Minnesota Extension Service. Their support is greatly appreciated.

[2] D. Ginting, J.F Moncrief, S.C. Gupta, B.J. Johnson and A. Ranaivoson are Graduate Student, Associate Professor, Professor, and Assistant Scientists respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. S.D. Evans and G.A. Nelson are professor and Assistant scientist, West Central Experiment Station, University of Minnesota, Morris, MN.

of 0.1 N NaOH, a procedure in the literature that has been correlated with a procedure on algal growth to estimate algal available-P. Extraction was conducted by shaking for 18 hours on a reciprocating shaker. Soluble-P was measured after filtration of suspension through 0.45 micron filter paper, preceded by centrifugation. Phosphorus was then determined 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, 1992.

Tillage

No-till
Ridge till (July 21, 1992)
Spring moldboard (May 6, 1992)

Cropping History

1991-Alfalfa
1992-Corn Pioneer-3751
-Corn Pioneer-3617
-Corn Pioneer-3921

Planting and Harvest Dates

Corn - was planted with a Hiniker 4 row planter with 30 inch 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	32,000 seeds/A	Corn was chopped, and left on field (10/23/92)
	May 29, 1992	40,000 seeds/A	
	June 15, 1992	60,000 seeds/A	

1992 Manure Analysis

							Total			Solids		
Manure source	Rate	Date Applied	NH4	NO3	Mineral	Organic	N	P	K	Total	Volatile	fixed
			%									
Beef Manure	25t/a	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

								Total		
Manure source	Rate	Date Applied	NH4	NO3	Mineral	Organic	available N	N	P2O5	K2O
			lb/a							
Beef Manure	25 t/a	May 6/92	107.5	2.5	110.0	320.0	190.0	430.0	331.0	334.0

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

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 ppm respectively.

Weed Control

Lorsban 15G ,10 lbs/A (May 7, 1992)
Ranger 1 lb/A+2,4-D ester 0.5 lb/A+Banvel 0.25 lb/A+Lasso EC 4 lb/a+Bladex DF (90%) 2.2 lb/A (5/8/92)
Ranger 1 lb/A only on no till plot to kill grasses and alfalfa (5/22/92)

Results And Discussions

The results presented in this report are preliminary. There were three rainfall events in June 1992 that produced runoff. Mean values indicated that moldboard plowing resulted in significantly greater total-P, bioavailable-P and soluble-P in the runoff, compared to no-till (Table 2). This was mainly due to greater volume of runoff and sediment amount that resulted from moldboard plowing (Table 3). The concentration of total-P, bioavailable-P and soluble-P was always higher in no-till runoff compared to moldboard plowed plots. Since the runoff volume and sediment were much lower in no-till, total amount were also lower in no-till than moldboard system. The distribution of cumulative total-P, bioavailable-P and soluble-P in runoff water and precipitation overtime is presented in Fig. 1.

Manure application resulted in significantly higher total-P although the bioavailable and soluble-P are relatively similar compared to non-manure application. The application of manure combined with moldboard plowing resulted in 167 % higher total-P compared to non-manure application. This was mostly due to increased sediments produced in the non-manure plot. Sediment production in moldboard, non-manured plot was 141 % higher than the sediment produced from moldboard, manured plots (Table 3). The distribution of cumulative runoff volume and sediments over time during three events of runoff are presented in Fig. 2.

Table 2. Cumulative Total-P, bioavailable-P (bio-P) and soluble-P (sol-P) in runoff at Morris Agricultural experiment Station, MN (During June, 1992).

Tillage	Manure			No manure			Means		
	Total-P	Bio-P	Sol-P	Total-P	bio-P	Sol-P	Total-P	bio-P	Sol-P
	g/ha								
No till	6.6	5.4	2.9	7.0	3.1	2.0	**6.8**	**4.3**	**2.5**
Moldboard	365.4	38.1	15.6	218.6	28.1	14.9	**292.0**	**33.1**	**15.3**
Means	**166.0**	**21.8**	**9.3**	**112.8**	**15.6**	**8.5**			

Table 3. Cumulative Runoff volume and sediment at Morris Agricultural experiment Station, MN (During June, 1992).

Tillage	Manure		No manure		Means	
	runoff vol.	sediment	runoff vol.	sediment	runoff vol.	sediment
	----kL/ha--	--kg/ha---	-----kL/ha--	--kg/ha---	-----kL/ha--	-- kg/ha--
No till	1.0	2.2	2.0	5.7	**1.5**	**4.0**
Moldboard	36.0	354.6	39.4	500.6	**75.4**	**427.6**
Means	**18.5**	**178.4**	**20.7**	**253.2**		

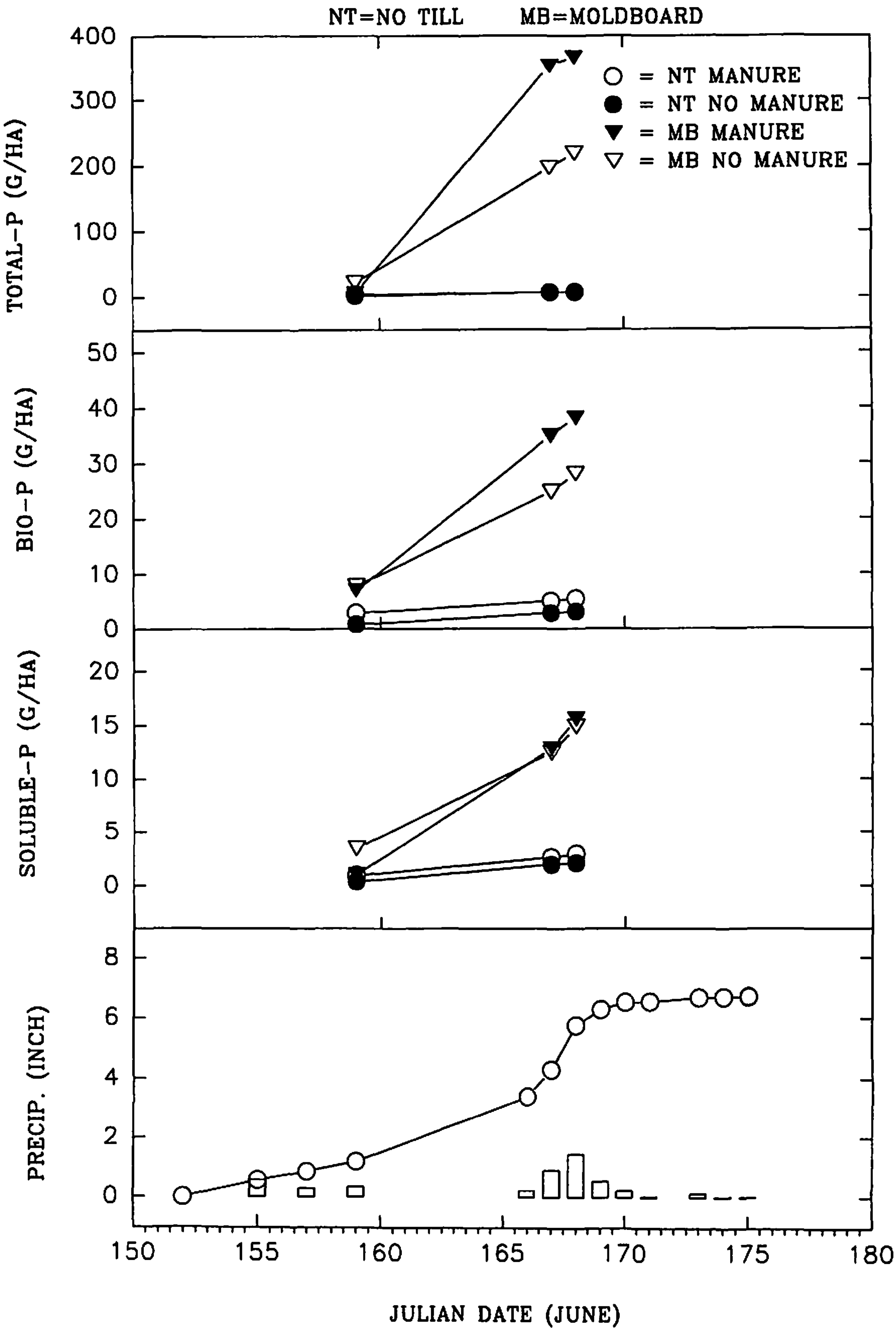


FIG. 1. CUMULATIVE TOTAL, BIOAVAILABLE, SOLUBLE PHOSPHORUS AND PRECIPITATION OVER TIME AT MORRIS EXPERIMENTAL STATION, MORRIS, MN (JUNE, 1992).

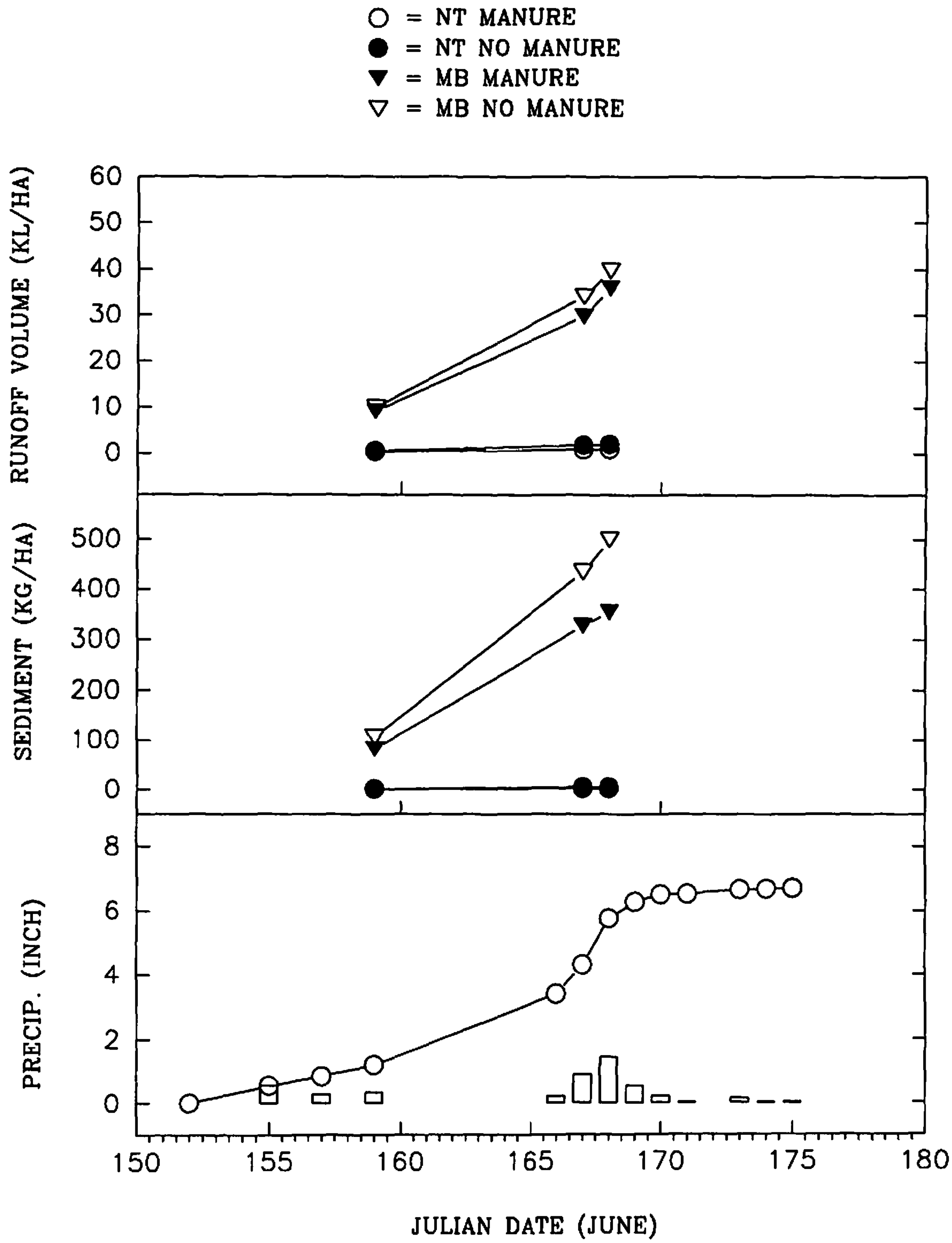


FIG. 2. CUMULATIVE SEDIMENT AND RUNOFF VOLUME AND PRECIPITATION OVER TIME AT MORRIS EXPERIMENTAL STATION, MORRIS, MN (JUNE, 1992).

THE IMPACT OF POTASH FERTILIZATION, TILLAGE SYSTEM AND CORN HYBRID ON CORN YIELD IN WEST-CENTRAL MINNESOTA

George Rehm, Sam Evans, and George Nelson[1/]

ABSTRACT: This study was conducted at the West-Central Experiment Station at Morris to further evaluate the interactions among tillage system, corn hybrid, and potash fertilization on corn yield. Yields were significantly affected by all variables. There were significant interactions between tillage system and hybrid as well as between tillage system and placement of potash fertilization. Yield was not affected by hybrid when the chisel plow and moldboard plow planting systems were used. The highest yield was associated with the Pioneer 3737 hybrid when the ridge-till and no-till planting systems were used. The placement of potash fertilizer had a significant effect on yield when corn was planted with the no-till and ridge-till planting systems.

The problem of potassium (K) deficiencies in corn planted with ridge-till and no-till planting systems was recognized in 1989. Since that time, several studies have been conducted to evaluate the impact of rate of applied potash and hybrid selection on this problem. There was also a continuing need to further evaluate the effect of potash placement on corn response to applied potash.

Objective:

Recognizing the questions cited above, this study was conducted to evaluate the effect of potash fertilization tillage system, and hybrid selection on corn production in West-Central Minnesota.

Experimental Procedure:

This study was conducted at the West-Central Experiment Station at Morris. The experimental area had been used for a number of years to compare the impact of four tillage systems on the yield of continuous corn. The tillage systems were retained for this study. Four potash treatments (control, 200 lb. 7-21-7/acre, 40 lb. K_2O banded to a depth of 3-4 inches into the old row, 80 lb. K_2O/acre broadcast in the fall) were applied to two corn hybrids (Pioneer 3737, Pioneer 3732). A split plot arrangement was used with four replications. The tillage systems were the main plots. The potash treatments and corn hybrids were the split plots.

The banded and broadcast treatments were applied in late October in 1991. The fall plow and chisel plow tillage operations were completed immediately after the fall fertilizer application. Corn was planted in early May. A starter (10-34-0) was used for the treatments where potash was not applied in the starter at planting. Other management practices conducive to optimum corn production in the region were used. Grain yields were measured in October and corrected to 15.5% moisture.

Results and Discussion:

Grain yields are summarized in Table 1. Yield was significantly affected by tillage, potassium treatment and hybrid. The interaction between tillage system and hybrid was also highly significant. Yields of both hybrids were nearly equal in the moldboard plow and chisel plow systems. However, yields were significantly higher for Pioneer 3737 when the ridge-till and no-till planting systems were used.

There was also a highly significant interaction between tillage system and the potassium treatment. The response to applied potash was much greater when the ridge-till and no-till planting systems were used.

When averaged over both hybrids and all potassium treatments, highest yields were produced by the moldboard plow system. The use of the no-till system produced the lowest yield. Yields from the other two systems were intermediate.

When averaged over tillage system and hybrid, the banded application of potash in the fall of 1991 produced the highest yield. Yields from other potash placements were lower and nearly equal. The lowest yield was associated with the control treatment.

[1/] Extension Soil Scientist, St. Paul; Professor, and Junior Scientist, West-Central Experiment Station, respectively.

Table 1. Corn yield in West-Central Minnesota as affected by tillage system, potash fertilization and hybrid.

Tillage System	K_2O Treatment	Hybrid: Pioneer 3732	Hybrid: Pioneer 3737
		- - - - - bu./acre - - - - - -	
Fall Chisel	control	86.8	91.3
	200 lb. 7-21-7/A starter	92.1	80.2
	40 lb. K_2O/A fall band	91.2	89.5
	80 lb. K_2O/A fall bdcst	89.8	85.5
	starter + fall band	98.3	89.4
Ridge-Till	control	63.7	91.5
	200 lb. 7-21-7/A starter	85.0	84.7
	40 lb. K_2O/A fall band	92.3	97.5
	80 lb. K_2O/A fall bdcst	85.1	94.3
	starter + fall band	87.3	91.5
Fall Plow	control	104.4	101.4
	200 lb. 7-21-7/A starter	111.6	106.6
	40 lb. K_2O/A fall band	112.8	104.8
	80 lb. K_2O/A fall bdcst	112.3	107.6
	starter + fall band	108.6	106.0
No-Till	control	76.4	62.8
	200 lb. 7-21-7/A starter	69.5	63.1
	40 lb. K_2O/A fall band	80.0	76.4
	80 lb. K_2O/A fall bdcst	72.1	67.5
	starter + band	78.5	60.5

POTASSIUM FERTILIZATION OF ALFALFA GROWN ON AN IRRIGATED SANDY SOIL

George Rehm, Dan Schmitz, and Andy 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 5 rates of annual K_2O (0, 60, 120, 180, 240 lb./acre) in a complete factorial design. Three cuttings were harvested in 1992. Neither plowdown nor annual rate of K_2O had a significant effect on alfalfa yield in 1992. The soil test value for K is low (63 ppm). The yield data does not provide an explanation for the lack of response. This study will be continued in 1993.

In recent years, some have questioned the potash recommendation for alfalfa currently used by the University of Minnesota. Alfalfa is a heavy user of potassium (K) and removal rates are 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 applications 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 summer of 1990. Soil samples 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, ppm	63

Plowdown rates of K_2O (0, 80, 160, 240, 320 lb. K_2O/acre) were combined with annual rates (0, 60, 120, 180, 240 lb. K_2O/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 supplied as 0-0-60 in all cases.

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/acre as granular gypsum was also incorporated over the entire plot area 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 and 1992. Each year, the alfalfa in all plots was topdressed with 50 lb. S/acre supplied as granular gypsum. Three cuttings were harvested each year. Whole plant samples were collected from each plot at each harvest and analyzed for K. Soil samples (0-6 inches) were taken from each plot in the fall of both 1991 and 1992. These samples were analyzed for K.

Results and Discussion:

The total dry matter yields for the 1992 growing season are summarized in Table 2. Plant uptake and soil test data are not summarized at this time. Statistical analysis of the data shows that neither rate of plowdown K_2O nor rate of K_2O applied on an annual basis had a significant effect on alfalfa yield in 1992.

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

These results are consistent with the results obtained in 1991, the first year of production. With the low soil test for K (63 ppm), a response to potash fertilizer would be expected. There is no easy explanation for the lack of response. It is possible that some K is applied with the irrigation and some is probably supplied from the subsoil. The data available do not provide an explanation for the lack of response.

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

Plowdown K_2O	Cutting	Annual Rate (lb. K_2O/acre) 0	60	120	180	240
lb./acre		ton dry matter/acre				
0	1	1.77	1.86	1.73	1.85	1.79
	2	1.08	1.07	1.10	1.20	1.16
	3	1.69	1.39	1.61	1.88	1.77
	Total:	4.53	4.33	4.43	4.93	4.72
80	1	1.90	1.82	1.84	1.76	1.82
	2	1.20	1.16	1.19	1.22	1.18
	3	1.78	1.79	1.62	1.75	1.49
	Total:	4.87	4.77	4.64	4.72	4.49
160	1	1.67	1.62	1.53	1.81	1.65
	2	1.20	1.26	1.17	1.27	1.27
	3	1.83	1.97	1.67	1.81	1.84
	Total:	4.70	4.85	4.38	4.88	4.75
240	1	1.94	1.90	1.83	1.82	1.84
	2	1.14	1.20	1.11	1.20	1.15
	3	1.62	1.63	1.91	1.76	1.71
	Total:	4.69	4.73	4.85	4.78	4.70
320	1	1.85	1.75	2.14	1.92	1.89
	2	1.11	1.10	1.26	1.20	1.24
	3	1.57	1.56	1.94	1.83	1.88
	Total	4.53	4.40	5.34	4.95	5.01

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

George Rehm, Dan Schmitz, Andy Scobbie, Craig Sheaffer, and Neal Martin[1/]

ABSTRACT: This study was conducted in both 1991 and 1992 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 legumes seeded in 1992. The method of establishment also had a significant effect on the density of stand measured in early September. This study will be continued in 1993.

There are legumes other than alfalfa that are adapted to the climate and soils of North-Central Minnesota. These legumes may be used for either pasture or 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 legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, red clover) are involved.

<u>Experimental Procedure</u>:

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. <u>Clean Seedbed</u>: With this method, Balan herbicide was applied at a rate of 3 quarts per acre at 2 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. <u>Conventional</u>: Oats is used as a companion or nurse crop. Oats was seeded into a prepared seedbed approximately 2 weeks before the seeding of the legumes. The legumes are then seeded into the emerging oats crop. The oats was harvested as oatlage when it reached the milk to soft dough stage of development.

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

D. <u>Lake Summer Companion Crop</u>: For this method, oats was planted in early spring and allowed to mature and the grain was harvested. A new seed bed was prepared by rototilling the stubble. A second oats crop was planted in late July. The legumes were seeded into the emerging oats in early August. Freezing temperatures in the fall kill the established oats.

E. <u>No-Till Establishment</u>: The legumes were seeded into existing 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 possibility of winter-kill would be reduced.

The legumes established in 1991 were harvested in 1992. Three cuttings of alfalfa were taken. The other legumes were harvested twice. One 1992 harvest was taken for all legumes established using methods A, B, and C in 1992.

Adequate fertilizer and lime was applied in both years of the study. Both experimental sites were irrigated as needed to prevent moisture stress in both 1991 and 1992.

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.

[1/] Extension Soil Scientist, Junior Scientist, Assistant Scientist, Professor, and Extension Specialist-Forage Crops, respectively.

Results and Discussion:

The 1992 yields of the legumes seeded in 1991 are summarized in Table 1. Total forage produced during the 1992 growing season was significantly affected by both legume and establishment method. There was also a highly significant interaction between legume and method of establishment.

Considering the legumes, the alfalfa and red clover produced the largest amounts of dry matter. Even though there were 3 cuttings of alfalfa and two of red clover, total yields for these 2 legumes were not statistically different. The cicer milkvetch produced the lowest amount of dry matter while birdsfoot trefoil yields were intermediate.

Table 1. The effect of method of establishment on 1992 yields of legumes established in 1991.

Legume	Cutting	Method of Establishment A	B	C	D	E
		ton dry matter/acre				
alfalfa	1	3.06	2.65	2.55	1.31	1.80
	2	1.60	1.61	1.53	1.25	1.37
	3	1.44	1.33	1.54	1.09	1.29
	Total:	6.10	5.59	5.62	3.65	4.46
birdsfoot trefoil	1	2.57	2.27	2.34	1.04	1.72
	2	1.86	1.98	1.95	2.02	2.06
	Total:	4.43	4.25	4.29	3.06	3.78
cicer milkvetch	1	1.87	.62	.84	.15	.25
	2	1.99	1.17	1.55	.90	1.19
	Total:	3.86	1.79	2.39	1.05	1.44
red clover	1	2.89	2.66	2.81	2.24	2.68
	2	2.33	2.44	2.60	2.24	2.50
	Total:	5.22	5.10	5.41	4.48	5.18

When averaged over all legumes, highest yields were associated with the clean seedbed method of establishment. Yields decreased significantly and progressively when methods B, C, D, and E were used. The 1992 yields from the methods that involved late summer seeding were substantially lower than yields from methods that utilized the early spring seeding. It's obvious that competition from the nurse or companion crop reduced the 1992 yield. There should be less competition from the oats if method C is compared to method B. Except for alfalfa, forage yields were higher for method C.

The 1992 yields for the legumes established in 1992 are summarized in Table 2. These yields were measured in early September. The yield of each legume (one cutting only) was significantly affected by method of establishment. Highest yields were recorded when no companion/nurse crop was used (Method A). Lowest yields were associated with the conventional method of establishment (Method B). The yields resulting form the use of method C were intermediate.

Table 2. Effect of method of establishment on the 1992 yields of legumes seeded in 1992.

Legume	Method of Establishment A	B	C
	ton dry matter/acre		
alfalfa	1.79	1.16	1.82
birdsfoot trefoil	1.38	.83	1.41
cicer milkvetch	1.24	.84	1.29
red clover	2.09	1.42	1.94

The stand densities measured in September for legumes seeded in 1991 and 1992 are summarized in Tables 3 and 4, respectively. For the 1991 seeding, density was significantly affected by both legume used and the method of establishment. There was, however, no significant interaction between these two factors.

For the 1991 seeding, stand density for all legumes was highest when the August seeding was made into emerging oats. The competition of the oats crop did not reduce the measured stand of alfalfa, birdsfoot trefoil, and red clover. The early season protection provided by the oats increased the stand of cicer milkvetch. The measured stand of cicer milkvetch was especially improved by the late summer seeding.

Table 3. The effect of establishment method used in 1991 on measured legume stand density in September 1992.

	Method of Establishment				
Legume	A	B	C	D	E
	plants/3 ft^2				
alfalfa	41	41	43	57	36
birdsfoot trefoil	28	27	30	49	37
cicer milkvetch	18	15	25	49	46
red clover	28	27	30	39	36

The measured stand from the 1992 seeding was significantly affected by both legume and method of establishment. There was no significant interaction between these two factors.

Except for the birdsfoot trefoil, measured stands were increased substantially by the late summer seeding (methods D, E). The competition from the oats crop had a mixed effect on the stands resulting from the use of methods A, B, and C. These legumes have not been subjected to the stress of winter and stands may be different in 1993.

Table 4. The effect of establishment method used in 1992 on measured legume stand density in September 1992.

	Method of Establishment				
Legume	A	B	C	D	E
	plants/3 ft^2				
alfalfa	56	55	37	70	89
birdsfoot trefoil	30	27	37	28	39
cicer milkvetch	35	54	33	63	66
red clover	55	55	67	87	82

TILLAGE AND ROW CULTIVATION EFFECTS ON RESIDUE MANAGEMENT, STAND ESTABLISHMENT, CORN PHENOLOGY, AND N AVAILABILITY TO IRRIGATED CORN [1]

J.F. Moncrief, B.J. Johnson, M.J. Wiens, and B. Sheets[2]

This study is designed to evaluate tillage and row cultivation on the N available to third year corn following alfalfa. Tillage and cultivation affected stand establishment and emergence rate. Corn grown under conservation tillage systems required more N than with a moldboard plowing system. The cultivation response by corn interacted with tillage system. Cultivation increased corn growth and N uptake most under no till conditions but also with moldboard plowing. Corn that was planted into spring discing plots resulted in a smaller increase in growth and N uptake when cultivated. This is consistent with previous years.

The objective of this study is to evaluate the effect of full width tillage and row cultivation in June on the amount of nitrogen available to corn from alfalfa. Alfalfa was killed with herbicide in the spring of 1990 and planted to corn. This is the third and final year of a three year study. The experimental design is a randomized complete block with split plots and four replications. Tillage main plots are split with four nitrogen rate subplots. Tillage systems established in the spring were: moldboard with plow packer, discing twice, and no tillage. All plots received 17 pounds per acre of urea as starter fertilizer at planting. Nitrogen was broadcast applied as urea in two equal applications at the 4-6 and 8-12 leaf growth stage of corn (table 1). Urea was irrigated in to prevent volatilization losses. Irrigation amounts and timing are presented in table 5. Thirty six pounds per acre of additional nitrogen was applied during the season with 5.99 inches of irrigation water. The resulting N rates (starter, broadcast, and irrigation water) are 53, 113, 193, and 273 pounds per acre.

Soil cover by corn residue was measured in (6" centered over the row) and between the row (the remaining 24") before and after planting but before cultivation. Corn emergence was also monitored in the same location as soil cover measurements in adjacent 10' rows at two places in each plot. These data are shown in table 2a and 2b.

Only the no till soil cover data is shown in table 2a. There was a significant but small affect of N rate on soil cover. Cultivation in 1991 reduced soil cover in the row 18%. Soil cover between the row was only reduced 6% due to the ridges left from the 1991 cultivation. The clearing discs on the planter reduced the "in row" cover from 81% and 99% before planting to 63% and 78% after planting for the cultivation and no cultivation treatments respectively in the no till plots. The ridge that was created in 1991 during cultivation helped move the residue out of the row area over winter and increased the effectiveness of the clearing discs on the planter. Disced plots had in row cover reductions due to cultivation in 1991 of only 9% after planting (table 2b).

The planter equipped clearing discs were only partially successful in removing crop residue from the row area even if ridges were built in 1991 with row cultivation. It is recommended that "in row" cover by corn residue be less than 10% to minimize the potential of detrimental effects on corn emergence and early growth.

The emergence rate date in table 2b is shown in figure 1. Emergence was delayed about ten days with the no till system compared to discing and moldboard plowing. Cultivation in 1991 had very little effect on emergence or final stand with the moldboard and disc systems. Cultivation in 1991 did increase the rate of emergence and final stand under no till conditions. Final stands were reduced significantly under no till conditions compared to moldboard and discing systems.

The dip in emergence for most treatments during the May 26th observation is the result of a frost on May 24th. The no till system without cultivation incurred the greatest drop in emerged corn. The stand reductions with other treatments were small. By May 28 corn regrowth showed very little permanent stand loss due to this frost. Frost damage elsewhere in Minnesota was correlated with high residue systems that allowed air temperatures to cool more just above the soil surface.

---

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

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

Treatment means and statistical significance are shown in tables 3, 4a, and 4b. Grain and stover yield, moisture, and stand were similar for the disc and moldboard systems. Corn grown under the no till conditions had reduced yield and increased moisture. A similar trend was found in N concentration and uptake. Corn responded up to 193 pounds of applied N. Nitrogen uptake continued to the 273 pound per acre rate.

The interaction between tillage and cultivation is shown in table 3 and figure 2. Cultivation generally increased yield, development, and N uptake. There were many interactions between cultivation and tillage system however. Reduced grain moisture due to cultivation (indicating increased development) occurred only with the no till system. There was a yield response with all systems although the response was the greatest with the no till grown corn. Corn grown with moldboard plowing and discing systems responded to row cultivation also however. Responses of corn to row cultivation have been consistently no till>moldboard>disc at this site. Cultivation of no till grown corn increased stand and harvest index also. The trends for the interaction between cultivation and tillage for N uptake followed yield trends.

There was a significant interaction between tillage and N rate for grain, stover, and total dry matter yields (figure 3). The corn grown with the no till and disc systems responded to the highest rate of N. Moldboard grown corn did not respond beyond the 193 pound per acre rate. Although the moldboard grown corn responded in N uptake to the highest rate of N the interaction was similar to the yield trends.

The amount of N applied in the irrigation is shown in table 5. The water source for this study is an open pit dug for irrigation purposes. Concentrations of nitrate increased through the season. A total of 36 pounds N per acre was applied with 5.99 inches of irrigation water. Concentrations in this pit are about three times what they were in 1991.

Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1992.

Tillage

No Till
Spring disc
Moldboard plowed with plow packer April 27
Cultivated with a Hiniker 5000 on July 18

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	Stover
Corn	May 5	35,200 seeds/A	October 15	October 16

Soil

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

Fertilizer 1990

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

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

Previous Crop | **1992 Crop**

Previous Crop		1992 Crop
Alfalfa	1987-89	Corn-Pioneer 3790
Corn	1990-92	

Fertilizer 1991

Material	Rate[3]	N	P_2O_5	K_2O	S	Zn	
Analysis	------	lb/A	------				Date Appied
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	Rate[3]	Actual N	Actual P_2O_5	Actual K_2O	Actual S	
Analysis	------	lb/A	--------			Date Applied
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 respectively.
3. The resulting N rates are: 53, 113, 193 and 273 lbs/A (36 lbs.NO_3-N/A from irrigation was added to N rates, refer to table 5).

Weed Control

2.25 pt/A (3.0 lb/A) Bladex + 2.0 pt/A (1.5 lb/A) Dual on 5/8/92.
1 qt/A 2,4-D Amine spot sprayed on 10/27/92.

Table 2a. Effect of row cultivation in 1991 on soil cover by corn residue on No Till plots.

N rate	IN ROW 5/5/92 C	IN ROW 5/5/92 NC	IN ROW 6/4/92 C	IN ROW 6/4/92 NC	BETWEEN ROW 5/5/92 C	BETWEEN ROW 5/5/92 NC	BETWEEN ROW 6/4/92 C	BETWEEN ROW 6/4/92 NC
(lb/a)								
53	76.5	98.0	63.5	76.0	87.5	89.0	74.0	80.0
113	76.5	98.5			88.0	93.5		
193	92.5	99.0			88.0	96.5		
273	80.0	100.0	63.0	80.0	88.0	97.0	67.0	82.0
mean	81.4	98.9	63.3	78.0	87.9	94.0	70.5	81.0

1.The p values for the 5/5 date for position relative to the row, cultivation, N rate, the N rate by cultivation, row position by cultivation and the N rate by cutivation by row position interactions are: .729, <.001, .084, .728, .015, .728, .305 respectively. C=cultivated NC=no cultivate

Table 2b. Effect of tillage on soil cover by corn residue, and emergence from 5-15-92 to 6-4-92 at Wadena Co[1].

Tillage	Residue[2] Date 6/4/92 In Row C	In Row NC	Bet Row C	Bet Row NC	5-15	5-17	5-19	5-21	5-26	5-28	6-1	6-4
					----------	----------	----------	plants/acre x 10^{-3}	----------	----------	----------	----------
No Till	63.2a	78.0a	70.5a	81.0a	1.7a	5.3a	8.3a	18.6a	26.2a	24.4a	27.7a	28.4a
Disc	31.5b	42.2b	36.5b	43.0b	7.7b	15.5b	18.7b	34.4b	37.1b	36.8b	36.8b	37.1b
Moldboard	7.5c	9.0c	17.2c	19.0c	13.9c	16.4b	19.1b	33.4b	35.0b	35.1b	35.3b	35.1b
Signif. (Pr > F)					.004	.016	.047	.001	.004	.004	.003	.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.

Table 3. Effect of tillage, nitrogen rate, and cultivation on corn response., 1992[1].

Treatment	Stover Moisture	Stover Yield	Grain Moisture	Grain Yield	Total D.M.	Harvest[1] Index	Final Stand	Grain Protein	Grain N	Stover N	N uptake Grain	N uptake Stover	N uptake Total
	--%--	-T/A-	--%--	-bu/A-	-T/A-		1000's Acre	--------%---------			---------lb/A---------		
Tillage (n=32)													
No Till	59.4a	1.6a	46.7a	37.8a	2.4a	0.36a	29.4a	8.6a	1.38a	.756a	24.8a	23.8a	48.6a
Disc	57.7a	1.7b	36.7b	62.4b	3.2b	0.46b	33.2b	8.0b	1.28b	.755a	39.1b	27.9a	67.0b
Moldboard	56.2a	1.8b	35.8b	68.5b	3.5b	0.46b	32.5b	8.3b	1.32b	.748a	43.9c	28.2a	72.6b
Sig. (Pr > F)	.309	.051	.001	.001	.002	.004	.016	.041	.041	.982	.001	.226	.003

1. Ratio of grain to total dry matter.

Treatment	Stover Moisture	Stover Yield	Grain Moisture	Grain Yield	Total D.M.	Harvest Index	Final Stand	Grain Protein	Grain N	Stover N	N uptake Grain	N uptake Stover	N uptake Total
N Rate lb N/A (n=24)													
53	57.6a	.74a	39.6b	25.8a	1.4a	0.44a	32.6a	7.7a	1.23a	.715a	14.7a	10.6a	25.1a
113	57.7a	1.6b	37.5a	52.3b	2.8b	0.43a	30.7a	7.2b	1.16b	.599b	28.3b	18.8b	47.1b
193	57.8a	2.1b	40.2b	70.9b	3.8c	0.43a	31.4a	8.7c	1.38c	.757a	46.1c	32.2c	78.3c
273	57.7a	2.3b	41.2b	73.1b	4.1c	0.41a	32.2a	9.5d	1.53d	.938c	52.5d	44.1d	96.6d
Sig. (Pr > F)	.999	<.001	.028	<.001	<.001	.484	.289	<.001	<.001	<.001	<.001	<.001	<.001
Cultivation (n=48)													
Cultivation	43.0a	1.7a	38.8a	63.3a	3.2a	0.46a	32.1a	8.2a	1.32a	.792a	40.5a	27.8a	68.6a
No Cultivation	41.6b	1.7a	40.5b	49.9b	2.9b	0.40b	31.3b	8.4a	1.34a	.714a	31.8b	25.7a	57.5b
Sig. (Pr > F)	.068	.627	.015	.000	<.001	<.001	<.001	.297	.297	.037	<.001	.196	<.001
Interactions													
Tillage X Cultivation (n=16)													
No Till W/	58.0	1.6	43.3	49.8	2.7	0.43	30.7	8.3	1.33	.755	32.0	23.6	55.6
No Till W/O	60.7	1.6	50.2	25.9	2.2	0.28	28.1	9.0	1.43	.757	17.7	24.1	41.8
Disc W/	57.0	1.7	36.6	65.3	3.3	0.47	33.4	8.1	1.30	.820	41.4	29.4	70.8
Disc W/O	58.3	1.8	36.7	59.4	3.2	0.45	32.9	7.9	1.26	.690	36.7	26.5	63.2
Mldbd W/	56.1	1.8	36.5	74.5	3.6	0.48	32.2	8.3	1.32	.798	48.0	30.0	78.0
Mldbd W/O	56.2	1.8	35.2	62.8	3.3	0.45	32.7	8.2	1.32	.698	40.1	26.4	66.5
Sig. (Pr > F)	.350	.848	<.001	.006	.028	<.001	.089	.017	.017	.308	.032	.524	.162
Tillage X N Rate lb N/A (n=16)													
Notill 53	58.7	.64	48.4	17.1	1.0	0.37	32.3	8.4	1.34	.826	10.4	10.6	21.0
Notill 113	62.1	1.4	44.6	31.5	2.2	0.33	27.6	7.6	1.22	.602	18.1	17.2	35.3
Notill 193	58.0	1.8	45.9	47.0	2.9	0.38	29.0	9.0	1.44	.752	31.7	26.7	58.4
Notill 273	58.6	2.1	48.5	50.5	3.3	0.34	29.4	9.5	1.52	.860	35.5	37.4	72.9
MEAN	59.4	1.5	46.8	37.8	2.4	0.36	29.4	8.6	1.38	.756	24.8	23.8	46.9
Disc 53	57.0	.67	35.8	25.8	1.3	0.47	33.1	7.3	1.17	.640	14.3	8.6	22.9
Disc 113	57.8	1.6	34.4	61.3	3.0	0.47	32.9	6.9	1.10	.641	31.9	20.7	52.6
Disc 193	59.0	2.2	37.7	76.5	4.0	0.45	31.9	8.4	1.34	.753	48.4	33.2	81.6
Disc 273	56.9	2.5	38.8	86.0	4.5	0.45	34.9	9.5	1.52	.988	61.8	49.3	111.1
MEAN	57.7	1.7	36.7	62.4	3.2	0.46	33.2	8.0	1.28	.755	39.1	28.0	67.0
Mldbd 53	57.5	.89	36.4	33.1	1.7	0.48	32.4	7.6	1.21	.707	18.8	12.6	31.4
Mldbd 113	53.1	1.6	33.5	64.1	3.2	0.48	31.5	7.2	1.16	.555	35.0	18.3	53.3
Mldbd 193	56.5	2.4	37.1	89.3	4.5	0.47	33.1	8.6	1.38	.766	58.4	36.6	95.0
Mldbd 273	57.5	2.4	36.4	83.0	4.3	0.44	32.8	9.6	1.54	.966	60.2	45.4	105.7
MEAN	56.2	1.8	35.8	68.4	3.4	0.47	32.5	8.3	1.32	.748	43.9	28.2	72.6
Sig. (Pr > F)	.225	.008	.750	.001	.003	.891	.560	.787	.787	.225	.042	.062	.001

1. Means within a column followed by the same letter are not significantly different at α=0.10 according to Duncan's Multiple Range Test. Means within the same column with the same mean are not significantly different.

Table 4a. Interaction of tillage, nitrogen rate, and cultivation on corn response., 1992[1].

Treatment		Stover Moisture		Stover Yield		Grain Moisture		Grain Yield		Total D.M.		Harvest Index		Final Stand	
		---%---		-T/A-		---%---		-bu/A-		-T/A-				Plants Ax10[-3]	
Till x N Rate (lb/A) x Cult, (n=4)															
		C[2]	NC[2]	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
NT	53	60.2	57.2	.69	.59	45.9	50.9	24.0	10.3	1.3	.83	0.44	0.29	33.3	31.2
NT	113	61.0	63.1	1.5	1.4	41.6	47.6	42.1	20.9	2.5	1.9	0.40	0.26	28.4	26.8
NT	193	54.3	61.6	1.7	1.9	42.4	49.3	59.3	34.8	3.1	2.7	0.46	0.31	31.8	26.3
NT	273	56.9	60.2	2.1	2.2	44.0	53.0	67.4	33.6	3.7	3.0	0.43	0.26	30.1	28.7
MEAN		58.0	60.7	1.5	1.5	43.5	50.2	49.8	25.9	2.6	2.1	0.43	0.28	30.7	28.1
DISC	53	56.5	57.4	.71	.63	36.2	35.4	25.8	25.8	1.3	1.2	0.46	0.48	34.6	31.5
DISC	113	57.6	58.1	1.6	1.6	34.2	34.6	65.5	57.0	3.1	3.0	0.49	0.46	33.4	32.5
DISC	193	58.3	59.6	2.2	2.2	38.0	37.4	81.7	71.3	4.1	3.9	0.47	0.43	31.4	32.4
DISC	273	55.6	58.1	2.4	2.6	38.1	39.4	88.3	83.6	4.5	4.6	0.46	0.43	34.2	35.3
MEAN		57.0	58.3	1.7	1.8	36.6	36.7	65.3	59.4	3.3	3.2	0.47	0.45	33.4	32.9
MB	53	55.0	60.0	.99	.79	37.7	35.5	34.9	31.8	1.9	1.5	0.46	0.48	31.4	33.4
MB	113	56.0	50.1	1.6	1.7	35.1	31.8	64.1	64.1	3.1	3.2	0.49	0.47	29.4	33.7
MB	193	55.4	57.6	2.5	2.3	35.8	38.4	93.2	85.4	4.7	4.3	0.47	0.47	34.3	32.0
MB	273	58.0	57.3	2.3	2.5	37.9	35.0	96.0	67.0	4.5	4.1	0.50	0.37	33.8	31.7
MEAN		47.7	50.3	1.8	1.8	36.5	35.2	74.5	62.8	3.5	3.3	0.48	0.45	32.2	32.7
SIG. (Pr> F)		.075		.747		.718		.226		.685		.808		.138	

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

Table 4b. Interaction of tillage, nitrogen rate, and cultivation on various corn response at Wadena Co., 1992[1].

Treatment		Grain Protein		Grain Nitrogen		Stover Nitrogen		N uptake Grain		N uptake Stover		N uptake Total	
		---------------%---------------						-----------lb/A-----------					
Till x N Rate (lb/A) x Cult, (n=4)													
		C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
NT	53	7.7	9.0	1.23	1.44	.880	.773	13.8	7.0	12.0	9.2	25.8	16.2
NT	113	7.4	7.9	1.18	1.26	.573	.631	23.6	12.6	16.8	17.7	40.4	30.3
NT	193	8.9	9.0	1.43	1.44	.763	7426	40.0	23.4	26.1	27.3	66.1	50.7
NT	273	9.1	9.9	1.45	1.60	.836	.885	46.0	25.0	36.4	38.4	82.4	63.4
MEAN		8.3	9.0	1.33	1.43	.755	.757	32.0	17.7	22.8	23.1	53.8	40.2
DISC	53	7.3	7.3	1.16	1.17	.723	.558	14.1	14.4	10.3	6.8	24.4	21.2
DISC	113	7.2	6.5	1.15	1.04	.736	.546	35.8	28.1	23.8	17.7	59.6	45.8
DISC	193	8.6	8.1	1.38	1.30	.788	.722	53.0	43.7	33.7	32.7	86.7	76.4
DISC	273	9.4	9.6	1.50	1.54	1.04	.936	62.8	60.7	50.0	48.6	112.8	109.3
MEAN		8.1	7.9	1.30	1.26	.820	.690	41.4	36.7	29.4	26.5	70.9	63.2
MB	53	7.7	7.4	1.24	1.19	.778	.636	20.1	17.9	15.0	10.1	35.1	28.0
MB	113	7.1	7.3	1.14	1.18	.561	.549	34.1	35.8	17.8	18.9	51.9	54.7
MB	193	8.6	8.6	1.38	1.38	.812	.720	60.9	55.8	39.9	33.3	100.8	89.2
MB	273	9.6	9.6	1.54	1.53	1.04	.889	69.8	50.8	47.4	43.5	117.2	94.3
MEAN		8.3	8.2	1.32	1.32	.798	.698	48.0	40.1	30.0	26.4	76.2	66.5
SIG. (Pr> F)		.466		.466		.956		.417		.942		.681	

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

Table 5. Irrigation water and nitrate amounts in the Irrigation Center pit for the 1992 growing season.

Date	6/6	6/10	6/13	7/1	7/23	7/28	7/30	8/4	8/14	8/21	**Total**
Amount (in.)	.45	.24	.65	.60	.88	.37	.45	1.15	.70	.50	**5.99**
NO_3 Conc. (ppm)	23.5	23.7	21.9	2[illegible].1	21.8	29.7	23.7	29.7	34.6	42.3	
NO_3-N (lbs/Acre)	2.39	1.28	3.22	2.86	4.34	1.98	2.41	7.72	5.47	4.78	**36.4**

Fig. 1a. Effect of Tillage and row cultivation in 1991 on corn emergence at Staples, Mn. 1992

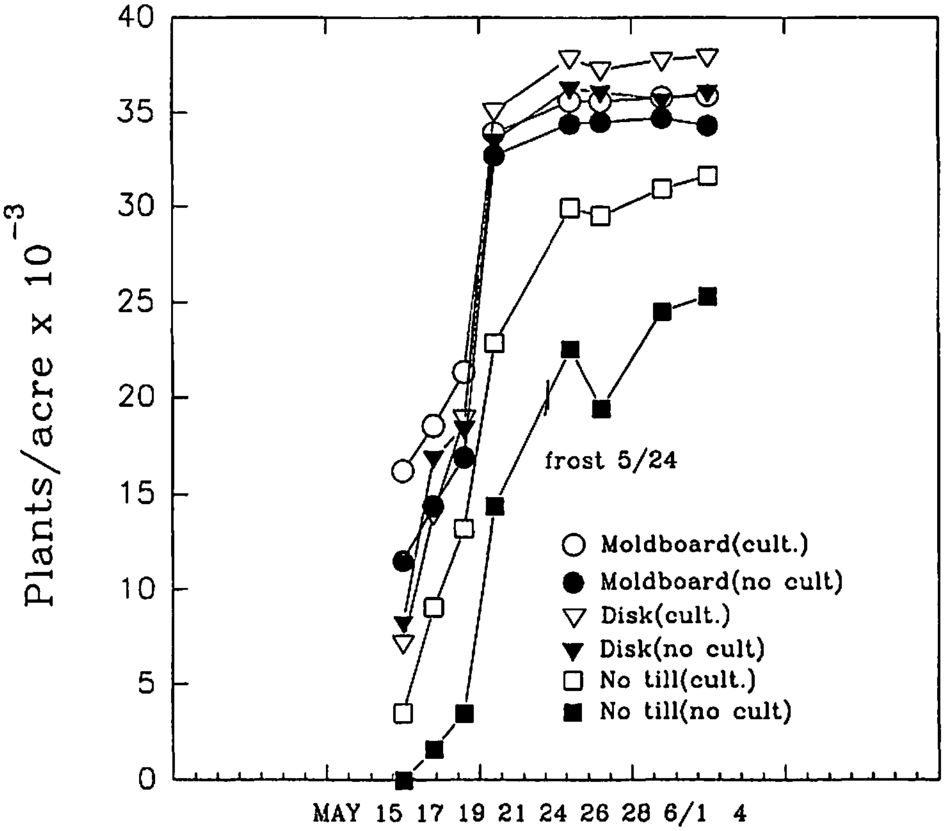


Fig. 1b. Growing degree days for 1992 growing season.

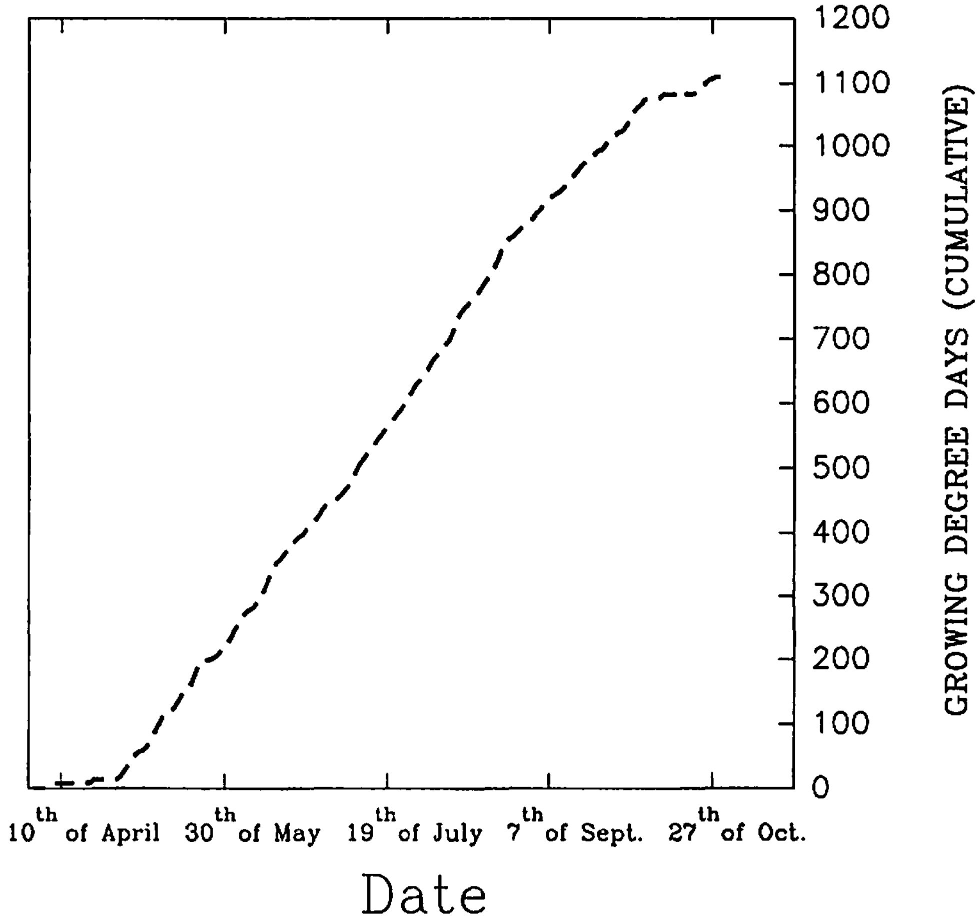


Fig. 2a. Grain yield and moisture response to tillage and cultivation treatments. Staples, Mn, 1992.

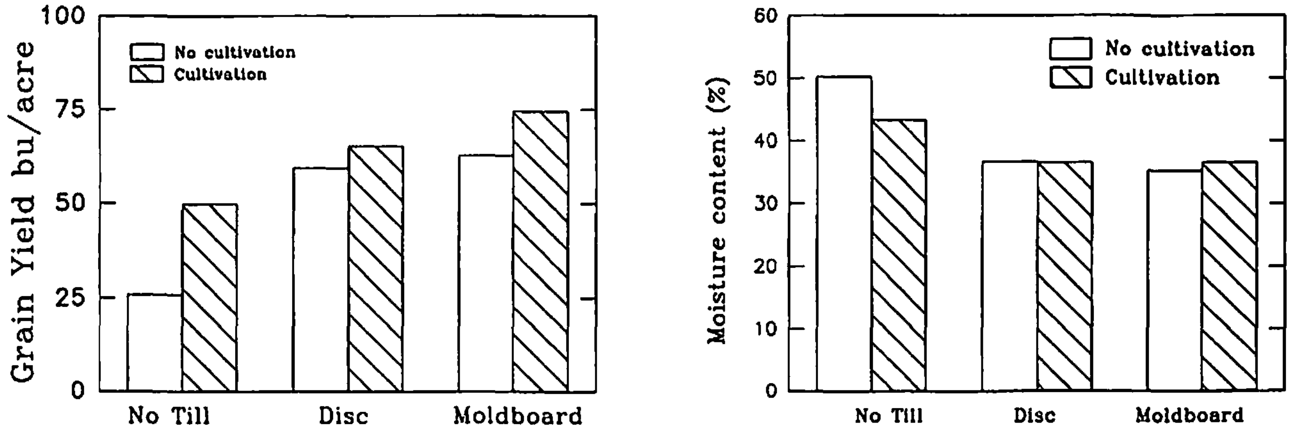


Fig. 2b. Barren and Total plant number response to tillage and cultivation treatments, Staples, Mn, 1992.

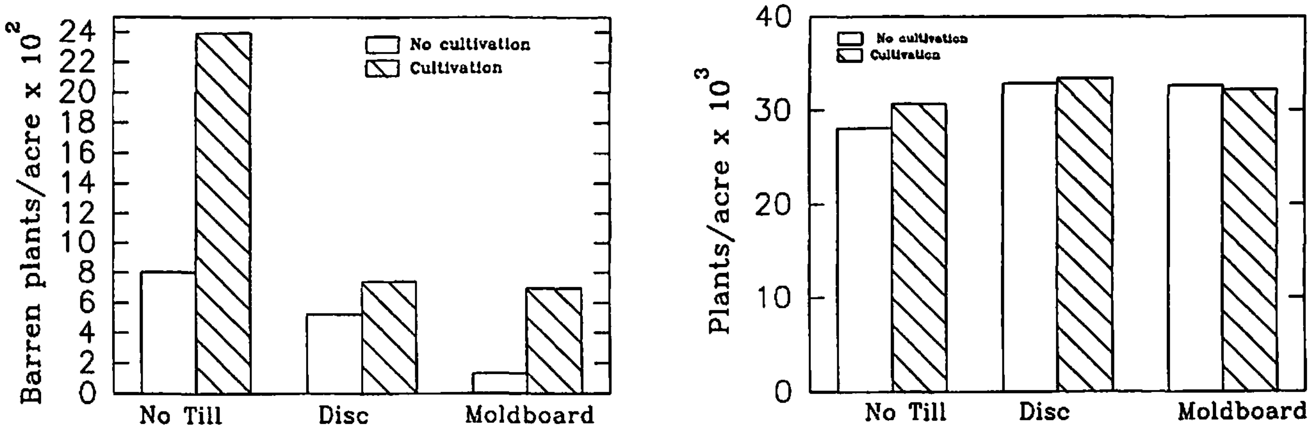


Fig. 2c. Total dry matter and harvest index response to tillage and cultivation treatments, Staples, Mn., 1992

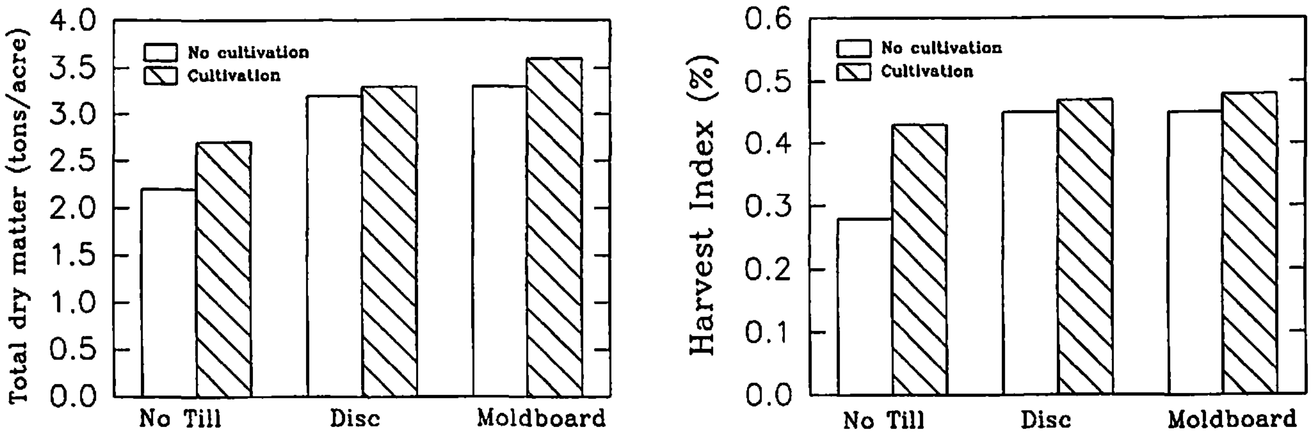
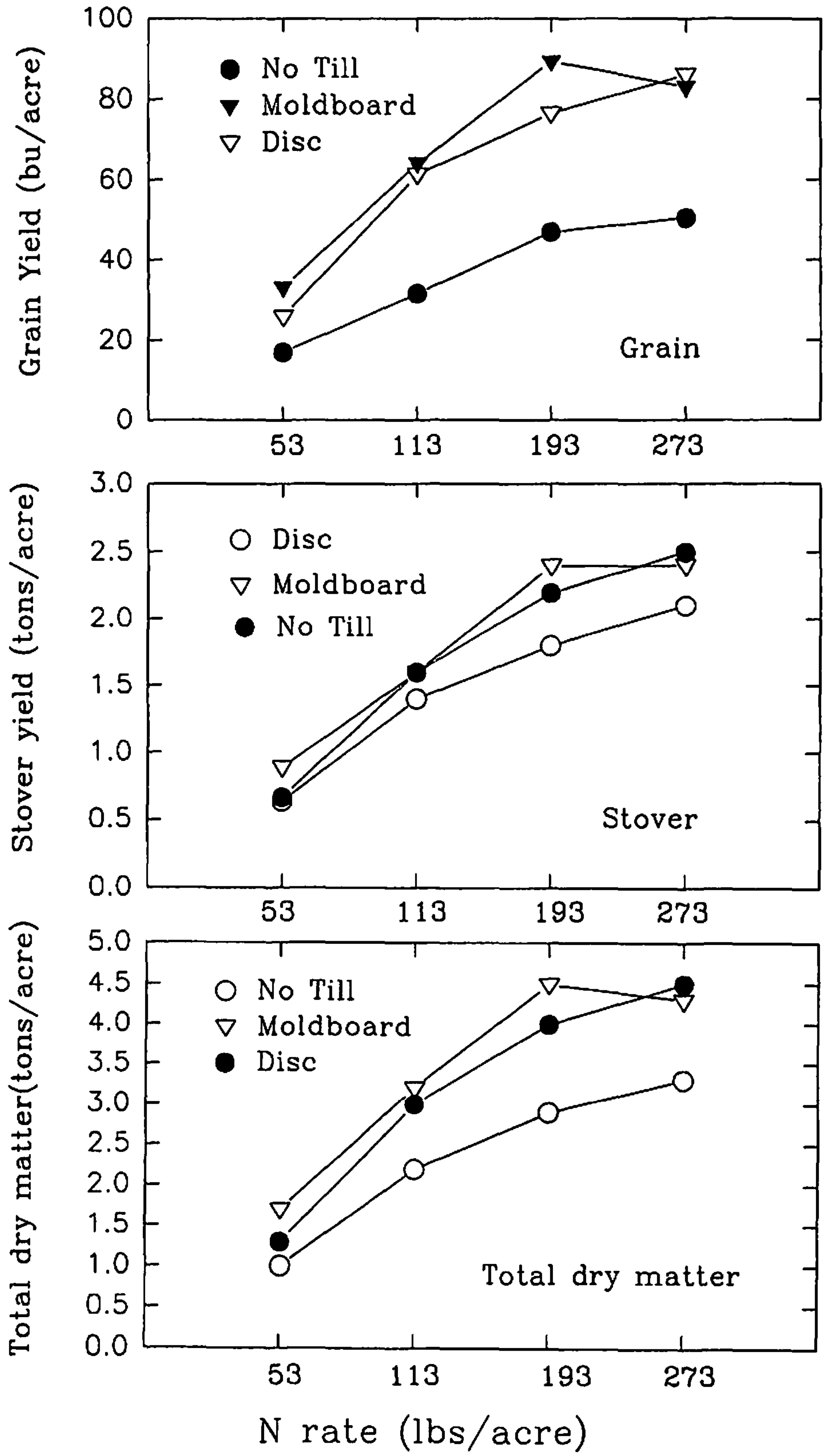


Fig. 3 Yield responses to four nitrogen rates of urea (split application) at Staples, Mn. 1992



Potato Hill Shape Influences on Yield, Infiltration, and Nitrate Concentrations

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

Abstract

Three types of hilling systems were investigated to determine the possible effects on the Russet Burbank potato. No significant differences were noted in growth, yield, and infiltration. The major finding was that soil water nitrate concentrations in the furrows were approximately three times higher than in the rows. In addition calculated water infiltration was often twice as high in the row as compared to the furrows. Based on these discoveries further investigation of the preferential leaching process is planned.

Introduction

Recently hill shape has been discussed by growers as having a possible effect on potato yields. This study explored some effects of hill shape on the Russet Burbank potato. In order to evaluate this two hilling types were studied: a pointed shape, a more rounded type, and a no-hill control. Plots were located at the Staples Irrigation Center, which is in a high potato production region.

Methods

Nine plots were laid out consisting of three blocks and three hilling treatments (POINT, ROUND, and NO-HILL). Each plot had five 25 ft. rows spaced 36 in. apart running east to west, giving an overall dimension of 15 ft. by 25 ft. Russet Burbank seed pieces were planted 12 in. apart giving a plant density of 3.6 plants/m^2. Soil at the site was a Verndale sandy loam, with 0 to 2 percent slopes. Previous crops were lupines and peas. The site was moldboard plowed, and packed prior to planting.

Planting occurred on 5 May, with emergence on 27 May. Ammonium Nitrate was applied as a nitrogen source, in three splits of approximately 53 lb. N/A for a total of 160 lb. N/A. These were banded in at planting, just prior to emergence (24 May), and at hilling (8 June). The POINT treatment hills had the geometry of a triangle with approximate dimensions of base 90 cm and height 22 cm. The ROUND treatment hills had a geometry of a trapezoid with approximate dimensions of base 80 cm, top 40 cm, and height 13 cm. No hilling was done on the NO-HILL treatment. Herbicides applied were Treflan, on 7 May, pre-emerge at a rate of 1.2 Pt/A incorporated, and Dual at 3 Pt/A + Lorax at 2 Pt/A on 10 May. Bravo fungicide was applied on 6, 13, and 20 July. In addition Sevin insecticide was applied periodically to control the presence of Colorado Potato Beetle (*Lepitnotarsa decemlineata*).

A weather station was installed 40 ft to the north of the third series. Measurements of wind speed, wind direction, solar radiation, air temperature, relative humidity, and precipitation were taken every 10 s and either averaged or totaled (as appropriate) every hour and stored on a Campbell Scientific 21x datalogger. An additional tipping bucket rain gauge was installed in the alley between the second and third series to monitor irrigation water.

A Tektronix® 1502B Time Domain Reflectometry (TDR) unit was installed in conjunction with the weather station. Wave guides were buried in plots 201, 301, and 302, each corresponding to a different hill type. Guides were buried 5 and 15 cm from the surface in the row and furrow, and then midway in between in the shoulder. The TDR unit, coupled with the datalogger monitored volumetric water contents every 15 min.

Pan lysimeters were installed in each plot on 7 July. They were placed beneath the row and furrow at the top of the argillic horizon (approximately 20 in. deep). In addition, suction samplers were installed in the first series so that soil water could be sampled during unsaturated flow. They too were positioned in the row and furrow, approximately 18 in deep from the average soil level. Roughly 2.5 in of precipitation were necessary to get a sample in the event samplers. Samples were taken from the suction samplers corresponding to irrigations.

Leaf area index (LAI) readings were taken every 5 to 10 days using a Licor LAI-2000. With this the growth and progress of the plants was monitored.

Irrigation was scheduled using the Checkbook method, and was handled by the staff of the Irrigation center. Fixed standpipe irrigation was used for the study. In addition to standard waterings three large irrigation events were applied late in the year after the plants were mostly dead, so that additional data from the event samplers could be collected.

Due to early blight the plants began to die off on 6 August, and were approximately 95 % dead by 26 August. Because of this a defoliant was not needed to kill the plants for harvest. Potatoes were harvested on 17 September using a single row lift. Tubers were then separated into size classes, with special attention paid to green and damaged potatoes which were inherent to the no hill plots.

Results

Yield. With the growing season cut short from early blight, it is hard to compare yield data to normal yields. The main thing that can be done is to look at the treatments versus one another. The total yields of grade 1 potatoes was very low for all treatments, but there was not significant difference between the treatments. This is the same for all grades with the exception of misshapen, where the pointed and flat treatments differed significantly. Since the relative yields of misshapen potatoes was rather small it is not of interest as to why this was. Total yields, while low, were respectable and showed no significant difference between treatments.

Table 1. Effect of potato hill shape on marketable yields.

	MARKETABLE	TOTAL
	----------cwt./A--------	
POINT	300	405
ROUND	269	380
FLAT	259	379

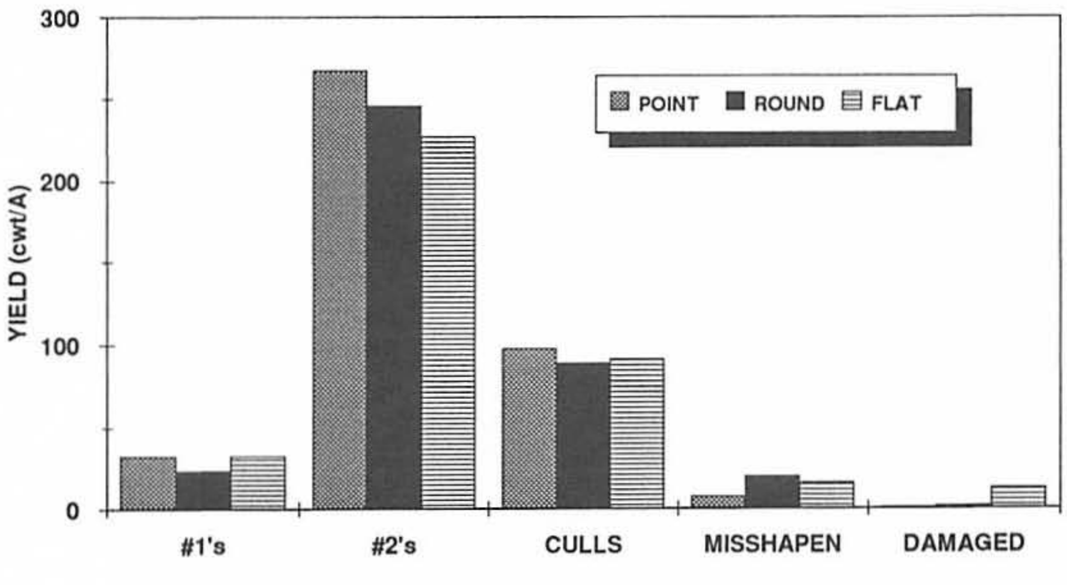


Figure 1. Effect of potato hill shape on graded yields.

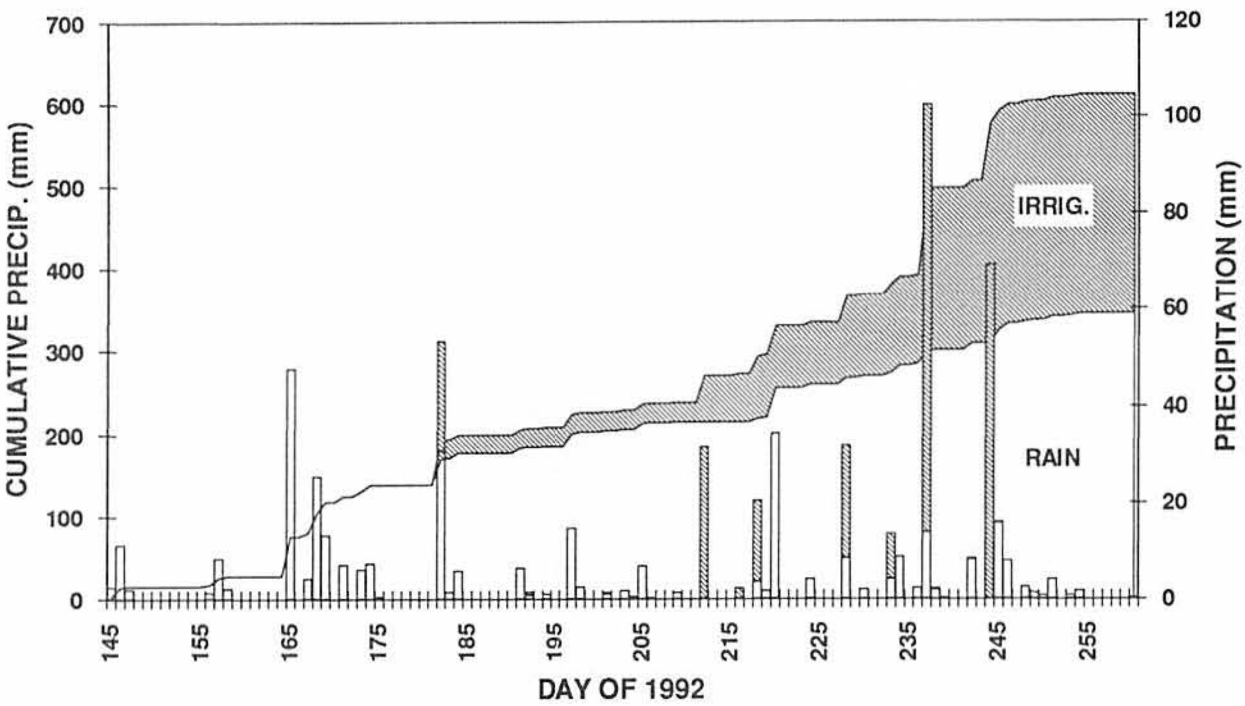


Figure 2. Rain and irrigation summary.

Infiltration. Figure 2 summarizes the rain and irrigation for the growing season. We calculated changes in soil water storage over the 20 cm depth during precipitation using our TDR data. If drainage past the 20 cm depth was negligible, then we can interpret the change in soil water storage as the amount of infiltration under each row position. We found infiltration under the row was consistently greater than under the furrow for all hilling treatments and days. Table 2 shows infiltration data for selected days for the NO-HILL and POINT treatments. Early in the growing season and prior to hilling (Day 156), infiltration in the row was slightly greater than in the furrow. At peak growth (Day 212), infiltration in the row was twice as much as in the furrow. Late in the growing season when plants were dying (Day 228), infiltration in the row was approximately 1.5 times infiltration in the furrow. Mass balance of water was within 25% of total precipitation using this analysis.

Table 2. Differences in soil water storage according to row position and hilling treatment on selected days.

		NO-HILL			POINT		
Day of 1992	Precipitation	Row	Shoulder	Furrow	Row	Shoulder	Furrow
		mm					
156	13.5	17.0	15.3	14.8	15.3	15.3	11.2
212	31.8	31.6	25.5	15.6	32.5	26.2	15.2
228	32.0	29.0	25.8	18.4	27.5	24.8	16.2

Nitrate Concentration. The event samplers tended to be very sporadic in capturing samples. And since only three plots contained suction samplers, soil water nitrate concentration could not be compared by hilling treatment. The data did however show a very notable trend. This is that the nitrate concentrations of samples from the furrow tended to be roughly three times as great as samples taken from the row. this trend continued through the year, until after the plants had been long dead. At that time the concentrations of samples from the row began to rise until on the last sampling date concentrations in the row were higher than in the furrow. This was possibly caused by the breakdown of root material in the row, and seems logical since 20 to 30 days had passed since the plants were approximately 95% dead. It should be noted that these samples were the results of intense irrigation, and the concentrations are relatively low compared to those obtained earlier in the year.

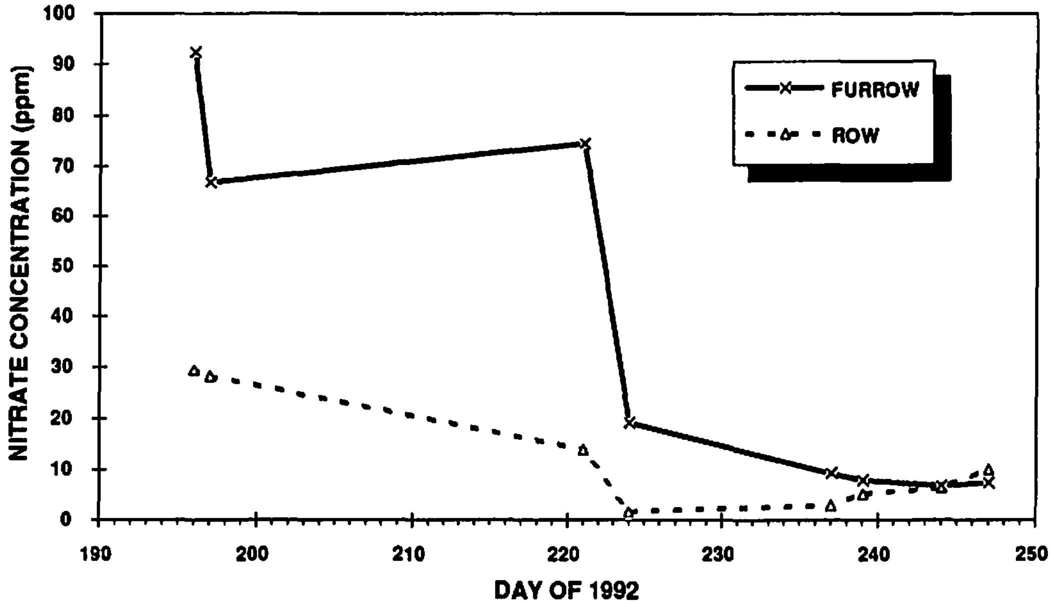


Figure 3. Soil water nitrate concentrations at top of argillic horizon.

Leaf Area Growth. Growth of the plants (as measured using LAI) for each treatment followed each other quite closely. A drop in LAI associated with day 198 (16 July) can be attributed to a storm which lodged many plants. The plants did recover, and grew through day 211 (29 July). This corresponds closely to the day in which the first symptoms of early blight are noticed (day 219). As the disease progresses the LAI falls rapidly, until the latter readings are mostly stems. the last reading was taken on day 239 (26 August), the day on which an estimated 95% of the plants were dead.

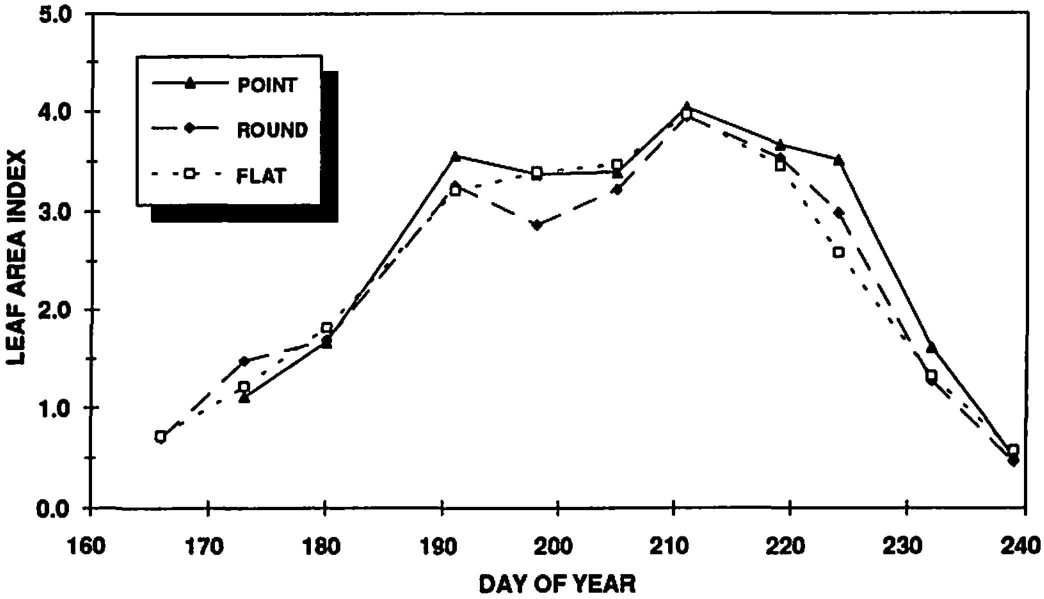


Figure 4. Effect of potato hill shape on leaf area index. (n=3)

Discussion and Conclusions

Even though no major differences were found between treatments in any of the measured quantities, hill shape should not be discounted as having no effect on some properties of potato production. Since the number of repetitions was rather small, one might want to investigate the effects of hill shape more extensively, possibly including more sites, before any real solid conclusions could be drawn. Something to consider about the hilling treatments is that even though little difference was noted in yield and growth characteristics the flat treatment is more difficult to harvest, causes some damage to tubers, and requires more power from the harvester to operate. These factors all lead to decreased profits. Therefore it is not advisable that unhilled potatoes be thought of as equal to hilled ones.

The most interesting aspect of our research from 1992 is that soil water nitrate concentrations immediately below the rooting zone differ markedly between the furrow and the row. This combined with the infiltration findings adds an interesting twist to the topic of preferential flow which is currently getting much attention. Since the water budget does not equal out, our measurements may only be used to hypothesize what happened. It is our feeling that the missing water can be accounted for from the storage above the wave guides, as well as the water necessary to wet the plants. Increased flow in the row is most likely caused by the "funneling" of water down the stems of the plants. Differences in nitrate concentration may be caused by fertilizer placement, or by uptake by the roots. The implications of our findings are that even though more water is entering the profile in the row there is still more nitrate flux in the furrow. The impacts of this phenomenon may lead to a greater reliance on fertigation which might minimize nitrogen loss to the furrow. Because of the potential impacts on management we will be using the data from this study to launch a more extensive look at the leaching process as it applies specifically to position underneath the plant canopy.

CORN NITROGEN RATE STUDY

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

ABSTRACT: A nitrogen rate study was initiated in 1990 on an irrigated sandy loam soil on the research area at the Staples Irrigation Center. The study is a multi-year ongoing research project to determine the optimum yield of irrigated corn in response to applied N, and intensive management.

Introduction: Production of high yields of corn on coarse textured soils with optimum use of supplemental moisture from irrigation is a common practice. These soils are subject to leaching of soluble constituents, especially nitrates. This study evaluates the response of corn to various rates of applied nitrogen.

Experimental: A Pioneer hybrid 3861 was seeded with a Duetz-Allis Model 385 four-row planter in 30-inch rows on April 30, 1992. The rate of planting was 32,000 seeds per acre. Nitrogen as urea was applied in three equal applications beginning one month following planting, one month later, and the last increment was applied just prior to tassel. Nitrogen was applied at the 60, 90, 120, 150, 180, 210, and 240 pounds of N per acre.

Discussion: The 1992 growing season was unseasonable cold. Yields were disappointingly low. Highest yield resulted from 120 pounds of applied nitrogen.

Table 1. N rates, corn yield and grain moisture. Staples 1992.

N Treatment	Grain Yield[1]	Grain Harvest Moisture
lbs/A	bu/A (15.5% H_2O)	%
0	39.8	30.2
60	83.0	26.7
90	96.6	27.0
120	112.5	25.8
150	106.1	28.3
180	102.5	29.0
210	103.0	28.2
240	112.1	27.0

[1] Average of four replications

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

LUPIN BEAN STUDY

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

ABSTRACT: Organic residues were added to the soil prior to planting and incorporated to measure impact of an improved soil environment on lupin production. Alfalfa meal at the rate of 3.3 tons/A and aged turkey litter at the rate of 10 tons/A were applied uniformly over the designated plots in a randomized design with four replications. Seed corn maggots devastated the plots receiving organic additions. Lupins should receive a seed corn maggot treatment at planting as a precautionary measure.

Table 1. Lupin seed yield, population, and treatments, Staples, 1992.

Treatment	Yield Bu/A @ 13.5% H_2O	Stand Count x 1000
Turkey litter @ 10 T/A	26.8	112
Alfalfa meal @ 3.3 T/A	33.7	183
Control	36.6	248

[1/] Regional Manager, TVA; Research Plot Supervisor, Staples Irrigation Center; Assistant Scientist; Junior Scientist, University of Minnesota, respectively

CORN SOYBEAN AND LUPIN ROTATION

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

ABSTRACT: A rotational study was initiated in 1992 with lupins, soybeans, and corn. Corn follows either lupins or soybeans in the rotation.

Table 1. Corn yields and grain moisture from plots where previous crop was soybeans or lupins, Staples 1992.

Previous Crop	Grain Yield Bu/A @ 15.5% H_2O	Grain Moisture % H_2O
Lupins	131.0	24.6
Soybeans	133.8	27.0
Corn	112.5*	25.8

* From continuous corn plot, nitrogen rate study.

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

WATER QUALITY STUDIES

H. Meredith and Mel Wiens[1/]

ABSTRACT: For the past several years, a limited quantity of irrigation water samples have been collected and analyzed. Samples were taken from pumping wells, streams, and dug pits. The purpose of this study is to monitor the contents of dissolved nutrients from the irrigation water and to use this information as a guide to measure the long-term effects of irrigation.

The primary nutrients of significance are calcium and magnesium. Sodium, of great concern in arid regions where irrigation is common, is uncommonly low in Minnesota water used for irrigation.

Table 1. Analysis of Irrigation Water in Proximity of Staples, MN - 1992

	PPM or Mg/L							
Lab #73	N	P	K	Ca	Mg	Na	S	Conductivity from HOS/cm
1	7.7	.16	23.3	41	12	9	7	375
2	0.5	.16	1.0	45	12	5	5	234
3	0.5	.17	1.7	95	28	4	1	369
4	0.5	.30	2.3	76	29	17	1	390
5	0.5	.16	2.3	74	27	13	1	362
6	17.0	.08	2.3	156	47	22	17	835
7	0.5	.34	1.2	49	15	11	1	268
8	0.5	.07	0.9	91	28	4	8	389
9	0.5	.16	1.6	76	25	23	8	387
10	0.5	.30	2.1	99	32	10	1	485
11	0.5	.40	5.0	72	38	52	1	525
12	0.5	.16	.7	-	-	185	14	645
13	0.5	.27	2.5	99	32	7	6	478
14	0.5	.16	2.8	90	25	7	4	444
15	4.7	.07	2.3	84	25	4	6	444
16	3.0	.10	1.8	197	64	30	23	1100
17	0.5	.11	2.1	94	28	8	10	460
18	3.1	.18	1.6	51	13	32	3	350
19	13.5	.15	16.9	120	42	14	9	695
20	0.5	.12	2.0	93	20	5	8	363
21	0.5	.29	4.8	27	20	102	1	577
22a	0.5	.13	4.4	63	18	28	1	458
22b	0.5	.28	2.7	57	28	15		327
23	7.9	.07	9.1	77	27	10	2	468
24	0.5	.18	2.4	64	27	10	1	475
25	0.5	.35	2.3	80	33	24	9	527
26	0.5	.08	2.4	91	27	4	9	497
27	0.5	.66	2.0	72	30	6	1	360
28	0.5	.13	2.1	119	19	5	14	600
29	0.5	.20	2.4	95	29	11	3	550
30	1.0	.09	2.5	78	33	5	20	393
31	0.5	.23	3.0	84	30	8	7	319
32	0.5	.22	3.2	72	32	11	13	332
33	0.5	.29	3.3	70	36	14	1	355
34	0.5	.30	3.0	76	32	10	1	307
35	0.5	.17	2.5	70	28	4	1	349
36	0.5	.24	1.4	63	8	4	1	267
37	7.7	.13	1.7	88	23	3	4	284
38	13.4	.09	1.9	92	26	3	7	472
39	10.8	.08	1.9	65	28	4	12	404
40	-	-	-	-	-	-	-	-
41	3.5	.13	1.8	74	19	2	4	377
42	5.8	.11	2.1	55	17	7	6	278
43	0.5	.10	1.4	51	11	3	4	184
44	7.2	.10	2.9	65	21	4	14	346
45	0.5	.14	1.6	65	19	3	12	280
46	1.8	.09	2.0	68	20	4	16	309
47	1.3	.10	2.0	74	25	5	4	265
48	0.5	.14	2.2	106	36	5	6	533
49	0.5	.22	2.6	69	31	4	2	437
50	12.2	.07	4.5	26	29	17	5	340

SOUTHERN EXPERIMENT STATION
1101 WEST ELM
WASECA, MINNESOTA

WEATHER DATA - 1992

Month	Period	Precipitation 1992	Precipitation Normal[1/]	Avg. Air Temp. 1992	Avg. Air Temp. Normal[1/]	Growing Degree Units 1992	Growing Degree Units Normal[1/]
		------ inches -----		------- °F ------			
January	1-31	2.26	0.96	21.2	10.2		
February	1-29	1.29	0.97	27.0	16.1		
March	1-31	3.34	2.28	32.5	29.1		
April	1-30	3.18	2.97	41.7	43.1		
May	1-10	0		60.5		133.5	
	11-20	1.62		62.7		135.0	
	21-31	1.32		57.7		122.0	
	Total	2.94	3.65	60.2	57.7	390.5	327
June	1-10	.25		65.8		162.5	
	11-20	3.04		71.3		208.0	
	21-30	.59		61.6		127.5	
	Total	3.88	4.11	66.2	67.1	498.0	515
July	1-10	2.52		66.3		165.0	
	11-20	.57		65.3		153.0	
	21-31	1.20		62.7		144.0	
	Total	4.29	4.21	64.8	71.3	462.0	646
August	1-10	3.24		69.2		188.5	
	11-20	1.08		62.3		132.0	
	21-31	1.69		64.5		165.5	
	Total	6.01	4.20	65.3	68.4	486.0	567
September	1-30	3.23	3.56	58.6	59.9	345.5	316
October	1-31	4.24	2.45	47.2	47.9	0	31
November	1-30	3.86	1.72	30.4	32.3		
December	1-31	1.44	1.35	19.5	16.2		
Year	Jan-Dec	39.96	32.43	44.6	43.4	2182.0[2/]	2402
Growing Season	May-Sep	20.35	19.73	63.0	64.9	2182.0	2371

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

Notes:
1) Eighth highest annual precipitation in 78-year record.
2) Highest 24-hour precipitation on October 7 - - - 2.18".
3) Growing degree units 9% below normal for season, 4th lowest since 1950.
4) Coldest July in 78-year record.
5) Highest temperature on May 2 - - - 91°F.
6) Only 6 days of ≥90°F.
7) Last spring frost - - - May 26.
8) First fall frost - - - September 29.

1992 Soil Moisture

0-5′ Profile, Webster Clay Loam

Continuous Corn

Southern Experiment Station, Waseca, MN 56093

Depth	4/15	5/1	5/18	6/1	6/15	6/30	7/15	7/31	8/14	8/31	9/14	10/1	10/16	10/30	11/16
inches	inches available water in zone														
0 - 6[1]	.73	.95	.85	.97	.57	.50	.86	.71	.92	.83	.99	.72	.95	.80	1.06
6 - 12	.68	.79	.83	.83	.51	.43	.56	.44	.65	.49	.49	.47	.71	.67	.72
12 - 18	.90	.82	.83	.81	.58	.68	.68	.41	.69	.83	.81	.70	.77	.69	.80
18 - 24	.61	.66	.69	.64	.44	.54	.58	.39	.71	.56	.63	.57	.61	.63	.75
24 - 36	1.54	1.79	1.84	1.77	1.12	1.52	1.47	1.34	1.57	1.36	1.72	1.35	1.93	1.90	2.08
36 - 48	2.51	2.75	3.05	2.79	1.92	2.18	2.29	2.16	2.27	2.09	2.41	1.91	2.43	2.54	2.69
48 - 60	2.16	2.16	2.62	2.82	1.44	1.49	1.64	2.14	2.16	1.79	1.95	1.31	1.54	1.65	2.64
Total available water in 0-5′ profile (inches)	9.13	9.92	10.70	10.63	6.58	7.33	8.08	7.59	8.98	7.94	8.99	7.03	8.93	8.88	10.76
% of Capacity[2]	83	90	97	96	60	66	73	69	81	72	81	64	81	80	97

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

[2] Assuming 11.05" field moist capacity.

Available soil moisture in the five-foot profile was plentiful throughout 1992. Lowest soil moisture levels occurred in June prior to the onset of the cool weather and on October 1 after a 3-wk dry period and some warm temps in September. Soil moisture conditions going into 1993 are saturated with the profile being 97% full in mid-November.

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

Waseca, 1992

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

ABSTRACT: No tillage (NT) is thought to increase infiltration and, therefore, should increase the amount of water percolating through the soil compared to conventional tillage. This long-term study is being conducted to determine if greater amounts of NO_3-N and pesticides are being lost to tile drainage water with NT compared to moldboard plow (MP) tillage. Rainfall during 1992 was 7.5" above normal and tile flow was plentiful. The slightly higher tile drainage with NT was offset by higher NO_3-N concentrations with the MP system. Nitrate-N losses to the tile lines were 20% higher for the MP system. Corn yields, N uptake, and N removal in the grain were all significantly higher for MP compared to NT. Grain yield was 47% less with NT. Low but equal amounts of NO_3 remained in the 8-foot soil profile in November with the two tillage systems.

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

EXPERIMENTAL PROCEDURES

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

In the fall of 1981, eight plots with the most uniform tile flow rates over the 1975-81 period were selected. Two tillage treatments (fall moldboard plow and no tillage) were replicated four times and randomized over the previous plot histories. Beginning in 1990, three replications and 6 plots were used. Corn was grown on these plots in 1982 through 1990. The stalks were chopped in October, 1990 and moldboard plots plowed.

On April 30, 180 lb N/A as ammonium nitrate was broadcast applied to the surface of all plots. The moldboard treatment was then field cultivated. Corn (Dekalb 547) was planted on May 4 at a population of 27700 plants/A with a John Deere Max-Emerge planter equipped with ripple coulters. Starter fertilizer was not used because of the high soil tests. Counter was applied at 1 lb (ai)/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3-1/2 lb/A) and Bladex (3 lb/A) applied May 8. Weed and insect control were excellent. Percent surface residue was measured on April 6 and averaged 13 and 98% for the MP and NT systems, respectively.

The leaf opposite and below the ear was taken from 10 randomly selected plants per plot at silking (MP = July 31 and NT = August 10) and was analyzed for N. Silage yields were taken at physiological maturity by hand harvesting 40' of row from each plot.

Grain yields were taken by combine from 2 - 45' rows. Tile line flow began on March 2 and continued with some flow each month until Nov. 25. 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, 1992. Fifteen soil cores were taken on Sept. 25 from each plot in 0-2", 2-4", 4-6", 6-9" and 9-12" layers, composited by depth, and analyzed for total N.

RESULTS

Yields, N uptake by the whole plant (silage), and N removal in the grain were all significantly higher for the moldboard plow (MP) system compared to no tillage (NT) (Table 1). This was the seventh year of eleven where MP yields were significantly higher. Grain moisture at harvest was significantly higher with NT. Leaf N and grain N concentration were not affected by tillage (P = 90% level). Final population was slightly higher with MP.

Precipitation during the growing season and for the year was 0.6 and 7.5" above normal, respectively. Consequently, tile flow was higher than usual and averaged about 27% higher with NT compared to MP tillage (Table 2). Flow-weighted NO_3-N concentration for the season averaged 52% 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 21% and 26% of the fertilizer N added for NT and MP, respectively.

---

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

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

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1992.

Tillage System	Final Population	Leaf N	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	26.1	2.40	6.22	129.9	120.9	1.44	82.6	31.0
No Tillage	24.3	2.38	4.52	95.1	63.8	1.59	48.1	37.9
Signif. Level (%):[1/]	97	10	97	94	99	84	97	99
CV (%) :	1.6	7.7	7.3	10.	4.8	5.6	12.	2.2

[1/] Probability level of significance.

Table 2. Influence of tillage system on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1992.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in.	ppm	lb/A
		Moldboard plow	
March	4.09	16.1	14.33
April	3.45	14.1	10.60
May	0.86	13.5	2.48
June	2.04	13.2	6.09
July	0.27	12.4	0.72
August	0.33	10.4	0.87
September	0.22	10.9	0.52
October	2.18	10.1	5.00
November	2.33	10.3	5.33
Total	15.77	Avg = 12.8	45.94
		No tillage	
March	3.55	8.6	6.94
April	4.08	7.5	6.76
May	1.42	7.1	2.21
June	2.87	8.4	5.40
July	0.92	10.1	2.03
August	1.12	11.4	2.84
September	0.37	9.6	0.86
October	2.58	8.7	5.13
November	3.15	8.7	6.28
Total	20.06	Avg = 8.4	38.15

Residual NO_3-N in the soil profile at the end of the 1992 growing season showed equal amounts of N remaining in the two systems (Table 3). The largest differences between the two tillage systems occurred in the 1 to 3' zone where more NO_3 accumulated with MP. These results are different from previous years where MP tillage consistently contained higher amounts of residual NO_3-N. The low amounts found in 1992 probably reflect the wet conditions and higher drainage losses in the past two years and the cool temperatures in 1992.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in Oct., 1992.

Profile depth	Tillage System: Mb. Plow	Tillage System: No Tillage
feet	NO_3-N (lb/A)	
0-1	8.7	8.9
1-2	6.7	3.3
2-3	6.8	2.8
3-4	7.7	8.1
4-5	9.6	9.7
5-6	9.9	9.5
6-7	10.3	10.5
7-8	9.1	12.1
Total (lb NO_3-N/A 0-8')	68.7	65.1

Soil samples analyzed for total N indicated higher N concentrations in the top 4" with NT, but no large differences between the two tillage systems at depths below 4" (Table 4). Assuming a bulk density of 1.2 g/cc in the 0-6" depths and 1.25 g/cc in the 6-12" depth, NT contained 218 lb more total N/A than did the MP tillage system. This is approximately the difference in the amount of N removed in the grain between the two tillage systems (Table 5).

Table 4. Total N in the 0-12" soil layer as affected by tillage system.

	Tillage	
Depth	MP	NT
inches	%	
0 - 2	.243	.285
2 - 4	.246	.255
4 - 6	.250	.253
6 - 9	.235	.223
9 - 12	.165	.168

ELEVEN-YEAR SUMMARY

The cumulative totals for the 11-year period (1982-1992) are shown in Table 5. Corn yields over this period averaged 21.8 bu/A better with moldboard plow tillage. Approximately 23% more N has been removed in the grain with moldboard plow tillage. This has been due to both higher yields and slightly higher grain N concentrations with the moldboard tillage system some years. As a result an equivalent of 51 and 42% of the applied N has been removed in the grain by the MP and NT systems, respectively. Even though total water flow through the tile lines was 13% higher with NT compared to MP tillage, 5% more NO_3-N was lost via the tile lines with MP. This was due to higher NO_3-N concentrations, especially in the last three years. This small difference is considered to be insignificant when considering tile flow variability among the plots. The equivalent of 20 to 21% of the fertilizer N applied to these plots has been lost to tile drainage over this 11-year period.

Table 5. Cumulative effects of the two tillage systems over the 11-year period.

	Tillage System	
Parameter	Mb. plow	No tillage
Fert. N applied (lb/A)	1980	1980
Corn grain removed (bu/A)	1516	1287
N removed in grain (lb/A)	1011	823
N removed in grain as a percent of applied N (%)	51	42
Tile flow (acre inches)	120.4	136.4
Nitrate-N lost in tile (lb/A)	418.6	399.2
N lost via tile lines as a percent of applied N (%)	21	20

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

Waseca, 1992

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

ABSTRACT: A study to determine the influence of time of N application and N-Serve on the uptake of N by corn and the loss of NO_3 to tile drainage was continued in 1992. Results from this sixth year showed significant yield improvement over the control with all N treatments, but no differences among the four primary application time/method treatments. Nitrogen efficiency, however, was consistently highest with the spring N treatments. Tile lines flowed from early March through mid-November. Tile flow averaged 6.62" for corn and 8.06" for soybean. Highest NO_3-N losses in the corn plots occurred with the fall application of N without N-Serve while the highest 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 six years were 70% higher than from the fertilized corn. This was due to moderately high levels of NO_3 throughout the 8-foot profile as a result of soil mineralization and no crop uptake.

Nitrogen (N) losses to tile drainage water have been directly linked to N additions, crop grown, and soil organic matter level. Research has been conducted on NO_3 losses to tile water in Minnesota since 1972. This research has focused primarily on the effects of rates and timing of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of time of N application and the use of a nitrification inhibitor on NO_3 movement and accumulation in the soil, NO_3 losses via tile drainage, and yield and N uptake by corn grown in a rotation with 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 basic N treatments (see Table 1) are applied to the corn phase each year with the residual effects measured in the soybean phase. Three additional N treatments were replicated four times around the edge of the core 16-tile-plot area and were planted to corn. These three treatments were analyzed along with the other four as a completely randomized design.

Anhydrous ammonia was applied at a rate of 135 lb/A for all N treatments while N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 22. Average soil temperature at the 4" depth on that date was 51°F with an average of 47°F over the following 10-day period. Spring preplant treatments were applied on May 6. The sidedress portion (60%) of the split treatments was applied at the V-8 stage on June 26.

The soybean area that was planted to corn in 1992 was field cultivated once before planting. The corn area (1991), however, was fall chiseled and field cultivated once prior to planting soybean. Surface residue accumulation was not estimated in 1992. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3578) was planted at 30,200 plants/acre on May 8 with a JD Max-Emerge planter equipped with waffle coulters. A corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A).

Soybeans (Sturdy) were planted in 30" rows at 9 beans per foot of row on May 8. Weeds were chemically controlled with 3.0 lb/A Lasso preemergence plus a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage.

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-5 stage and plots were thinned to a uniform population. Eight randomly selected plants were removed from the center rows at silk initiation (July 31) and were chopped, dried, weighed and ground for total dry matter accumulation and analyzed for total N concentration. Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yields and 60' of row for grain yields and moisture. Chemical analyses of whole plant, stover and grain samples were performed by the Research Analytical

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

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

Laboratory, University of Minnesota. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis.

Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from the fallow plots and selected corn and soybean plots on April 28. The same technique was used to sample all fallow and corn plots and selected soybean plots on November 16.

RESULTS AND DISCUSSION

Plant

Whole plant N concentration at the silking stage was highly affected by the N treatments (Table 1). This is similar to 1991. Plant N concentrations at silking tended to be higher with the spring N applications compared to fall application but these differences were not statistically significant at the P = 95% level. Dry matter accumulation at silking was increased significantly over the control by all but one of the N treatments with no consistent differences between fall and spring application. Stover N concentration was increased significantly over the control by all spring applications but not by either of the fall-applied treatments. Dry matter yield of the stover at physiological maturity (PM) was increased by all of the N treatments over the control. However, no consistent trend between fall and spring application was observed except that spring-applied N with N-Serve resulted in significantly higher stover yield than all other treatments. Final population was not significantly different among the N treatments.

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

N application		Whole Plant Silk Stage		Stover		Final
Time	N-Serve	N	DM	N	Yield	Population
		%	g/plt	%	TDM/A	ppA x 10^3
Primary trts						
Fall (Oct.)	No	1.19	115	.37	3.06	29.3
Fall (Oct.)	Yes	1.18	122	.39	2.99	29.3
Spr. (April)	No	1.24	116	.44	2.91	29.4
Split[1]	No	1.29	108	.48	3.17	29.4
Additional trts						
Check	-	0.83	98	.34	2.09	29.4
Spr. (April)	Yes	1.29	128	.47	3.71	29.4
Split[1/]	Yes	1.34	118	.50	3.15	29.4
		Statistical Analysis				
Latin square (Primary Trts)						
Signif. Level (%) :		55	64	99	49	8
BLSD (.05) :		-	-	.05	-	-
CV (%) :		8.4	8.8	7.3	7.9	1.4
Completely randomized (7 trts)						
Signif. Level (%) :		99	99	99	99	2
BLSD (.05) :		.17	12	.06	.49	-
CV (%) :		10.	6.7	9.2	11.	1.2

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

Grain and silage yields were increased significantly over the check (0 lb N/A) by all of the N treatments (Table 2). However, grain and silage yields were not significantly different between fall and spring application and between with and without N-Serve. Grain moisture at harvest was not affected by any of the N treatments. Grain N concentration and N removal in the grain were increased over the 0-lb control by all of the N treatments. Even though no significant (P = 95% level) differences between fall and spring application or between with and without N-Serve for grain N or N removal were found, fall application consistently showed less grain N and N removal regardless whether N-Serve was used or not. Total N uptake was increased over the control by 52.1 lb/A (91%) for the fall N without N-Serve, 55.1 lb/A (97%) for the fall N with N-Serve, and over 70 lb/A (129%) with the four spring N treatments.

Total N removal in the grain ranged from 86.3 to 104.0 lb/A for the six N treatments (Table 2). Based on these removal amounts, N efficiency (N removed by a treatment - N removed in the check ÷ 135 lb N/A) ranged from 32 to 45% for the six N treatments. Efficiency of the spring treatments ranged from 38 to 45% and was somewhat higher than the 32 and 34% with the fall treatments without and with N-Serve, respectively. Nitrogen efficiency based on total plant uptake ranged from 39 to 58% for the six N treatments. Again, N efficiency with the spring N treatments (46 to 58%) was clearly higher than from the fall treatments (39 to 41%) regardless if N-Serve was used.

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

N application		Grain					Total N
Time	N-Serve	Yield	H_2O	N	N removal	Silage	uptake
		bu/A	%	%	lb/A	TDM/A	lb/A
Primary trts							
Fall (Oct.)	No	141.8	31.2	1.28	86.3	6.42	109.1
Fall (Oct.)	Yes	143.8	31.6	1.31	88.9	6.39	112.1
Spr. (April)	No	141.8	32.7	1.40	94.3	6.26	119.7
Split[1/]	No	156.7	31.4	1.36	101.3	6.88	132.1
Additional trts							
Check	-	99.6	32.1	0.91	43.1	4.45	57.0
Spr. (April)	Yes	155.4	33.4	1.36	100.4	7.39	135.6
Split[1/]	Yes	149.9	32.8	1.46	104.0	6.70	135.9
			Statistical Analysis				
Latin square (Primary trts)							
Signif. Level (%) :		46	45	82	45	60	75
BLSD (.05) :		-	-	-	-	-	-
CV (%) :		11.	4.8	5.7	16.	7.8	13.
Completely randomized (7 trts)							
Signif. Level (%) :		99	87	99	99	99	99
BLSD (.05) :		19.8	-	.09	16.5	.85	20.0
CV (%) :		9.8	3.7	5.2	14.	9.5	13.

[1/] 40% preplant + 60% sidedress

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

N application		Fodder N Yield at[1/]		Grain N Yield at PM			
Time	N-Serve	Silk	PM	Total	OLD[2/]	NEW[3/]	NEW[3/]
		lb N/A					%
Primary trts							
Fall (Oct)	No	89.1	22.8	86.3	66.3	20.0	21
Fall (Oct)	Yes	92.3	23.2	88.9	69.1	19.8	22
Spr (April)	No	94.4	25.4	94.3	68.9	25.3	27
Split[4/]	No	90.0	30.8	101.3	59.2	42.1	41
Additional trts							
Check	-	52.9	14.0	43.1	38.9	4.2	8
Spr (April)	Yes	107.5	35.2	100.4	72.3	28.1	28
Split[4/]	Yes	102.5	31.9	104.0	70.6	33.4	31
			Statistical Analysis				
Latin square (Primary trts)							
Signif. Level (%):		6	99	45	32	85	78
BLSD (.05) :		-	3.7	-	-	-	-
CV (%) :		14.	8.2	16.	20.	49.	47.
Completely randomized (7 trts)							
Signif. Level (%):		99	99	99	99	98	83
BLSD (.05) :		18.1	6.3	16.5	15.4	21.1	-
CV (%) :		14.	17.	14.	16.	52.	61.

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

Total N uptake by the plants receiving fertilizer N prior to silking (Fodder N yield at silking) divided by total N uptake at PM shows that from 59 to 92% of the N was accumulated by the plants prior to silking (Table 3). NEW N in the grain (assumed to be taken up by the plant after silking and translocated to the grain) ranged from 8% in the check treatment to between 21 and 41% for all treatments receiving fertilizer N. Under the 1992 conditions there was a consistent trend toward greater amounts of post-silk (NEW N) N uptake into the grain with the spring treatments, especially the split treatments. However, these differences were not statistically significant (P = 90% level) due to the high variability (CV = 61%).

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 4 show no consistent yield and N efficiency differences among the N-Serve treatments with fall-applied N. Spring application of N showed significant advantages over fall-applied N for stover and grain N concentration, grain N removal, and silage N uptake. With the exception of grain moisture at harvest, there was no difference between the spring preplant and split application of N.

Table 4. 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 (%)		
DM Yield at Silking	73	87	86
Plant N Conc. at Silking	14	80	36
Stover N Conc. at PM	46	99	91
Grain N Conc. at PM	49	99	58
Grain Moisture	40	78	92
Grain Yield	18	69	89
Stover Yield	23	5	71
Silage Yield	5	42	85
Final Population	8	58	0
Grain N Removal	25	92	61
Silage N Uptake	24	96	78

Water

Weather conditions during the 1992 growing season were colder than normal but were 7.5" wetter than normal. Rainfall during April through October totaled 2.62" above normal. This resulted in tile flow from March 5 through November 16. Tile drainage volumes shown in Table 5 indicate highest flows in April, June and October. Drainage from the 16 corn plots averaged 6.62" with a 1.88" range among the four time/method treatments. Soybeans showed slightly more tile drainage compared to corn with an average of 8.06" from the 16 plots and a range of 1.29" 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 ranged from 10 to 15 mg/L in March and April but increased slightly to 13 to 19 mg/L in July (Table 6). Nitrate-N concentrations generally decreased after July to November when concentrations ranged from 8 to 14 mg/L. Nitrate-N concentrations in the spring and early summer months were generally highest with the fall-applied N treatments while highest concentrations in the fall were noted with the spring and split treatments. Flow-weighted NO_3-N concentration for the year was highest for the fall treatment without N-Serve and the split application treatment. In the soybean plots, where N had been applied either in the fall of 1990 or spring of 1991, NO_3-N concentrations were consistently lower throughout the season and seldom averaged greater than 10 mg/L. The fall treatments did not produce any change in NO_3-N concentration over the 9-month period whereas NO_3-N concentrations in the spring treatments started at about 7.5 mg/L in March, rose to 11 mg/L in July and declined to about 6 mg/L in November. Highest flow-weighted annual NO_3-N concentrations were associated with the spring and split treatments applied to corn the previous year. Nitrate-N concentrations under a 6-year continuous fallow system (no fertilizer N applied) were approximately 2x and 4x higher as from corn and soybean, respectively, over the 9-month flow period.

Under corn, slightly higher NO_3-N losses occurred with the fall application without N-Serve compared to the remaining treatments (Table 7). Little difference was observed among the NO_3-N losses from the fall with N-Serve, spring and split treatments. Nitrate-N losses under soybean were highest for the spring and split application treatments that were applied for the 1991 corn crop. This was due primarily to higher NO_3-N concentrations with these two treatments. Very high NO_3-N losses occurred under the fallow system where mineralization of the soil organic matter was the nitrate source. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

Table 5. Tile water discharge from the corn, soybean, and fallow plots in 1992.

N application		Month									Year
Time	N-Serve	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
		acre-inches									
		CORN									
Fall (Oct.)	No	0.64	2.13	0.26	1.10	0.01	0.01	0.07	1.90	0.93	7.05
Fall (Oct.)	Yes	0.62	2.07	0.23	0.83	0.04	0.08	0.09	2.10	1.27	7.33
Spr. (April)	No	0.64	1.93	0.31	1.00	0.01	0.03	0.07	1.67	1.01	6.67
Split	No	0.47	1.38	0.05	1.01	0.04	0.16	0.01	1.54	0.79	5.45
		SOYBEANS									
Fall (Oct.)[1/]	No	1.73	1.82	0.28	1.42	0.10	0.06	0.03	1.54	1.11	8.09
Fall (Oct.)[1/]	Yes	1.85	2.05	0.30	1.69	0.10	0.02	0.03	1.59	1.18	8.81
Spr. (April)[1/]	No	1.53	1.83	0.21	1.37	0.12	0.14	0.01	1.34	0.97	7.52
Split[1/]	No	1.51	1.94	0.25	1.59	0.07	0.01	0.05	1.33	1.08	7.83
		FALLOW									
NONE		1.02	1.61	0.20	0.94	0.07	0.01	0.01	0.74	0.69	5.29

[1/] N applied for the 1991 corn crop.

Table 6. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1992.

N application		Month									Year
Time	N-Serve	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Avg.
		mg NO_3-N/L									
		CORN									
Fall (Oct.)	No	14.1	14.9	13.3	17.3	18.8	15.4	13.8	12.5	12.5	13.1
Fall (Oct.)	Yes	11.7	11.7	15.0	14.7	12.7	13.0	10.3	8.1	7.8	10.1
Spr. (April)	No	10.6	10.0	9.8	11.8	13.5	11.8	10.4	10.6	13.5	11.1
Split	No	12.8	13.0	7.4	15.7	17.4	14.9	15.8	11.7	10.7	13.4
		SOYBEANS									
Fall (Oct.)[1/]	No	6.3	5.2	4.9	6.0	5.2	6.0	5.1	6.1	6.0	5.4
Fall (Oct.)[1/]	Yes	6.6	5.5	5.9	6.0	5.2	7.4	6.1	5.3	4.4	5.6
Spr. (April)[1/]	No	7.0	7.4	11.4	8.4	10.8	11.2	13.3	7.0	5.9	8.6
Split[1/]	No	7.6	8.4	8.4	9.5	8.0	10.7	9.0	8.1	7.2	8.4
		FALLOW									
NONE		25.0	32.0	21.4	27.9	15.1	24.8	29.0	28.6	21.0	25.1

[1/] N applied for the 1991 corn crop.

Table 7. Nitrate-N loss for each month from the corn, soybean and fallow plots in 1992.

N application		Month									Year
Time	N-Serve	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
		lb NO_3-N/A									
		CORN									
Fall (Oct.)	No	2.02	6.67	0.78	3.94	0.01	0.05	0.23	4.87	2.36	20.93
Fall (Oct.)	Yes	1.62	5.29	0.67	2.90	0.11	0.23	0.16	3.64	2.13	16.75
Spr. (April)	No	1.57	4.41	0.70	2.68	0.03	0.08	0.17	4.14	2.99	16.77
Split	No	1.53	4.40	0.09	3.65	0.14	0.52	0.05	4.14	2.05	16.57
		SOYBEANS									
Fall (Oct.)[1/]	No	2.46	2.12	0.34	1.84	0.11	0.07	0.03	1.69	1.22	9.88
Fall (Oct.)[1/]	Yes	2.90	2.53	0.38	2.17	0.11	0.03	0.04	1.66	1.20	11.02
Spr. (April)[1/]	No	2.72	3.64	0.62	2.96	0.29	0.24	0.06	2.36	1.79	14.68
Split[1/]	No	2.78	3.89	0.59	3.36	0.14	0.03	0.13	2.43	1.62	14.97
		FALLOW									
NONE		5.75	9.88	0.98	5.44	0.23	0.02	0.08	4.42	3.34	30.12

[1/] N applied for the 1991 corn crop.

Nitrate-N losses to the tile drainage water were normalized to tile water flow to minimize the influence of water flow volume among the N treatments on the interpretation of the data (Table 8). Normalized values for corn were highest for the fall w/o N-Serve and split application treatments with no difference between them. In the year following corn and its associated treatments, normalized losses ranked in the order split = spring preplant > fall w/N-Serve = fall w/o 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 two spring application treatments and lowest for the fall w/N-Serve treatment. Additional years with adequate drainage losses are necessary to determine if these findings are consistent over time.

Table 8. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1992.

Crop[1/] System	Time/Method of N Application: Fall No N-Serve	Fall N-Serve	Spring No N-Serve	Split No N-Serve
	NO_3-N Lost (lb/A/inch of drainage)			
Corn	2.97	2.28	2.51	3.04
Soybean	1.22	1.25	1.95	1.92
C-Sb System	2.04	1.72	2.22	2.38

[1/] Continuous fallow (6 years without fertilizer N) = 5.69

Soil

Nitrate-N remaining in the 0-8' soil profile in late-April was high in the fallow plots (214 lb/A) compared to those where soybean was grown in 1991 (Table 9). Soybean that had not received fall-applied N averaged 98 lb/A with 52 lb/A remaining in the top 5'. Distribution of NO_3 within the profile was markedly different among the crop/fallow systems. In the fallow plots NO_3-N concentration increased with depth to 4 feet and then remained consistently high. With soybean, NO_3-N concentrations were highest in the surface foot, decreased in the 1-3' layer, and then increased slightly throughout the rest of the profile.

Table 9. Nitrate-N in the soil profile in April, 1992 as influenced by previous crop in 1991.

Profile depth	1991 Crop: Fallow	Soybean
feet	lb/A	
0 - 1	11.3	13.7
1 - 2	15.4	6.2
2 - 3	22.6	8.3
3 - 4	32.5	10.3
4 - 5	41.4	14.0
5 - 6	37.9	13.1
6 - 7	29.0	15.2
7 - 8	23.5	16.9
Total in		
0 - 5' profile	123.2	52.5
0 - 8' profile	213.6	97.7

A comparison of the residual NO_3 amounts found in April, 1992 (Table 9) with those amounts found in the same plots in October, 1991, shows the spring NO_3 levels to be approximately 25% less for the fallow plots.

Residual NO_3-N remaining in the 0 to 5' profile after the 1992 season shows very low amounts of NO_3 and somewhat less than after the 1991 season (Table 10). This was not surprising considering the high amount of rainfall and subsequent leaching in both years. Residual NO_3 in the fallow plots was reduced 41% in the 0-5' profile and 42% in the 0-8' profile in this one-year period. The low amounts of NO_3 found in all of the corn plots showed no large differences among time/method of application or between the N-Serve treatments. The spring preplant application of N with N-Serve, however, did show slightly higher amounts of residual NO_3 in the top four feet. Residual NO_3-N levels for the fallow plots were slightly lower in October than in April (Table 9).

Table 10. Residual NO_3-N remaining in the 0-8' soil profile after harvest as influenced by time of N application and N-Serve.

Profile depth	Fallow	Check	Application Time: N-Serve Fall	N-Serve Preplant	N-Serve Split	No N-Serve Fall	No N-Serve Preplant	No N-Serve Split
feet	lb NO_3-N/A[1/]							
0-1	21.6	10.3	5.5	15.0	13.4	8.2	9.0	6.7
1-2	18.9	6.0	4.3	7.1	8.8	3.5	4.2	5.0
2-3	17.7	2.3	4.7	13.2	4.7	2.3	4.9	3.9
3-4	18.7	2.7	3.7	6.3	5.2	2.5	7.5	4.2
4-5	19.1	3.2	4.6	7.6	6.6	7.2	6.8	5.6
5-6	22.8	4.2	5.4	8.8	6.6	8.6	7.8	7.3
6-7	19.6	6.0	7.9	9.9	10.7	10.0	7.4	8.9
7-8	25.2	11.3	8.6	7.1	7.7	12.6	8.1	9.7
Total in								
0-5' profile	96	24	23	49	39	24	32	26
0-8' profile	164	46	44	75	64	55	56	51

[1/] Avg. of 4 replications

CONCLUSIONS

The cold and wet conditions resulted in fair corn production and adequate tile drainage. Corn production was greatly improved by the various N treatments over the control. Corn grain and silage production was not influenced by time of application (fall, spring or split) or by the inclusion of N-Serve with the fall-applied anhydrous ammonia. Nitrogen uptake (efficiency) was consistently higher with the spring and split treatments, however. Tile flow data indicated only small differences among the four N treatments with respect to amount of drainage but did show slightly elevated NO_3-N concentrations and losses with the fall application w/o N-Serve and split application compared to the single spring application and fall application w/N-Serve. 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 end of the season was low except in the fallow plots. These data again indicate the importance of growing a crop to utilize the N mineralized from these high organic matter soils.

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

1992

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 10% at both Waseca and Morris in 1992. Soil test K increased by 10% at Waseca and decreased by 15% at Morris. Soybean yields were increased 28 to 62% over the long-term control plots at the two sites when soil test Bray P_1 was greater than 22 lb/A. Soil K tests of >300 lb/A at Waseca resulted in 6 to 8 bu/A higher yield than plots testing about 250 lb K/A. Over the 6-year (1986-92) period soil test P declined by 1.3, 4.2 and 5.4 lb/A/yr when no fertilizer P was applied to soils testing 16, 48 and 89 lb/A initially 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 4.7 lb/A/yr when the initial Bray P_1 test was 66 lb/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 corn residue in the fall of 1991 10. Specific experimental procedures used for soybeans 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 soybeans on the high P and K rate study at the two branch stations in 1992.

	Location	
Variable	Morris	Waseca
Planting date	5/12	5/13
Row spacing	30"	30"
Planting rate (plants/A)	10-12 seeds/ft	9-10 seeds/ft
Variety	Evans	Sturdy
Herbicide	3# Lasso (Bdct)	3# Lasso + 4 oz Pursuit/A (Bdct)
Harvest date	10/25	10/14
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 86 lb/A (Table 2). Soil test P declined about 10% compared to 1991, but soil test K increased by 10% even though K was not applied. Soybean yields were increased significantly by P but plateaued at soil P levels higher than 22 lb/A. Soybean yield was also reduced about 6 to 8 bu/A where K was not added and soil test K was less than 260 lb/A.

---

[1] Funding provided by the TVA-National Fertilizer Development Center.

[2] Soil scientists and professors at the Southern Experiment Station (Waseca) and West Central Experiment Station (Morris), respectively.

At Morris, Bray P_1 ranged from 9 to 67 lb/A while Olsen's $NaHCO_3$ test ranged from 11 to 55 lb P/A (Table 3). Soil test P values declined about 10% at Morris, while soil K values decreased about 15%. Soybean yields at the Bray P_1 levels of 9 and 20 lb/A were significantly lower than those from the plots testing 41 lb/A and above.

Table 2. Soil test values, seed moisture, and seed yield as influenced by 19 years' application of P and K at Waseca.

	P and K Treatments		Soil Test[2]			Seed	
	Total						
No.	1973-84	1985-91[1]	pH	P	K	Moisture	Yield
	------- lb P_2O_5 + K_2O/A -------			---- lb/A ----		%	bu/A
2	0 + 1200	0 + 100	6.9	7	316	9.5	34.5
3	600 + 1200	0 + 100	6.7	22	349	9.8	42.6
4	1200 + 1200	0 + 100	6.9	57	309	10.1	43.1
5	600 + 1200	100 + 100	6.8	86	319	10.4	45.3
6	1200 + 0	100 + 0	7.0	84	247	9.7	37.1
7	1200 + 600	100 + 0	7.0	85	259	9.7	39.4
	Signif. Level (%):		22	99	99	86	97
	BLSD (.05) :		-	12	32	-	7.0
	CV (%) :		3.3	12.	5.9	3.9	8.8

[1] Treatments applied each fall. P was discontinued for treatments 6 & 7 in 1988.
[2] Samples were taken in October before 1992 treatments were applied.

Table 3. Soil test values, seed moisture, and seed yield as influenced by 19 years' application of P and K at Morris.

	P and K Treatments		Soil Test[2]				Seed	
	Total							
No.	1973-84	1985-91[1]	pH	P_1	P_{ol}	K	Moisture	Yield
	---- lb P_2O_5 + K_2O/A -----			------- lb/A -------			%	bu/A
2	0 + 1200	0 + 100	7.8	9	11	484	9.8	27.2
3	600 + 1200	0 + 100	7.9	20	18	402	10.0	34.0
4	1200 + 1200	0 + 100	7.8	41	31	428	9.9	43.1
5	600 + 1200	100 + 100	7.8	67	55	436	10.0	44.6
	Signif. Level (%):		-	99	99	94	24	99
	BLSD (.05) :		-	25	19	-	-	9.1
	CV (%) :		-	45.	41.	8.2	2.6	15.

[1] Treatments applied each fall.
[2] Samples were taken in October before 1992 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 6-year period (1986-1992) 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 6-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 6-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 48 and 89 lb/A, soil Bray P_1 declined by 4.2 and 5.4 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 4.3 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 much lower in 1987 and 1990.

At Morris, soil test P variability was high and decline rates could not be calculated from the regression equations, which were not significant, for treatments 2 and 3. However, soil P did decline by 4.7 lb/A/yr when P was not added to the plots that initially tested 66 lb P/A. This decline rate was slightly less than at Waseca where soil P test was also very high.

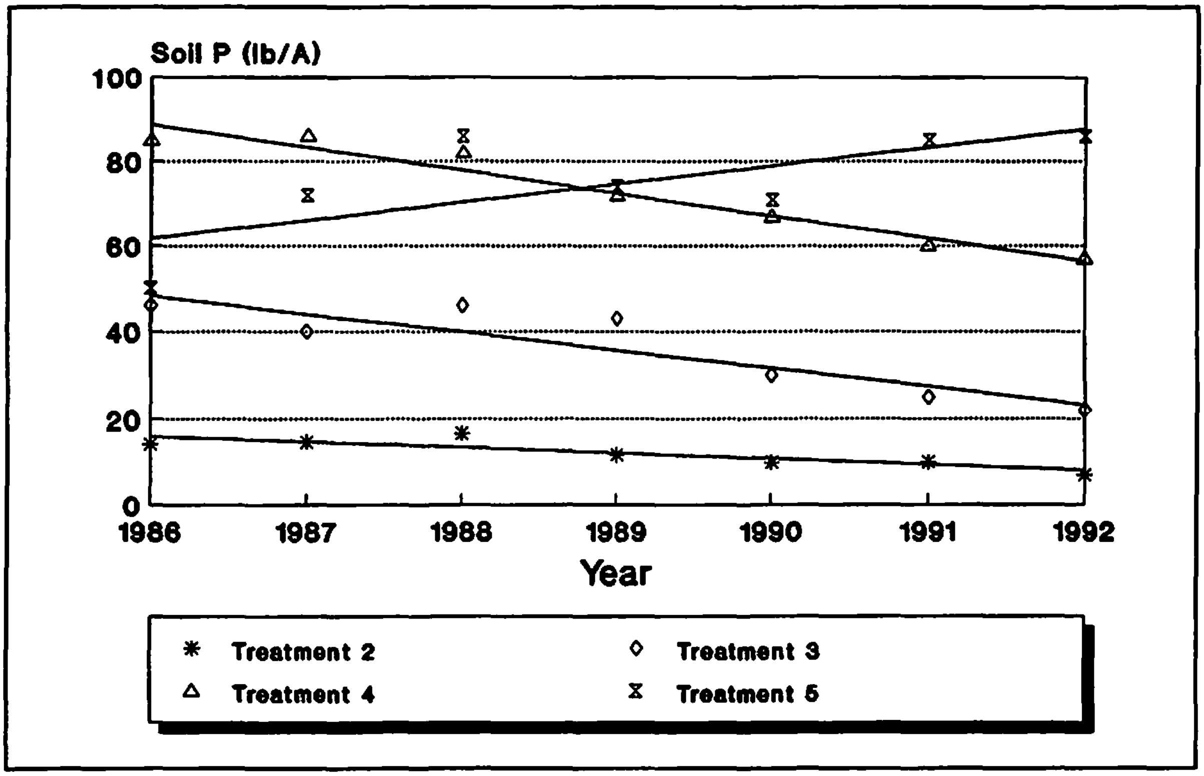


Figure 1 Decline rate of soil P over a 6-year period as influenced by P treatment at Waseca.

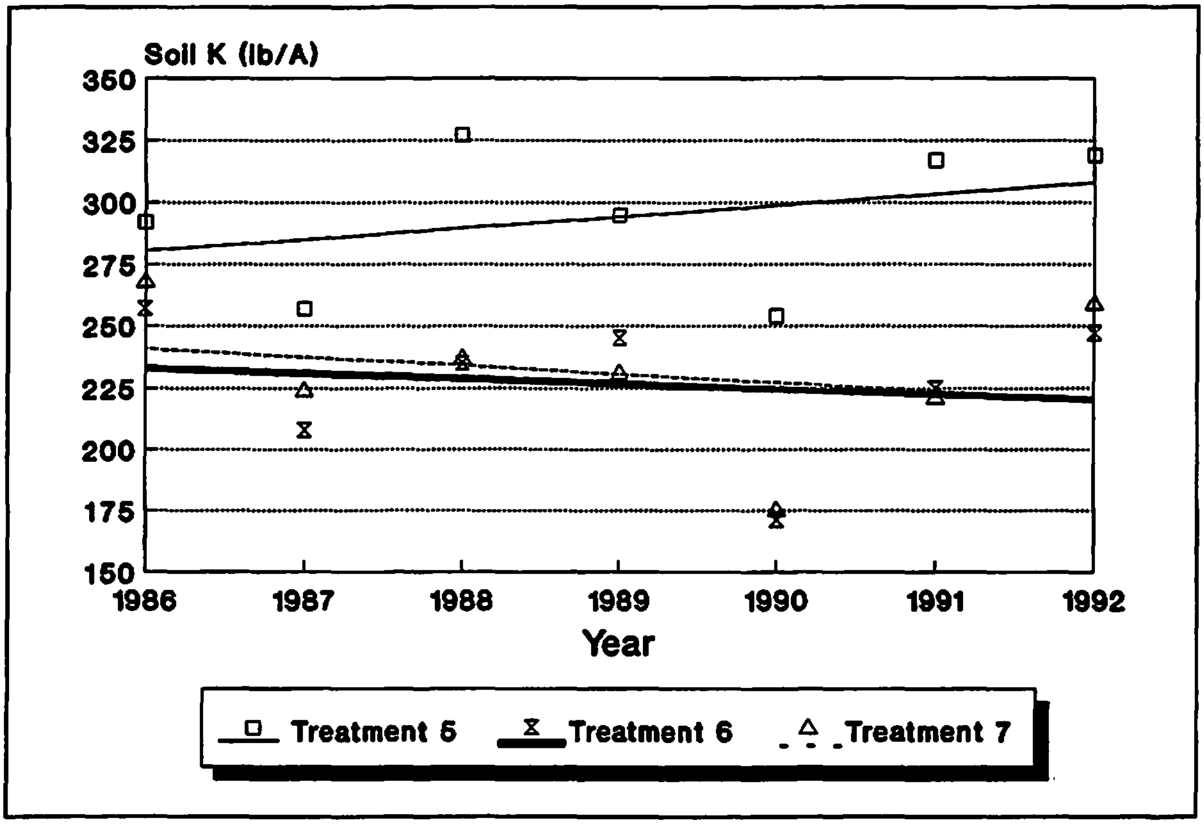


Figure 2 Decline rate of soil K over a 6-year period as influenced by K treatment at Waseca.

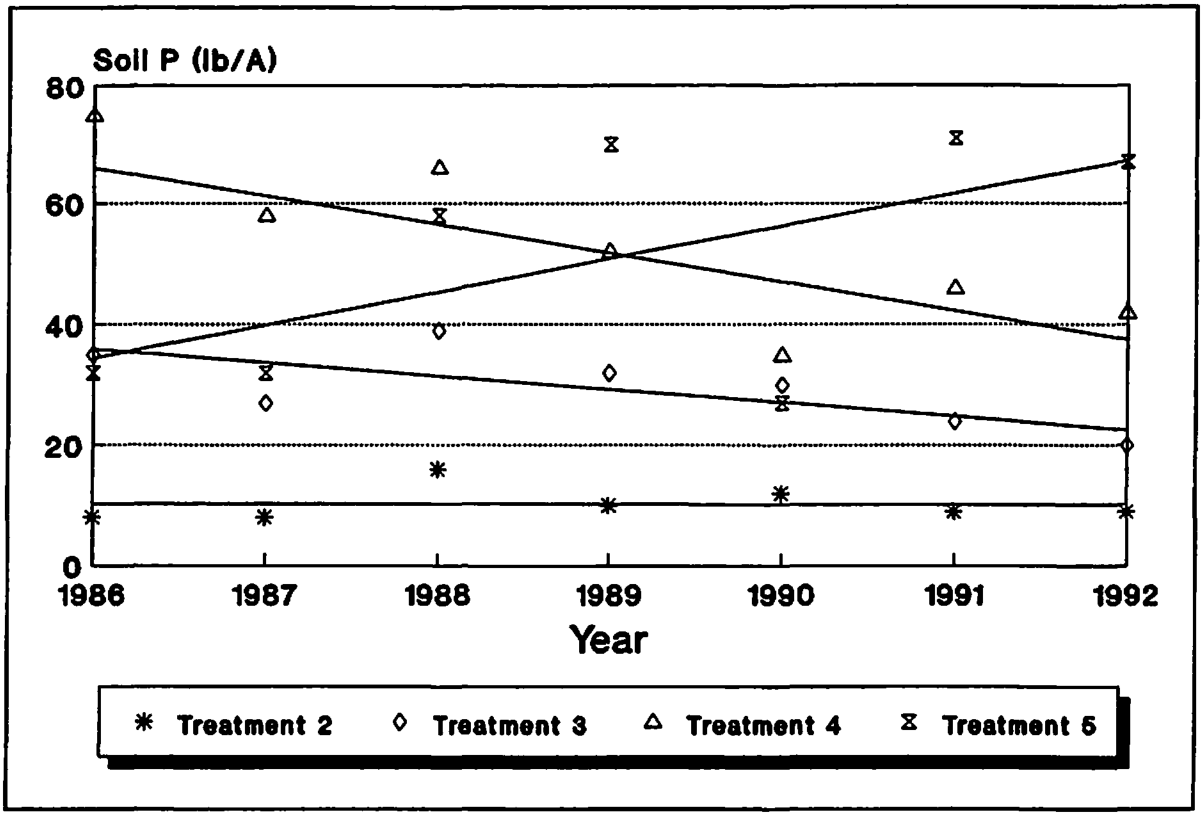


Figure 3 Decline rate of soil P over a 6-year period as influenced by P treatment at Morris.

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	1.31 X	56.6**
"	P	3	ST =	48.2	- 4.15 X	65.0**
"	P	4	ST =	88.7	- 5.38 X	86.3**
"	P	5	ST =	61.8	+ 4.30 X	30.0*
"	K	5	ST =	280.5	+ 4.58 X	5.2^{NS}
"	K	6	ST =	233.0	- 2.10 X	1.2^{NS}
"	K	7	ST =	240.8	- 3.42 X	3.3^{NS}
Morris	P	2	ST =	10.3	- 0.02 X	0.0^{NS}
"	P	3	ST =	36.0	- 2.22 X	8.2^{NS}
"	P	4	ST =	66.0	- 4.74 X	35.6**
"	P	5	ST =	34.5	+ 5.45 X	19.7*

[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. Soybean yields were optimized over the no P treatments at soil test P levels of 22 lb/A or higher at Waseca. Yields were consistently higher at Waseca when soil K tested >300 lb/A compared to those plots testing around 250 lb K/A. At Morris, soybean yields were improved about 16 bu/A with soil test P levels of 41 lb P/A and higher. Soil test P declined by about 10% at both Waseca and Morris. Soil test K was increased by about 10% at Waseca and decreased by about 15% at Morris in 1992. Over the 6-year period (1986-92), soil Bray P_1 tests declined by 1.3, 4.2 and 5.4 lb/A/yr when no fertilizer P was applied to these soils initially testing 16, 48 and 89 lb/A, respectively, at Waseca. When 100 lb P_2O_5/A was added annually, soil Bray P_1 increased by 4.3 lb/A/yr when the initial test was 62 lb/A. At Morris, soil test P was more variable, but soil P declined by 4.7 lb/A/yr when the initial Bray P_1 was 66 lb/A. 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.

NITROGEN FERTILIZATION OF ESTABLISHED REED CANARYGRASS

Waseca, 1992

G. W. Randall, M. P. Russelle, and B. W. Anderson[1/]

ABSTRACT: Recently developed low-alkaloid varieties of Reed canarygrass are being considered as an alternative forage for dairy enterprises. This one-year study was conducted to determine the optimum nitrogen (N) rate for Reed canarygrass and whether a split application would be superior to a single application. Forage yields and N concentration in the forage (quality) were optimized at the 250-lb N rate. Total N uptake and protein levels (as high as 19.5%) were maximized at the 300-lb N rate. Residual soil NO_3-N in the 0-3' profile after the third cutting was not affected by any of the fertilizer N rates. Based on these 1-year data Reed canarygrass production can be optimized with N rates from 250 to 300 lb/A without impact on NO_3 leaching from the rooting profile.

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 purpose of this study was to determine the optimum rate of N and whether split application was advantageous over a single application for an established stand of low-alkaloid Reed canarygrass.

EXPERIMENTAL PROCEDURES

Reed canarygrass (var. Palaton) was established in 24 plots each measuring 24' x 54' in August 1990. These plots were intended for use in 1991 as part of a graduate thesis study. Because these plots were not used, they were maintained without additional fertilization and were harvested three times during 1991.

In early May 1992, 16 plots with the most uniform stand of Reed canarygrass were selected and fertilized with varying rates of N as ammonium nitrate (Table 1). After the first cutting on June 5, the main plots were split into four subplots. Four rates of N (0, 50, 100 and 150 lb/A) as ammonium nitrate were applied on June 9 to the subplots. The split-plot experimental design used for the second (July 20) and third (Oct. 29) cuttings was randomized four times on this Webster clay loam soil.

Yields were taken by harvesting two 3' x 50' swaths from each main plot for the first cutting and one 3' x 24' swath from each subplot for the second and third cuttings. Subsamples from the forage were taken for moisture and total Kjeldahl N analyses. The total N analysis was conducted by the Research Analytical Laboratory in St. Paul.

Soil samples were taken from one plot within each replication to a 5-foot depth on May 6 for NO_3-N analyses. On November 12, three cores per plot were taken to a 3-foot depth from the control and the six treatments that received 200 lb N/A or more. 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 cutting dry matter yields were increased significantly over the control by all of the May N treatments with no difference among the 50, 100 and 150-lb rates (Table 1). Dry conditions (2.97") during the 30-day period between N application and harvest may have limited the degree of response to the topdressed treatments.

Second cutting yields were increased significantly by both the May and June applications. The significant May x June interaction indicated that yields were increased by all of the June N rates when rates of 0 and 50 lb N/A were applied in May but not with the 100 and 150-lb June rates coupled with the 100 and 150-lb May rates. The 150-lb May rate without a June application gave a yield that was significantly less than the 150-lb rate applied in June when no N was applied in May. This latter treatment was sufficient for maximum yield. Third cut yields responded only to the 150-lb rate applied in May and to the 100 and 150-lb rates applied in June. There was no interaction between the May and June rates of application.

Total dry matter yield was maximized at the 250-lb N rate. Under this year's weather conditions, Reed canarygrass yields were impacted more with the June application than the May application. However, both application times increased yields significantly. Perhaps an application in mid-April prior to plant growth would have had a greater effect on first cut and total yield. The highly significant interaction for the May x June time of application is similar to that found with the second cutting. Total yield did not continue to increase with the 150-lb rate applied in June when 150 lb N/A had also been applied in May.

N Concentration

Total N concentration in the first cutting forage was increased significantly by each of the N rates applied in May (Table 2). In the forage from the second cutting, total N concentration was increased significantly up through the 100-lb rate applied in May and with all N rates applied in June. No interaction between the May and June applications indicated that the highest N concentration was achieved with the 150-lb rate applied in June regardless of the May treatments. Total N in the third cutting was not influenced by the May treatments but was significantly increased by only the 150-lb rate applied in June.

[1/] Professor, Southern Experiment Station, Waseca; Soil Scientist, USDA-ARS-US Dairy Forage Research Center, St. Paul; Asst. Scientist, Southern Experiment Station, Waseca.

Table 1. Dry matter yield of Reed Canarygrass as influenced by N fertilization at Waseca in 1992.

Rate/Time of N Applc'n		Cutting Number & Date			
May 7	June 9	1st 6/5	2nd 7/20	3rd 10/29	Total
------ lb N/A ------		------ Tons DM/A ------			
0	0	1.05	0.52	0.21	1.78
0	50		1.61	0.36	3.02
0	100		2.29	0.43	3.77
0	150		2.75	0.60	4.40
50	0	1.46	1.04	0.27	2.77
50	50		2.12	0.32	3.90
50	100		2.49	0.42	4.37
50	150		2.83	0.50	4.79
100	0	1.44	1.45	0.31	3.20
100	50		2.34	0.32	4.10
100	100		2.73	0.58	4.75
100	150		2.81	0.69	4.94
150	0	1.62	1.65	0.45	3.72
150	50		2.53	0.48	4.63
150	100		2.84	0.78	5.24
150	150		2.71	0.87	5.20
Individual Factors					
May N Rate					
0		1.05	1.79	0.40	3.24
50		1.46	2.12	0.38	3.96
100		1.44	2.33	0.48	4.25
150		1.62	2.43	0.65	4.70
Signif. Level (%):		99	99	93	99
BLSD (.05) :		0.33	0.17	-	0.57
June N Rate					
0		-	1.16	0.31	2.87
50		-	2.15	0.37	3.91
100		-	2.59	0.56	4.54
150		-	2.77	0.67	4.83
Signif. Level (%):		-	99	99	99
BLSD (.05) :		-	0.12	0.24	0.14
Interaction		Signif. Level (%)			
May x June Applc'n		-	99	43	99
CV (%):		14.	8.4	26.	5.6

Table 2. Nitrogen concentration in and N uptake by Reed Canarygrass as influenced by N fertilization in 1992.

Rate/time of N application		N Concentration			N Uptake		
May 7	June 9	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
---------lb N/A---------		-------------%-------------			-------------lb N/A-------------		
0	0	1.70	1.68	1.47	36.1	17.5	6.2
0	50		1.90	1.34		60.6	9.6
0	100		2.29	1.27		104.9	10.8
0	150		2.87	1.41		157.6	16.9
50	0	2.48	1.67	1.40	72.1	34.8	7.4
50	50		2.07	1.40		87.7	8.8
50	100		2.47	1.36		122.8	11.5
50	150		2.76	1.58		156.5	16.2
100	0	2.82	1.87	1.37	81.0	54.4	8.6
100	50		2.16	1.28		101.2	8.2
100	100		2.67	1.44		146.5	16.4
100	150		2.80	1.50		157.1	20.6
150	0	3.10	2.14	1.39	99.8	70.9	12.8
150	50		2.30	1.39		116.0	13.2
150	100		2.46	1.40		139.9	21.2
150	150		3.12	1.86		169.0	32.2
Individual Factors							
May N Rate							
0		1.70	2.19	1.37	36.1	85.2	10.9
50		2.48	2.24	1.43	72.1	100.5	11.0
100		2.82	2.38	1.40	81.0	114.8	13.4
150		3.10	2.51	1.51	99.8	123.9	19.8
Signif. Level (%):		99	97	80	99	99	98
BLSD (.05) :		0.24	0.23	–	18.1	14.0	6.4
June N Rate							
0		-	1.84	1.40	-	44.4	8.7
50		-	2.11	1.35	-	91.4	9.9
100		-	2.47	1.36	-	128.5	14.9
150		-	2.89	1.59	-	160.0	21.5
Signif. Level (%):		-	99	99	-	99	99
BLSD (.05) :		-	0.14	0.10	-	8.2	2.4
Interaction							
May x June Applc'n		-	73	80	-	98	93
CV (%):		6.1	9.2	11.	16.	12.	27.

N Uptake

Total N uptake for all cuttings was significantly increased by the May and June treatments (Table 2). The 150-lb N rate at each time of application resulted in the highest N uptake for all cuttings. However, the significant May x June interaction indicated a greater increase in N uptake with the high rates of June-applied N when no N was applied in May compared to when N was applied in May.

Total N uptake for the three crops was very high and related well to the N rates applied (Table 3). Apparent N recovery was also very high with values of 80% or more for all of the treatments. Highest percent recovery was generally obtained with the split applications; a single application of 100 or 150 lb N/A in May resulted in somewhat lower recoveries.

Table 3. Total N uptake and nitrogen use efficiency of Reed canarygrass as affected by N treatments in 1992.

Rate/Time of N Application		Total N	Apparent N[1/]
May 7	June 9	Uptake	Recovery
-------- lb N/A ----------		lb N/A	%
0	0	59.8	-
0	50	106.3	93
0	100	151.8	92
0	150	210.6	100
50	0	114.3	109
50	50	168.6	109
50	100	206.4	98
50	150	244.8	92
100	0	144.0	84
100	50	190.4	87
100	100	243.9	92
100	150	258.7	80
150	0	183.5	82
150	50	229.0	85
150	100	260.9	80
150	150	301.0	80

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

Soil Residual Nitrate-N

Soil samples taken on May 6 indicated very low amounts of NO_3-N in the 0-5' profile (13.0 lb/A). Samples taken in mid-November showed no impact of any of the N treatments on NO_3-N remaining in the 0-3' profile (Table 4). Reed canarygrass was capable of scavenging essentially all of the NO_3 from the soil system even when 300 lb N/A had been applied.

Table 4. Nitrate-N remaining in the 0-3' soil profile on Nov. 12 as influenced by N rates applied to Reed canarygrass.

N rate applied on:		NO_3-N in Soil Profile			
May 7	June 9	0 - 1'	1 - 2'	2 - 3'	0 - 3'
------------ lb/A ----------		--------------- lb NO_3-N/A ------------------			
0	0	10.5	5.1	5.7	21.3
50	150	12.0	6.3	7.3	25.6
100	100	8.9	5.8	7.0	21.7
100	150	10.7	6.5	6.9	24.1
150	50	13.8	7.1	7.0	27.9
150	100	13.7	7.4	7.5	28.6
150	150	12.6	6.2	7.0	25.8

NITRATE REMOVAL FROM THE SOIL PROFILE AS INFLUENCED BY CROP

Waseca, 1992

G. W. Randall, M. P. Russelle, and D. D. Walgenbach[1/]

ABSTRACT: Annual manure applications to the same field can lead to high levels of NO_3-N in the soil profile. The purpose of this first-year study was to determine the ability of four crops (corn, soybean, alfalfa, and Reed canarygrass) to remove NO_3 from the soil profile. Corn yield was excellent but soybean yield was depressed due to severe lodging. Alfalfa and Reed canarygrass yields were also very good in this establishment year. Highest total N uptake was obtained with alfalfa and Reed canarygrass. Nitrate removal from the 0 - 8' profile during the period from April to late October averaged 34, 35, 57 and 62% with corn, soybean, alfalfa and Reed canarygrass, respectively. These results indicate that soil NO_3 levels in the profile, especially in the top four feet, can be reduced considerably in one year by planting either alfalfa or Reed canarygrass.

Livestock producers are sometimes forced to land-apply manure at rates higher than nutrient removal by their crops. As a result nutrients, notably nitrate (NO_3), can accumulate in the soil profile and are susceptible to leaching toward surface and groundwaters. Evidence exists in the literature that alfalfa will scavenge large amounts of NO_3 from the soil rather than symbiotically fix atmospheric N to meet its high N needs. Soybean grown in Goodhue Co. in 1991 was also able to reduce soil NO_3 levels markedly. The purpose of this study was to determine the efficacy of four crops to scavenge NO_3 from soils that contained high levels of NO_3 due to past manure applications.

EXPERIMENTAL PROCEDURES

Liquid dairy manure was applied to a Nicollet clay loam from 1987 thru 1989 to build high levels of NO_3 in the soil profile. A study was established in 1990 to pursue the above objective but failed because of atrazine carryover. Thus, additional manure was applied in the fall of 1990 and spring of 1991 and a bulk crop of corn was grown in both years.

The experiment was re-established in 1992 with the planting of four crops (corn, soybean, alfalfa, and Reed canarygrass). Each plot measured 90' long by 30' wide and was replicated four times in a randomized, complete-block design. Establishment procedures, pesticides used, and harvest dates for each crop are shown in Table 1. Each plot was subdivided into the north 30', center 30' and south 30' to determine if significant variability existed within the individual plots. Crop yields were taken from 27' long sections within the center of each 30' long subplot. Soil samples were taken in 1-foot increments to an 8-foot depth from the center of each subplot in April prior to establishment and again in late October after harvest. Grain, stover, seed or forage samples were taken from each subplot, dried, ground and submitted to the Research Analytical Laboratory for total N analyses. All soil samples were forced-air dried at 125°F immediately after sampling, ground and analyzed for NO_3-N and NH_4-N.

RESULTS AND DISCUSSION

Crop yields, N concentrations, and N uptake by each of the crops are shown in Table 2. Although corn yield was very high, low N concentrations limited total N uptake by corn. The grain was removed while the stover was returned to the soil. Soybean yield was surprisingly low, primarily due to severe lodging that began in late July shortly after flowering started. Apparently the Sturdy variety, known for lodging resistance, was not able to tolerate the high levels of manure-supplied NO_3 in the profile. The severe lodging negated obtaining soybean stover yields. Two cuttings each of alfalfa and Reed canarygrass were taken. Yields in this establishment year were quite good and N concentrations high. As a result N removal by alfalfa (219 lb/A) and Reed canarygrass (189 lb/A) greatly exceeded the N removal by corn (113 lb/A) and soybean (101 lb/A).

Soil NO_3-N in late April was quite uniform among the plots where each of the crops were to be established (Table 3). Most of the variability existed in the 0-5' profile where the amount of NO_3-N ranged from 247 to 309 lb/A. Nitrate-N in the 5-8' profile was substantially higher than in the surface five feet but was much more uniform among the cropped areas. Apparently, much of the NO_3 from the surface four feet was leached into the 5 to 8 foot layer during 1991 when record precipitation was recorded (50.5"). Total NO_3-N in the 0-8' profile ranged from 569 to 645 lb/A.

At the end of the season substantially less NO_3-N remained in the 0-8' profile with the alfalfa and Reed canarygrass crops than with corn or soybean (Table 4). Most of the NO_3 removal occurred in the top four feet. Over 65% and 80% of the NO_3-N in the 0-5' profile at the beginning of the season was not found in the alfalfa and Reed canarygrass plots, respectively, at the end of the season. Presumably, most of the change in soil NO_3-N was due to crop uptake in this year of normal growing season precipitation. Only 46 and 36% of the NO_3-N in the 0-5' layer of the corn and soybean plots, respectively, was not found at the end of the season. In the 5-8' layer, 23, 33, 49 and 46% of the early season NO_3-N was not found after harvest in the corn, soybean, alfalfa and Reed canarygrass plots, respectively. Post-harvest NO_3-N amounts in the 0-8' profile were 66, 65, 43 and 38% of the early-season amounts for corn, soybean, alfalfa and Reed canarygrass, respectively.

CONCLUSIONS

High levels of NO_3-N in the soil did not hamper establishment or yields of corn, alfalfa or Reed canarygrass; however, soybean lodging was severe and yield poor. Total N uptake was markedly higher for alfalfa and Reed canarygrass compared to corn and soybean. In addition, substantially more NO_3 was removed from the 0-8' soil profile with alfalfa and Reed canarygrass than with corn and soybean. Although the majority of NO_3 removal occurred in the top four feet NO_3 reductions from 23 to 49% were found in the 5-8' profile. Very little difference was observed between alfalfa and Reed canarygrass in this establishment year.

[1/] G. W. Randall is Professor, So. Expt. Stn., Waseca; M. P. Russelle is Soil Scientist, USDA-ARS, US Dairy Forage Research Center, St. Paul; D. D. Walgenbach is Superintendent, So. Expt. Stn., Waseca.

Table 1. Experimental procedures for the Nitrate Removal Study in 1992.

Crop	Procedures
Corn	
Secondary Tillage	Field cultivated
Hybrid	Northrup King 4428
Planting rate & date	30,200 on May 1
Row width	30"
Insecticide	Counter at 8.7 #/A
Herbicide - date	3.5 #/A Lasso + 3 #/A Bladex (PE) on May 8
Harvest date	Oct. 20
Fall tillage	Moldboard plow on Nov. 16
Soybean	
Secondary tillage	Field cultivated
Variety	Sturdy
Planting rate & date	9 - 10 beans/ft on May 22
Row width	30"
Herbicide - date	3 #/A Lasso (PE) on June 2
	4 oz/A (2nd trifol.) Pursuit on June 30
Harvest date	Oct. 23
Fall tillage	None
Alfalfa	
Secondary tillage	Field cultivated 2x on April 28
Herbicide	1 gal/A Balan (Incorp.) on April 28
Seeding rate & date	12 #/A on May 1
Harvest dates	1st cutting - July 20
	2nd cutting - Sept. 10
Reed Canarygrass	
Secondary tillage	Field cultivated on April 28
Seeding rate & date	10 #/A on May 1
Harvest dates	1st cutting - July 20
	2nd cutting - Oct. 29

Table 2. Crop yields, N concentration, and N uptake in 1992.

Cropping System	Yield	N Concentration	N Uptake
		%	lb/A
Cont. Corn			
Grain (bu/A)	184.5	1.29	112.6
Stover (lb DM/A)	6008.	0.65	39.0
Total	8.17 T DM/A		151.6
Soybean-C			
Seed (bu/A)	30.5	6.36	101.2
Alfalfa			
1st Cut (lb DM/A)	4315	2.75	118.7
2nd Cut (lb DM/A)	2978	3.38	100.7
Total	7293		219.4
Reed Canarygrass			
1st Cut (lb DM/A)	4466	2.91	129.9
2nd Cut (lb DM/A)	1779	3.35	59.4
Total	6245		189.3

Table 3. Soil NO_3-N amount in the 0-8' profile on April 27, 1992 prior to establishment of the crops.

Depth	Crop to be planted			
	Corn	Soybean	Alfalfa	Reed Canarygrass
feet	lb/A			
0 - 1	47.3	44.6	45.5	57.7
1 - 2	51.6	56.5	47.4	65.4
2 - 3	44.9	44.7	39.8	54.0
3 - 4	42.0	45.7	41.6	55.4
4 - 5	75.5	73.8	72.9	76.4
5 - 6	108.7	108.6	114.7	106.7
6 - 7	103.3	119.5	111.7	123.1
7 - 8	95.3	98.5	132.6	106.5
Total in				
0 - 5	261.3	265.3	247.3	308.9
5 - 8	307.3	326.6	359.0	336.3
0 - 8	568.6	591.9	606.3	645.3

Table 4. Soil NO_3-N amount in the 0-8' profile on October 30, 1992.

Depth	Crop grown			
	Corn	Soybean	Alfalfa	Reed Canarygrass
feet	lb/A			
0 - 1	48.4	47.6	30.8	20.8
1 - 2	22.8	25.6	12.8	8.8
2 - 3	14.0	17.6	8.4	6.4
3 - 4	17.6	31.6	8.8	8.8
4 - 5	38.4	45.6	18.4	16.4
5 - 6	66.8	62.0	41.2	42.8
6 - 7	80.0	73.2	67.2	65.6
7 - 8	90.0	83.2	72.8	73.2
Total in				
0 - 5	141.2	168.0	79.2	61.2
5 - 8	236.8	218.4	181.2	181.6
0 - 8	378.0	386.4	260.4	242.8

WATER QUALITY RESEARCH WITH NITROGEN AT THE HERMAN ROSHOLT WATER QUALITY RESEARCH FARM, WESTPORT, MN 1992 [1]

Small plot phases

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

Abstract: The objective of the **small plot** water quality research phase is to evaluate and quantify the impact of a variety of agricultural practices on crop nitrogen utilization efficiency and the potential impact on water quality. Currently agricultural practices such as crop rotation, tillage, and fertilizer N management including, rates, sources, time of application, methods of application and use of nitrification inhibitors are being evaluated. Corn grain yields were approximately 10% higher when the previous crop was soybeans rather than corn. Corn grain yields were not influenced by tillage systems (chisel-plow vs. ridge-till systems). Nitrogen fertilizer significantly increased corn grain yield when 105 lbs N/A was applied to both continuous corn or corn following soybeans. No yield increase was obtained with N rates over 105 lbs N/A with either system. The weather conditions in 1992 were probability the single most important factor to influence crop production. Corn grain moisture was in excess of 30% at harvest on Oct. 20th.

In 1987 three phases of nitrogen (N) research were started at the Herman Rosholt Water Quality Research Farm at Westport, MN. The three phases of research included a lysimeter phase, a large plot groundwater phase and a small plot N management/crop production phase. The large plot phase was terminated in 1991, and the small plot phases are reported here, the lysimeter phase will be reported separately.

The soil at the Rosholt farm is an Estherville sandy loam with 15-30 inches of sandy loam soil overlying glacial outwash composed mainly of coarse sand and gravel. Because of the coarse nature of these soils and the low water holding capacity, they are frequently irrigated to attain high yields. The higher yield potential along with higher fertilizer inputs, low water holding capacity, and shallow underlying aquifer create conditions which could result in groundwater contamination with nitrate N. Improper fertilizer N management can result in reduced yields, reduced fertilizer use efficiency, decreased profits, and increased groundwater contamination. The purpose of these phases of research was to determine the impacts of different N and crop management practices on crop yield, N utilization and their resulting impacts on groundwater quality.

Experimental Procedures

Small Plot N Management/Crop Production Phase: consisted of 25 N treatments randomized within a split-split plot design with three replications. The main plot consisted of two cropping sequences (continuous corn and corn following soybeans) with the sub-plots being tillage (ridge till and chisel plow). Ridges were constructed in 1987. In 1992 the entire experiment was planted to corn and in 1991 soybeans were planted in the corn-soybean rotation. The 25 N treatments within each sub-plot consisted of a control (zero N) plus four N rates (60, 120, 180, and 240 kg N/ha -- these will be reported as 50, 105 160, and 215 # N/A), two nitrification inhibitors (none and N-Serve) and three times/methods of application (all N early-3 leaf growth stage, all N late-8 leaf growth stage, and split with 2/3 N early and 1/3 N late). All fertilizer N treatments were applied as anhydrous ammonia. Early application was applied on June 2nd and late application was applied on June 29th. The nitrification inhibitor N-Serve was applied with an in-line injection pump which inserted the chemical in front of a bidirectional flow integrator and the manifold. N-Serve was applied at a rate of 0.5 #/A active ingredient.

1. Funding provided by the University of Minnesota Agricultural Expt. Station and the Center for the Impacts of Agricultural Practices on Water Quality. Appreciation is also expressed to Pioneer Hybrid International for supplying the seed.
2. Professor and Asst. Scientist respectively, Dept. of Soil Science. University of MN.

Soil samples were taken from 0-1 and 1-2 ft depth from 13 of the 25 treatments on April 23th before planting . The soil samples were analyzed for ammonium and nitrate concentration and the data is reported in table 4. Spring samples were taken on corn following corn and the corn following soybeans check plots.

Corn (Pioneer 3787 - 95 day R.M.) was planted on May 6th in 30 inch rows at a population of 30,700 seeds/A using a two row Hiniker planter. Starter fertilizer was placed below the seed at planting at the rate of 10 gal/A of 7-21-7 and Counter (8 #/A) was banded in the row at planting to control insects. Lasso (1.75 #/A) and Bladex (1.75 #/A) was applied on May 13th for weed control. For additional weed control the corn was cultivated and ridges were built on June 25th. The irrigation program (traveling boom) was started on July 24th with a total of 5 inches of water being applied through irrigation. An additional 11.85 inches of water was obtained during the growing season as rainfall.

Corn grain yields were obtained on October 20th by hand harvesting 100 ft^2 of plot area. All corn grain yields were adjusted to 15.5% . Grain yields and N concentration are reported in table 1,2 and 3.

General Results

Corn grain yields were poor in 1992. The cool growing season resulted in slow crop development and high moisture grain at harvest. Tillage system had no influence on grain yield regardless of previous crop. An N rate of 105 lbs N/A was needed to reach optimum yields in both corn following corn and corn following soybeans sequence. Grain yields following soybeans were approximately 10 % higher than corn yields with previous crop of corn. Time of fertilizer N application and/or the use of a nitrification inhibitor had relatively little influence on crop production. Soil samples collected in the spring indicated that very little residual nitrate-N was present in the soil profile from the applications made the previous year. A portion of the fertilizer-N in excess of crop need was probably moved deeper into the soil profile and toward the groundwater during late fall or early spring.

Table 1. Influence of N-rate, nitrification inhibitors, method of application and tillage on **continuous corn** grain yields, N-concentration, and N removal. Westport, MN. 1992

Total N-Rate	Early N	Inh.	Late N	Tillage	Grain Yield	Grain N-content	Grain N-removal
#/A	#/A		#/A		Bu/A	%	#/A
Control	----	--	----	C	47.7	1.05	23.86
50	50	--	----	C	86.1	1.40	56.97
50	----	--	50	C	82.1	1.28	50.06
50	35	--	15	C	82.1	1.16	45.00
50	50	NS	----	C	78.3	1.17	43.37
50	----	NS	50	C	89.6	1.23	52.11
50	35	NS	15	C	88.5	1.52	63.60
105	105	--	----	C	93.3	1.43	63.11
105	----	--	105	C	90.0	1.40	59.84
105	70	--	35	C	92.8	1.54	67.65
105	105	NS	----	C	92.6	1.31	57.27
105	----	NS	105	C	87.6	1.51	62.41
105	70	NS	35	C	94.8	1.58	70.94
160	160	--	----	C	85.0	1.67	67.10
160	----	--	160	C	91.3	1.44	62.16
160	105	--	55	C	98.1	1.55	71.96
160	160	NS	----	C	85.9	1.70	68.97
160	----	NS	160	C	89.2	1.55	65.44
160	105	NS	55	C	87.6	1.47	61.00
215	215	--	----	C	94.2	1.64	73.13
215	----	--	215	C	92.6	1.46	64.75
215	145	--	70	C	91.7	1.68	72.82
215	215	NS	----	C	95.4	1.65	74.54
215	----	NS	215	C	87.7	1.59	66.17
215	145	NS	70	C	92.9	1.68	73.88
Control	----	--	----	R	45.1	0.99	21.15
50	50	--	----	R	76.9	1.33	48.51
50	----	--	50	R	77.0	1.07	39.19
50	35	--	15	R	81.3	1.33	50.74
50	50	NS	----	R	80.0	1.40	53.14
50	----	NS	50	R	80.7	1.29	49.42
50	35	NS	15	R	82.0	1.49	57.95
105	105	--	----	R	85.3	1.59	64.06
105	----	--	105	R	96.8	1.45	66.22
105	70	--	35	R	88.9	1.49	62.60
105	105	NS	----	R	79.7	1.33	50.08
105	----	NS	105	R	89.2	1.43	60.49
105	70	NS	35	R	84.6	1.39	55.41
160	160	--	----	R	95.4	1.61	72.48
160	----	--	160	R	87.7	1.50	62.19
160	105	--	55	R	87.7	1.63	67.70
160	106	NS	----	R	89.6	1.49	63.37
160	----	NS	160	R	91.1	1.42	61.62
160	105	NS	55	R	82.4	1.55	60.56
215	215	--	----	R	84.3	1.73	68.96
215	----	--	215	R	86.4	1.65	67.37
215	145	--	70	R	88.5	1.65	69.11
215	215	NS	----	R	89.6	1.61	67.99
215	----	NS	215	R	85.9	1.42	57.72
215	145	NS	70	R	91.7	1.55	67.40

Table 1. continued. Continuous Corn Split Plot Statistical Analysis

	Corn Grain		
	Yield	N-Content	N-Removal
	Bu/A	%	#/A
Tillage			
Chisel	89.6	1.48	63.0
Ridge Till	85.9	1.47	60.1
P-Value	54	31	83
N-Rate X Method X Inhibitor			
N-Rate #/A			
50	82.0	1.30	50.8
105	89.6	1.45	61.6
160	89.2	1.54	65.3
215	90.1	1.61	68.6
P-Value	99	99	99
BLSD (.05)	2.6	0.16	2.3
Method			
1. 4 leaf	87.0	1.50	62.0
2. 8 leaf	87.8	1.41	59.1
3. Split 2/3 1/3	88.5	1.51	63.6
P-Value	51	99	99
BLSD (.05)		0.03	2.2
Inhibitor			
None	88.1	1.48	62.2
N-Serve	87.4	1.47	61.0
P-Value	56	63	79
N-Rate X Method	30	99	98
N-Rate X Inhibitor	86	99	99
Method X Inhibitor	6	99	94
N-Rate X Method X Inhibitor	73	99	99
N-Rate X Method X Inhibitor X Tillage			
N-Rate X Tillage	61	42	35
Method X Tillage	57	57	47
Inhibitor X Tillage	1	99	9
N-Rate X Method X Tillage	99	99	85
N-Rate X Inhibitor X Tillage	55	99	93
Method X Inhibitor X Tillage	9	54	37
N-Rate X Method X Inhibitor X Tillage	46	99	95

Table 2. Influence of N-rate, nitrification inhibitors, method of application and tillage on corn grain yields, N-concentration, and N removal following soybeans. Westport, MN. 1992

Total N-Rate	Early N	Inh.	Late N	Tillage	Grain Yield	Grain N-content	Grain N-removal
#/A	#/A		#/A		Bu/A	%	#/A
Control	----	--	----	C	50.5	1.08	25.79
50	50	--	----	C	83.5	1.49	58.86
50	----	--	50	C	90.2	1.29	54.96
50	35	--	15	C	86.2	1.35	54.98
50	50	NS	----	C	92.6	1.35	59.38
50	----	NS	50	C	80.1	1.34	51.02
50	35	NS	15	C	96.3	1.48	67.40
105	105	--	----	C	103.6	1.57	77.04
105	----	--	105	C	103.8	1.47	72.12
105	70	--	35	C	91.1	1.70	73.16
105	105	NS	----	C	88.7	1.42	59.56
105	----	NS	105	C	93.9	1.50	66.67
105	70	NS	35	C	103.2	1.53	74.91
160	160	--	----	C	97.2	1.62	74.30
160	----	--	160	C	92.8	1.63	71.41
160	105	--	55	C	97.2	1.49	68.43
160	160	NS	----	C	89.5	1.55	65.55
160	----	NS	160	C	99.2	1.62	75.93
160	105	NS	55	C	85.6	1.55	62.92
215	215	--	----	C	89.6	1.74	73.74
215	----	--	215	C	105.5	1.59	79.59
215	145	--	70	C	94.0	1.58	70.26
215	215	NS	----	C	96.3	1.70	77.49
215	----	NS	215	C	96.4	1.51	69.13
215	145	NS	70	C	96.6	1.71	78.05
Control	----	--	----	R	62.1	1.11	32.80
50	50	--	----	R	87.8	1.53	63.38
50	----	--	50	R	95.5	1.44	64.79
50	35	--	15	R	97.9	1.49	69.09
50	50	NS	----	R	82.7	1.35	53.04
50	----	NS	50	R	99.3	1.43	67.35
50	35	NS	15	R	98.8	1.51	70.67
105	105	--	----	R	93.3	1.53	67.54
105	----	--	105	R	87.5	1.49	61.55
105	70	--	35	R	100.2	1.62	76.95
105	105	NS	----	R	101.1	1.60	76.64
105	----	NS	105	R	85.3	1.52	61.52
105	70	NS	35	R	92.3	1.61	70.37
160	160	--	----	R	97.5	1.63	75.23
160	----	--	160	R	88.9	1.49	62.45
160	105	--	55	R	96.2	1.50	67.91
160	106	NS	----	R	95.2	1.59	71.51
160	----	NS	160	R	104.3	1.57	77.55
160	105	NS	55	R	99.0	1.50	70.49
215	215	--	----	R	97.6	1.61	74.61
215	----	--	215	R	102.5	1.63	78.87
215	145	--	70	R	100.9	1.74	83.01
215	215	NS	----	R	97.4	1.58	72.81
215	----	NS	215	R	93.4	1.53	67.43
215	145	NS	70	R	103.5	1.53	74.97

Table 2. continued. Corn Soybean Rotation Split Plot Statistical Analysis

	Corn Grain		
	Yield	N-Content	N-Removal
	Bu/A	%	#/A
Tillage			
Chisel	93.9	1.53	68.2
Ridge Till	95.8	1.54	69.9
P-Value	89	77	97
N-Rate X Method X Inhibitor			
N-Rate #/A			
50	90.9	1.41	61.2
105	95.3	1.54	69.8
160	95.2	1.56	70.3
215	97.8	1.62	74.9
P-Value	99	99	99
BLSD (.05)	2.9	0.03	2.4
Method			
1. 4 leaf	93.4	1.55	68.7
2. 8 leaf	94.9	1.50	67.6
3. Split 2/3 1/3	96.2	1.55	70.8
P-Value	90	99	98
BLSD (.05)		0.03	2.4
Inhibitor			
None	95.0	1.54	69.7
N-Serve	94.6	1.52	68.4
P-Value	31	93	84
N-Rate X Method	91	99	99
N-Rate X Inhibitor	42	52	74
Method X Inhibitor	55	94	82
N-Rate X Method X Inhibitor	99	96	99
N-Rate X Method X Inhibitor X Tillage			
N-Rate X Tillage	99	88	99
Method X Tillage	88	18	81
Inhibitor X Tillage	63	30	33
N-Rate X Method X Tillage	99	90	99
N-Rate X Inhibitor X Tillage	86	99	99
Method X Inhibitor X Tillage	89	87	98
N-Rate X Method X Inhibitor X Tillage	99	74	96

Table 3. Continuous Corn And Corn Soybean Combined Split Plot Statistical Analysis Westport, MN 1992

	Corn Grain		
	Yield	N-Content	N-Removal
	Bu/A	%	#/A
Previous Crop			
Corn	87.7	1.47	61.6
Soybeans	94.8	1.53	69.0
P-Value	99	91	99
N-Rate X Method X Inhibitor X Tillage			
N-Rate #/A			
50	86.5	1.36	56.0
105	92.5	1.49	65.7
160	92.2	1.55	67.8
215	93.9	1.61	71.8
P-Value	99	99	99
BLSD (.05)	1.9	0.02	1.7
Method			
1. 4 leaf	90.2	1.52	65.4
2. 8 leaf	91.4	1.46	63.4
3. Split 2/3 1/3	92.3	1.53	67.2
P-Value	95	99	99
BLSD (.05)	1.9	0.02	1.5
Inhibitor			
None	91.6	1.51	65.9
N-Serve	91.0	1.49	64.7
P-Value	58	94	94
Tillage			
Chisel	91.7	1.50	65.6
Ridge Till	90.8	1.50	65.0
P-Value	76	5	60
N-Rate X Method	65	99	99
N-Rate X Inhibitor	85	99	99
N-Rate X Tillage	96	98	96
Method X Inhibitor	32	99	99
Method X Tillage	20	14	18
Inhibitor X Tillage	48	98	64
N-Rate X Method X Inhibitor	99	99	99
N-Rate X Method X Tillage	79	99	73
N-Rate X Inhibitor X Tillage	66	99	86
Method X Inhibitor X Tillage	79	92	96
N-Rate X Method X Inhibitor X Tillage	99	84	96
N-Rate X Method X Inh. X Tillage X Provious Crop			
N-Rate X P-Crop	62	99	98
Method X P-Crop	24	85	44
Inhibitor X P-Crop	48	45	8
Tillage X P-Crop	99	63	99
N-Rate X Method X P-Crop	82	92	99
N-Rate X Inh. X P-Crop	44	95	90
N-Rate X Tillage X P-Crop	90	42	74
Method X Inh. X P-Crop	41	39	27
Method X Tillage X P-Crop	94	60	88
Inhibitor X Tillage X P-Crop	48	92	87
N-Rate X Method X Inh. P-Crop	68	73	67
N-Rate X Method X Tillage X P-Crop	99	99	99
N-Rate X Inh. X Tillage X P-Crop	83	99	99
Method X Inh. X Tillage P-Crop	61	25	73
N-Rate X Method X Inh. X Tillage X P-Crop	99	99	97

Table 4. Influence of N-rates, nitrification inhibitors, method of application and tillage in **continuous corn** on soil ammonium and soil nitrate from spring soil samples depth 1 (0-1 ft) and depth 2 (1-2 ft) Westport, MN 1992.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonia	Nitrate
#/A	#/A		#/A			---------ppm----------	
Control	---	---	---	C	1	3.9	2.9
					2	2.8	2.6
50	50	---	---	C	1	4.9	3.6
					2	3.2	2.9
50	---	---	50	C	1	3.9	4.0
					2	3.4	4.2
105	105	---	---	C	1	4.9	3.5
					2	3.0	3.9
105	---	---	105	C	1	5.1	2.2
					2	3.0	2.4
160	160	---	---	C	1	5.6	3.3
					2	3.2	3.2
160	---	---	160	C	1	8.6	3.5
					2	3.2	4.2
160	105	---	50	C	1	4.8	4.1
					2	3.0	4.3
160	160	NS	---	C	1	9.6	4.4
					2	4.1	5.6
160	---	NS	160	C	1	6.0	5.8
					2	3.7	6.9
160	105	NS	50	C	1	7.7	2.5
					2	3.2	4.8
215	215	---	---	C	1	6.4	4.0
					2	3.3	4.8
215	---	---	215	C	1	9.5	2.8
					2	3.4	4.1
Control	---	---	---	R	1	3.7	5.2
					2	3.1	2.6
50	50	---	---	R	1	3.9	5.1
					2	2.8	4.3
50	---	---	50	R	1	4.4	5.1
					2	2.8	5.5
105	105	---	---	R	1	4.3	6.1
					2	3.4	4.5
105	---	---	105	R	1	3.9	4.9
					2	3.1	4.3
160	160	---	---	R	1	6.2	5.7
					2	3.7	6.5
160	---	---	160	R	1	4.4	4.9
					2	3.2	4.1
160	105	---	50	R	1	4.3	6.0
					2	3.1	4.6
160	160	NS	---	R	1	5.8	5.1
					2	3.5	5.9
160	---	NS	160	R	1	4.6	6.8
					2	3.2	5.9
160	105	NS	50	R	1	4.4	6.6
					2	3.4	4.2
215	215	---	---	R	1	5.1	6.1
					2	3.5	6.7
215	---	---	215	R	1	3.9	6.1
					2	3.3	7.4

USE OF THE SPAD 502 CHLOROPHYLL METER TO MONITOR THE NITROGEN STATUS OF CORN[1]

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

Abstract

Nitrogen management decisions which improve fertilizer efficiency should decrease the potential for nitrate contamination of the ground water and increase profitability for corn producers. The use of the chlorophyll meter which quantifies leaf greenness could rapidly and effectively monitor N requirements of the crop and thus improve N management programs for those producers with sidedress or fertigation capabilities. In 1991 a study was initiated to determine if the Minolta SPAD 502 chlorophyll meter could be utilized to predict N deficiency in corn. In 1992 the study was conducted on corn-corn and a soybean-corn rotation. Meter reading and nitrogen concentrations from plants at 5-, 9-, 12-leaf, silking, blister, and milk growth stages were compared for their ability to predict nitrogen deficiencies in corn. The correlation between meter readings and leaf N concentrations and grain yield increased with increasing age of the plant. The chlorophyll meter provided higher correlation coefficient with yield than did tissue analysis. The chlorophyll meter also detected N deficiencies earlier in the growing season. Neither system was very good before the 12-leaf growth stage. While it is not possible to recommend rates of fertilizer via chlorophyll meter readings at this time, the data would suggest that the meter may be better than leaf tissue analysis effective in monitoring the N status of corn.

Tissue analysis has been used and is an effective method for predicting the N status of corn, but cost and time involved prevent such methods from being widely used as tools to improve nitrogen management. The chlorophyll meter can rapidly and non-destructively measure the degree of leaf greenness and thus has potential for contributing to greater nitrogen fertilizer efficiency for producers that apply nitrogen by sidedress application or through irrigation water. The objective of this study was to compare the chlorophyll meter with leaf N concentrations for their ability to predict nitrogen deficiencies of corn.

Experimental Procedures: This study was conducted at the Herman Rosholt Water Quality Research Farm, Westport, MM. during the 1992 growing season. The soil is an Estherville sandy loam and the crop sequence was either continuous corn or soybean-corn in 1992. Both crop sequences were evaluated under chisel and ridge till systems. Corn (Pioneer 3787 95 day R.M.) was planted on May 6th in 30 inch rows at a population of 30,700 seeds/A using a two row Hiniker planter. Starter fertilizer 7-21-7 was applied as a band below the seed at the rate of 10 gal/A and Counter 8 #/A was banded in row at planting for insect control. Nitrogen fertilizer in form of anhydrous ammonia was applied at the rates of 0, 50, 105, 160, and 215 lbs N/A on June 2nd. (3-leaf stage) and June 29th (8-leaf stage). Lasso (1.75 #/A) and Bladex (1.75 #/A) was applied on May 13th for weed control. For additional weed control the corn was cultivated and ridges were also built on June 25th. The irrigation program (traveling boom) was started on July 24th with 5 inches of water being applied through irrigation. An additional 11.85 inches of water was obtained during the growing season as rainfall.
At 5-leaf (June 11th), 9-leaf (June 29th), 12-leaf (July 16th), silking (August 4th), blister (August 17th.) and milk (August 26th.) growth stages, chlorophyll meter reading were taken from 20-30 different plants from one row of each plot. Leaf samples were taken from 15-20 plants in the adjacent row, dried, ground and analyzed for N concentrations. For 5, 9, and 12-leaf stages, the youngest leaf with a collar was measured, while the leaf opposite and below the developing ear was used at silking, blister and milk stages. Meter readings (one per plant) were taken at a location approximately midleaf, from base to tip and from the midrib to outer leaf margin. Corn was hand harvested from 100 sq.ft. of plot area on October 20th. Corn grain yields were adjusted to 15.5%.
General Results: Chlorophyll meter reading ,leaf N concentrations,and grain yield are presented in table 1. Meter reading were highly correlated with yield at all growth stages past 9-leaf while leaf N concentrations did not correlate with yield until 12-leaf. The correlation coefficients were higher at all sampling when the chlorophyll meter was utilized, suggested that the meter is more sensative to N limiting conditions than is plant analysis. Relative values for the meter reading, N concentrations, and yield are shown in table 2.

---

1. Funding provided by the Center for Agricultural Impacts on Water Quality. Appreciation is also expressed to Pioneer Hi-Bred International for supplying seed.
2. Professor, Assistant Scientist and Graduate Research Assistant respectively, Dept. of Soil Science, University of Minnesota.

Table 1. Chlorophyll meter reading, leaf N concentrations, and grain yield for combined corn-corn and corn following soybeans. Westport MN 1992.

Tillage	N-Rate (# N/A)	Application Time	Chlorophyll Meter Reading 5-leaf	9-leaf	12-leaf	silking	blister	milk	Bu/A
Chisel	0		45.8	44.8	42.0	36.5	34.4	32.4	49.1
	50	4-leaf	46.7	46.9	50.8	53.6	52.0	52.7	84.8
	105		46.4	48.3	52.3	56.1	58.1	58.2	98.5
	160		43.6	46.7	51.3	55.5	57.7	57.9	91.1
	215		45.9	48.4	52.4	56.6	58.9	59.7	91.9
	50	8-leaf	45.9	45.8	45.7	50.9	54.1	53.2	86.1
	105		45.9	46.6	47.0	54.2	56.9	56.7	96.9
	160		45.3	46.5	47.7	54.1	56.7	57.4	92.1
	215		47.0	47.2	48.2	53.5	54.6	56.0	99.0
Ridge	0		45.9	45.6	42.6	36.0	34.6	32.8	53.6
	50	4-leaf	46.6	47.8	51.0	53.3	54.4	51.7	82.3
	105		44.9	48.6	51.7	54.8	56.8	57.2	89.3
	160		46.0	48.8	53.3	56.5	58.5	57.5	96.4
	215		45.8	48.3	52.5	56.8	58.7	59.3	90.9
	50	8-leaf	47.3	46.8	45.8	50.8	50.6	50.1	86.2
	105		47.0	46.7	47.7	53.9	57.1	57.0	92.2
	160		46.3	46.9	46.9	55.0	56.9	56.7	88.3
	215		46.3	47.0	49.5	55.3	57.6	58.5	94.4
	(yield x meter) r =		0.17~	0.49**	0.63**	0.89**	0.88**	0.89**	

Tillage	N-Rate (# N/A)	Application Time	Leaf % N Concentrations 5-leaf	9-leaf	12-leaf	silking	blister	milk
Chisel	0		4.9	3.7	2.5	1.9	2.0	1.9
	50	4-leaf	4.3	4.1	3.3	2.4	2.3	2.3
	105		4.6	4.1	3.4	2.5	2.6	2.3
	160		4.9	4.0	3.6	2.5	2.6	2.5
	215		4.6	3.9	3.6	2.8	3.2	2.9
	50	8-leaf	4.3	4.1	3.4	2.4	0.9	0.9
	105		4.7	3.3	2.7	2.3	3.0	2.6
	160		4.9	3.8	3.1	2.4	2.8	2.7
	215		4.6	3.6	3.0	2.4	2.9	2.7
Ridge	0		4.9	3.7	2.4	2.0	2.0	1.9
	50	4-leaf	4.3	3.8	3.5	2.5	2.5	2.3
	105		5.3	4.0	3.5	2.5	2.8	2.7
	160		4.6	4.4	3.7	2.6	3.0	2.7
	215		4.9	4.0	3.7	2.7	2.8	2.7
	50	8-leaf	4.9	3.6	2.7	2.0	2.8	2.6
	105		5.2	3.7	3.0	2.3	2.8	2.6
	160		4.9	3.4	3.0	2.5	3.0	2.7
	215		5.2	3.8	3.3	2.6	2.8	2.8
	(yield x leaf N) r=		0.04	0.08	0.44**	0.39**	0.40**	0.38**

~,*,** Significant at the 0.10, 0.05, and 0.01 level respectively.

Table 2. Relative chlorophyll meter reading, leaf N concentrations, and grain yield for combine studies corn-corn and corn following soybeans. Westport MN 1992.

Tillage	N-Rate (# N/A	Application Time	5-leaf	9-leaf	12-leaf	silking	blister	milk	Rel. Yield
			Relative Chlorophyll Meter Reading						
Chisel	0		0.96	0.92	0.79	0.64	0.58	0.54	0.49
	50	4-leaf	0.98	0.96	0.95	0.94	0.88	0.88	0.85
	105		0.98	0.99	0.98	0.98	0.98	0.97	0.99
	160		0.92	0.95	0.96	0.97	0.98	0.97	0.92
	215		0.97	0.99	0.98	0.99	1.00	1.00	0.92
	50	8-leaf	0.97	0.93	0.85	0.89	0.91	0.89	0.87
	105		0.97	0.95	0.88	0.95	0.96	0.95	0.97
	160		0.95	0.95	0.89	0.95	0.96	0.96	0.93
	215		0.99	0.96	0.90	0.94	0.92	0.93	1.00
Ridge	0		0.97	0.93	0.80	0.63	0.58	0.55	0.54
	50	4-leaf	0.98	0.98	0.95	0.93	0.92	0.86	0.83
	105		0.95	0.99	0.96	0.96	0.96	0.96	0.90
	160		0.97	1.00	1.00	0.99	0.99	0.96	0.97
	215		0.97	0.99	0.98	1.00	0.99	0.99	0.91
	50	8-leaf	1.00	0.96	0.85	0.89	0.85	0.83	0.87
	105		0.99	0.95	0.89	0.94	0.96	0.95	0.93
	160		0.98	0.96	0.88	0.96	0.96	0.95	0.89
	215		0.97	0.96	0.92	0.97	0.97	0.97	0.95
(Rel. Yield x Rel. Meter) r=			0.17~	0.48**	0.63**	0.88**	0.88**	0.89**	
			Relative Leaf % N Concentrations						
Chisel	0		0.92	0.84	0.68	0.68	0.65	0.66	
	50	4-leaf	0.31	0.93	0.89	0.88	0.74	0.82	
	105		0.86	0.94	0.92	0.90	0.84	0.82	
	160		0.92	0.92	0.97	0.92	0.83	0.87	
	215		0.86	0.90	0.97	1.00	1.00	1.00	
	50	8-leaf	0.85	0.81	0.73	0.75	0.73	0.68	
	105		0.88	0.74	0.71	0.85	0.94	0.90	
	160		0.91	0.85	0.82	0.85	0.89	0.93	
	215		0.86	0.81	0.80	0.87	0.93	0.93	
Ridge	0		0.92	0.84	0.66	0.73	0.64	0.66	
	50	4-leaf	0.81	0.87	0.93	0.89	0.81	0.82	
	105		1.00	0.92	0.94	0.90	0.89	0.94	
	160		0.87	1.00	0.99	0.96	0.95	0.94	
	215		0.92	0.91	1.00	0.98	0.90	0.94	
	50	8-leaf	0.93	0.81	0.73	0.72	0.88	0.89	
	105		0.97	0.83	0.80	0.83	0.88	0.90	
	160		0.93	0.77	0.80	0.91	0.94	0.94	
	215		0.98	0.86	0.88	0.95	0.88	0.98	
(Rel. Yield x Rel. Leaf N) r=			0.04	0.07	0.44**	0.39**	0.40**	0.38**	

~,*.** Significant at the 0.10, 0.05, and 0.01 level respectively

Impact of Turkey Manure Application on Soybean Production and Potential Water Quality Concerns, Westport MN 1992.[1]

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

Abstract

A field study was initiate at Westport, MN. to study the impact of turkey manure application on irrigated corn and soybean production and the potential for water quality concerns on an Estherville sandy loam. In 1991 two rates of turkey manure (4 and 8 tons per acre on a wet weight basis) were compared with two rates of commercial fertilizer and an untreated check. Manure rates were computed to provide 70 and 140 lb of available N per acre similar to fertilizer treatments. A three year rotation of corn-soybeans-corn was established, in 1991 and in 1992 soybeans were planted and only turkey manure treatments were applied. Dry matter production and N uptake was determined on Sept. 10th. at the beginning of senescence and grain yields measured at maturity. Water percolation and N leaching were measured periodically throughout the growing season when needed. Soil profile samples were collected prior to planting and at harvest time and analyzed for nitrate and ammonium N. Residual effects of manure application or fertilizer (1991) had no influence on soybean grain yield. Higher rates of turkey manure in 1992 significantly reduced soybean grain yield. Concentrations of nitrate-N in the percolate water increased from 6 mg/L during May to in excess of 44 mg/L by September when the high rate of manure was applied in 1992.

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 agricultural production areas available to them for manure disposal. As production increases there will be an increased concern about manure disposal and potential water quality contaminations.

Turkey manure is rich in several nutrients. Recent survey done by University of Minnesota researcher (Moncrief et al.1991 unpublished date) revealed the nutrient composition of poultry manure on dry weight basis is 5.1% N, 2.2% P and 2.3% K respectively. It is estimated the 860,000 tons (dry wt.) of turkey manure produced per year will supply 87, 86 an 48 million pounds of N, P_2O_5 and K respectively.

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 in corn and soybean production. The objectives of this field study was to compare two rates of turkey manure (4 and 8 T/A on wet weight basis) and two fertilizer N (70 and 140 lb N/A) on dry matter production, N uptake, grain yields , crop rotations and leaching loss of NO_3-N.

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 filter candle was installed and connected to the soil surface by polyethylene tubing. Each lysimeter was placed in the center of 30' x 30' plots. Soil at the experimental site was 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.

---

1. Funding provided by the Center for Agricultural Impacts on Water Quality. Appreciation is also expressed to Pioneer Hi-Bred International for supplying seed.
2. Professor, Assistant Scientist and Graduate Research Assistant respectively, Dept. of Soil Science, University of Minnesota.

This site did not have any previous history of manure application. Cropping history was corn following corn in a corn-corn-soybean rotation. In 1990 corn was grown at this site without any fertilizers, in 1991 corn again was grown with different fertilizer and manure treatments and in 1992 soybeans were planted into the experimental area.

Table 1. Some chemical and physical properties of the Estherville 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 soybeans. 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.

Treatments in 1992 consisted of two rates of turkey manure (4 and 8 T/A, wet weight basis) and the 1991 residual treatment of manure and fertilizer N (70 and 140 lb N/A applied as urea) and a zero N control. 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 experimental design was a randomized complete block design with three replication. The entire study area was planted with soybeans (Pioneer 9061) on May 12th at a seeding rate of 9 seeds/foot or 175,000 seeds/A. A tank mix of Lasso (2 #/A) + Sencor (.75 #/A) was applied on May 13th for weed control.

Table 2.Turkey Manure Composition

Nutrients	lb/T
Total N	56
Inorg. NH_4^+-N	19
NO_3^--N	1
Organic N	36
P_2O_5	128
K_2O	28
Moisture %	50

+ Nutrient composition presented in wet basis.

Dry Matter production and N uptake were determined at senescence on Sept. 10th by hand harvesting two four foot rows. Grain yields were determined by harvesting two 20 foot rows at maturity Oct. 19th. Soybeans grain yields were reported at 13% 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

Residual N fertilizer application (1991) had no influence on soybean grain yield, dry matter production, or N utilization in 1992. (Table 3). Turkey manure applied in 1991 had no influence on grain yield in 1992 but a strong trend was observed for increase vegetative production and the total N removal in the crop. Turkey manure applied in 1992 increased N availabity removal at the high rate of application (8 T/A) and significantly reduced soybean grain yield. (Table 3).

Table 3. Soybean grain yield, dry matter production, and N utilization as influenced by turkey manure and residual fertilizer and manure treatments - 1992.

Treatments	Grain Yields	Dry Matter Production	N-Concentration Forage	N-Removal Forage
	Bu/A	T/A	% N	#/A
Control	44	2.88	2.89	166
70 lb N/A in '91, none'92	42	2.99	2.66	160
140 lb N/A in '91, none'92	41	2.81	2.70	152
TM 4 T/A in'91, none'92	44	3.32	2.90	193
TM 8 T/A in'91, none'92	44	3.34	2.86	192
'91 no TM, 4 T/A TM'92	42	3.12	2.75	172
'91 no TM, 8 T/A TM'92	36	3.37	3.12	211
P-Valve	99	73	93	87
LSD (0.05)	3			

* TM is turkey manure.

Fertilizer and manure treatments had no influence on the amount of water that percolated through the soil profile in 1992, but did influence the concentration and the amount of nitrate-N leached. Concentration of nitrate-N in the percolate water from fertilizer N applied in 1991 were similar to the control. Manure treatments applied in 1991, however, reflected increased concentrations of nitrate-N in proportion to the rate of manure applied. Turkey manure applied in 1992 exhibited an increasing concentration of nitrate-N in the percolate water late in growing season in proportion to the rate of manure applied. 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. Data collected to date would suggest a relatively long impact associated with manure application as compared to fertilizer N.

Table 4. Water percolation amount during 1992.

Treatments	Planting 5/6	Planting to harvest 6/23	7/15	8/11	9/2	Total
	Inches of H_2O					
Control	2.1	2.2	1.4	0.8	0.9	7.4
70 lb N/A in '91, none'92	2.3	2.7	1.5	0.7	0.9	8.1
140 lb N/A in '91, none'92	1.6	2.5	1.5	0.7	0.9	7.2
TM 4 T/A in'91, none'92	2.0	2.4	1.4	0.5	1.0	7.3
TM 8 T/A in'91, none'92	3.0	3.3	1.6	1.0	0.6	9.5
'91 no TM, 4 T/A TM'92	1.9	2.3	1.1	0.4	0.6	6.3
'91 no TM, 8 T/A TM'92	1.5	2.3	1.5	0.6	0.8	6.7
P-Value	55	44	76	50	14	51
LSD (0.05)						

* TM is Turkey manure.

Table 5. Concentration of NO_3^--N in leachate as influenced by fertilizer and manure treatments in 1992.

Treatments	Planting 5/6	Planting to harvest 6/23	7/15	8/11	9/2
	ppm NO_3^--N				
Control	4.1	6.3	9.8	11.8	15.6
70 lb N/A in '91, none'92	4.7	6.7	10.8	14.7	10.7
140 lb N/A in '91, none'92	7.3	7.2	10.4	12.6	10.5
TM 4 T/A in'91, none'92	9.8	11.3	16.2	21.4	18.8
TM 8 T/A in'91, none'92	13.7	14.0	22.4	20.6	32.0
'91 no TM, 4 T/A TM'92	4.6	9.7	14.7	18.8	25.7
'91 no TM, 8 T/A TM'92	6.1	8.7	16.9	40.7	44.2
P-Value	93	88	50	99	66
LSD (0.05)				12.0	

* TM is Turkey manure.

Table 6. Nitrate-N leached as influenced by fertilizer and manure treatments in 1992.

Treatments	Planting 5/6	Planting to harvest 6/23	7/15	8/11	9/2	Total
	lb/A NO_3^--N					
Control	2.3	3.1	3.1	2.1	2.8	13.4
70 lb N/A in '91, none'92	2.1	4.1	3.6	2.5	1.9	14.2
140 lb N/A in '91, none'92	3.3	4.8	3.6	1.9	2.1	15.7
TM 4 T/A in'91, none'92	4.4	6.1	5.1	2.6	3.9	22.1
TM 8 T/A in'91, none'92	9.7	10.8	8.4	5.3	2.9	37.1
'91 no TM, 4 T/A TM'92	2.0	5.0	3.4	1.5	3.7	15.6
'91 no TM, 8 T/A TM'92	2.2	4.5	5.4	5.8	5.6	23.5
P-Value	99	79	88	85	70	93
LSD (0.05)	4.0					

* TM is Turkey manure.

Table 7. Soil N levels sampled before planting and at harvest 1992.

Treatments	Depth	Ammonium Planting	Ammonium Harvest	Nitrate Planting	Nitrate Harvest	Total Inorg. Planting	Total Inorg. Harvest
		ppm		ppm		ppm	
Control	1	2.7	4.2	8.4	2.6	11.3	6.8
	2	2.5	3.2	3.3	1.3	5.7	4.5
	3	2.6	3.0	2.2	1.4	4.7	4.3
70 lb N/A in '91, none'92	1	2.8	4.4	7.7	2.4	10.5	6.8
	2	2.6	2.9	3.7	1.2	6.3	4.0
	3	2.8	2.9	3.1	1.5	5.8	4.4
140 lb N/A in '91, none'92	1	2.8	4.0	8.3	3.2	11.1	7.2
	2	2.8	2.9	4.4	1.4	7.1	4.3
	3	2.5	2.3	3.3	1.1	5.7	3.4
TM 4 T/A in'91, none'92	1	1.7	4.7	12.3	3.0	14.0	7.7
	2	2.6	2.5	5.4	1.5	8.0	4.0
	3	2.2	2.4	5.4	1.3	7.6	3.7
TM 8 T/A in'91, none'92	1	1.8	2.9	13.2	4.7	15.0	7.6
	2	2.3	1.9	8.3	2.6	10.7	4.5
	3	2.0	2.4	8.0	2.1	10.0	4.5
'91 no TM, 4 T/A TM'92	1	2.1	4.2	7.0	3.5	9.1	7.7
	2	2.3	2.9	3.2	1.9	5.4	4.9
	3	2.5	3.2	2.4	1.8	5.0	5.0
'91 no TM, 8 T/A TM'92	1	3.3	4.9	10.2	5.4	13.6	10.3
	2	2.9	3.2	4.3	2.3	7.2	5.6
	3	2.8	4.1	2.9	3.9	5.8	7.9

* TM is turkey manure. Depth 1 ,2 and 3 (0-6), (6-12), and (12-18) inches.

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

Center for Agricultural Impacts on Water Quality
G. Randall, J. Anderson, G. Malzer, and B. Anderson

ABSTRACT: Studies are being conducted on the silt loam soils of southeastern Minnesota to evaluate specific N and tillage practices for their role in providing profitability (BENEFIT) while minimizing NO_3 occurrences in the water below the root zone (RISK). In Olmsted Co. continuous corn yield was optimized at 120 lb N/A with no advantage for sidedress or split application over a preplant application. A single sidedress application at the 8-leaf stage actually reduced yields, increased grain moisture at harvest, and reduced total N uptake. Highest yield, lowest grain moisture, and highest N uptake was obtained with the 8650 gal/A liquid dairy manure treatment. Nitrate-N concentrations in the soil water at 5' and 7.5' reflected the impacts of the 1987-91 treatments and did not show an effect of the 1992 treatments. In Goodhue Co. corn production following soybeans was optimized at 60 to 90 lb N/A without a consistent advantage for split or sidedress N applications with disk tillage. Yields with no tillage averaged 36 bu/A less and 6.5 points wetter compared to chisel/disk tillage. Nitrate-N in the soil water at 5' in April and June reflected the 1987-90 treatments, but in late October lower NO_3-N concentrations suggested some influence of the 1992 treatments. In Winona Co. alfalfa production was not influenced by the previous tillage and N rates used for continuous corn (1987-90). However, NO_3-N in the soil water at 5' and 7.5' at the end of the season averaged <1.5 mg/L while soil NO_3-N totaled <65 lb/A in the top 7 feet. This suggests that first-production-year alfalfa can be extremely effective at removing excess NO_3 from the soil profile, thereby reducing the NO_3 concentration in water leaching out of the root zone.

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

EXPERIMENTAL PROCEDURES

Three sites were continued for the 1992 studies. The primary site with the most intensive investigation is being conducted in Olmsted Co. on the Lawler Farm. The other sites are in Goodhue Co. on the Foss Farm and in Winona Co. on the Kalmes Farm.

Olmsted County - Lawler Farm

In April of 1986 a 6.5 acre site of Port Byron soil was identified on the Richard Lawler and Sons Farm approximately 6 miles east of Rochester. A very comprehensive field history for the last 7 years was provided. Corn was grown in 1986. A randomized, complete-block with 4 replications and 10 treatments was established in the fall of 1986 and was continued through 1991. Research results have been reported annually in this publication.

In 1992, this experimental area was converted to another set of 10 treatments which focused on narrower rates of N application, split application and annual vs every-other-year manure application. All plots were chisel plowed on May 1. Urea was broadcast-applied and disked in on May 5. Liquid dairy manure was sweep-injected at rates of 3700 and 8650 gal/A on May 12. The whole experimental area was disked on May 14. Corn (Pioneer 3751) was planted on May 14 at 32000 plants per acre. Lasso (3 lb/A) and Bladex (2.5 lb/A) were applied the same day. Force was applied in the furrow at a rate of 8 oz/1000' of row to control rootworms. All plots were cultivated and hand-thinned to 29500 ppA on June 15. The sidedress N treatments were knifed-in about 4" deep as urea on June 24.

Stover yields were taken from 20' of row on Oct. 27. Grain yields and moisture were determined by combine harvesting two rows, each 60' long on Nov. 11. All samples were weighed, dried, ground and analyzed for total N.

Soil samples were obtained from each plot on April 14 and Nov. 12 by taking two 2-inch cores in 1-foot increments to the bedrock and then compositing the cores from each increment. The samples were forced-air, oven-dried at 120°F, ground and analyzed for inorganic N (NH_4-N and NO_3-N).

Suction porous cup samplers installed in 1987 at the 5 and 7.5-foot depths in each plot were used to extract soil water from these depths to measure NO_3 concentrations in the soil water. Samples were collected on April 14, July 17, and November 12.

Goodhue County - Foss Farm

In May of 1986 an area of 5.1 acres of Port Byron soil was identified on the Selmer Foss and Sons (James Foss) farm in Goodhue County. A good field history was provided for the past 6 years. Corn was grown in 1986 and received a minimal amount of N (75 lb N/A) because sweet corn was the previous crop. A randomized, complete-block design with 4 replications was established at this site in April, 1987 and was continued through 1991. Sixteen N and tillage treatments were applied to continuous corn over the four-year period (1987-90). In 1991,

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

the experiment was converted to a corn-soybean rotation to determine (1) if soybean responded to carryover NO_3 in the soil profile and (2) the extent to which excess residual NO_3 could be removed from the soil. Results from these studies have been reported annually in this publication.

In 1992, the no-till (NT) plots were continued but the previous fall chisel plots were only spring disked (1x) because the Halloween snowstorm in 1991 prevented chiseling. In addition, the 16 N treatments were applied using narrower rates of application and more split and sidedress treatments. Preplant N was broadcast-applied as ammonium nitrate on May 5 and disked in the same day. Corn (Pioneer 3751) was planted on May 13 at 33000 ppA. Lasso (3 lb/A) and Bladex (2.5 lb/A) was applied preemergence on May 20. Roundup was spot-sprayed on the NT plots to control patches of quack grass. All plots were hand thinned to 32000 ppA. The sidedress treatments were knifed-in about 4" deep as urea on June 24. Stover yields were taken from 20' of row on Oct. 27. Grain yields and moisture were determined by combine harvesting two rows, each 60' long on November 10. All samples were weighed, dried, ground, and analyzed for total N. Suction samplers installed in six treatments (24 plots) to a 5' depth in 1987 were sampled on April 10, Aug. 6, and Oct. 27 to determine the NO_3 concentrations in the extracted soil water.

Winona County - Kalmes Farm

A 3.0 acre contour strip of Seaton soil was identified in early April, 1987. This farm is owned by Eugene Kalmes and son, Robert Kalmes. A field history was provided for the last 4 years. Corn was grown in 1986 and received 70 lb N/A. Alfalfa was grown in 1983-85 and received manure in the fall of 1985. A randomized, complete-block design with 4 replications was established at this site in mid-April, 1987 and was continued through 1990. Twelve N treatments were established for a total of 48 plots. Each plot measured 20' wide by 65' long and was planted to continuous corn.

After four years of continuous corn and because substantial amounts of NO_3 had accumulated in the soil profile with some of the N treatments, this experiment was changed to determine if alfalfa could reduce the amount of residual NO_3 in the soil. All plots were fall chiseled and a field cultivator was used as secondary tillage just prior to planting. Alfalfa was companion seeded with oats to the whole experimental area in May of 1991. The oat was harvested as oatlage in July. Alfalfa yields were determined from selected plots on August 26, 1991 and again on June 3, July 9, and Aug. 19, 1992. On June 10, 150 lb K_2O/A was applied to all plots.

Porous cup suction samplers installed at the 5' depth in nine treatments and at the 7.5' depth in seven treatments were sampled on April 24, June 11 and November 25 to determine NO_3-N concentrations in the extracted water. Soil samples (two cores per plot) were taken to the 7-foot depth from selected plots after the first cutting (June 9). Because of the low NO_3-N amounts only three treatments were sampled on October 1. Cores from each 1-foot increment were composited for each plot, dried, ground and analyzed for NO_3-N.

RESULTS AND DISCUSSION

Olmsted County

Corn grain production was enhanced markedly by the N treatments even though yields were considerably lower in 1992 compared to the previous five years (Table 1). A 50 bu/A response was found with the 60-lb N rate; however, yield was optimized at the 120-lb fertilizer N rate. Split application of 90 and 120 lb N/A resulted in 4 to 7 bu/A lower yields (not statistically significant at the P = 95% level) compared to the single preplant application of urea. Sidedressing all of the 90-lb N rate at the 8-leaf stage did result in a significant yield depression of 14.5 bu/A. Grain yield from the 3700 gal/A liquid dairy manure treatment equalled that from the 120-lb fertilizer N rate. However, yield was increased another 22.6 bu/A with the 8650 gal/A treatment. This difference was noted throughout the season as the corn grown on these plots was considerably greener and taller.

Grain N concentration was increased over the control by all of the N treatments and was optimized at the 120-lb N rate regardless of time of application (Table 1). Even though grain yield from the 3700 gal/A manure treatment was equal to that from 120 lb/A of preplant N, grain N was significantly less with this manure treatment.

Grain moisture at harvest was significantly lower for most of the N treatments compared to the control (Table 1). Sidedressing all the N at the 8-leaf stage resulted in higher grain moisture as well as lower grain yield. Manure had the largest impact on grain moisture. The corn from the 8650 gal/A plots was 12 points drier than the corn from the control plots and about 8 points drier than the adequately fertilized N plots.

Nitrogen removal in the grain was highest with the 8650 gal/A manure treatment (Table 1). Fertilizer N applied preplant at the 120-lb N rate optimized grain N removal. Grain N removal was significantly reduced by the single sidedress application.

Grain:stover ratios were highest for the liquid dairy manure treatments (Table 1). Although all fertilizer N treatments increased the grain:stover ratios compared to the control, very little difference was found among the N treatments.

Stover yield was optimized at the 120-and 150-lb fertilizer N rates and the 8650 gal/A manure rate (Table 2). Stover yield was not affected as greatly as grain yield by the sidedress N treatment. However, stover N concentration was maximized by the sidedress treatment. Stover N concentration was not different between the 3700 gal/A manure rate and the 60-lb fertilizer N rate. This indicates that the 3700 gal/A manure rate was marginal for corn production under these conditions. With the exception of slightly lower final plant populations with the 8650 gal/A manure rate, no differences in population were found among the other treatments.

Silage yield and N uptake were maximized with the 8650 gal/A manure rate and optimized with fertilizer N rates of 120 and 150 lb/A (Table 2). The single sidedress application showed significantly lower silage yield and N uptake than the comparable N rate applied preplant. Total N uptake with the 3700 gal/A manure treatment was less than with the 90 lb/A fertilizer N rate; again suggesting that this manure rate was marginal.

Table 1. Corn grain production as influenced by rate, source and time of N application in Olmsted Co. in 1992.

Nitrogen[1/]		Grain				Grain:Stover
Rate	Time/Method	Yield	N Conc.	Moisture	N Removal	Ratio
lb/A		bu/A	%	%	lb N/A	
0	--	32.7	1.14	36.4	17.4	0.47
60	Spring Preplant	82.6	1.34	32.8	52.5	0.82
90	Spring Preplant	103.4	1.47	32.6	72.1	0.84
120	Spring Preplant	112.7	1.59	32.9	84.9	0.84
150	Spring Preplant	111.5	1.57	32.9	82.5	0.77
60 + 30	PP + SD (8 lf)	99.6	1.48	32.3	69.4	0.77
60 + 60	PP + SD (8 lf)	105.3	1.55	32.2	77.6	0.81
90	SD (8 lf)	88.9	1.52	35.0	64.0	0.78
3700 Gal. Man.[2/]	Annual	113.0	1.35	27.8	72.2	0.96
8650 Gal. Man.[2/]	Every other year	135.6	1.55	24.4	99.7	0.88
Signif.Level (%)	:	99	99	99	99	99
BLSD (.05)	:	11.0	0.12	3.6	8.0	0.12
CV (%)	:	8.5	5.9	7.9	8.8	11.

1/ As urea

2/ Manure analyses showed 45.0, 14.2, and 21.2 lb N + P_2O_5 + K_2O/1000 gal. Based on .214% NH_4-N (18.2 lb/1000 gal), the 3700 and 8650 gal/A manure treatments added 166 and 389 lb total N/A, respectively. Assuming 100% of the NH_4-N and 50% of the organic N to be "available" in this first year, these two manure rates added 112 and 273 lb "available" N/A.

Table 2. Corn population, stover and silage production as influenced by rate, source and time of N application in Olmsted Co. in 1992.

Nitrogen		Plant	Stover		Silage	
Rate	Time/Method	Population	Yield	N Conc.	Yield	N Uptake
lb/A		ppA x 10	TDM/A	%	TDM/A	lb N/A
0	--	29.4	1.60	0.49	2.37	33.1
60	Spring Preplant	29.5	2.43	0.64	4.38	84.0
90	Spring Preplant	29.5	2.93	0.83	5.37	120.7
120	Spring Preplant	29.2	3.16	0.82	5.83	136.8
150	Spring Preplant	29.5	3.42	0.88	6.06	143.0
60 + 30	PP + SD (8 lf)	29.4	3.07	0.82	5.43	118.4
60 + 60	PP + SD (8 lf)	29.4	3.09	0.90	5.58	133.2
90	SD (8 lf)	29.4	2.76	0.99	4.86	118.4
3700 Gal. Man.	Annual	29.5	2.78	0.61	5.46	106.1
8650 Gal. Man.	Every other year	28.4	3.67	0.85	6.88	162.1
Signif. Level (%)	:	99	99	99	99	99
BLSD (.05)	:	0.6	0.36	0.09	0.50	12.3
CV (%)	:	1.2	9.4	9.0	7.3	8.1

Nitrate-N concentrations in the soil water at 5' and 7.5' shown in Table 3 reflect the effect of the 1987-91 N treatments and do not indicate an influence of the 1992 treatments, due to the dry conditions during the season. Highest NO_3-N concentrations were associated with the previous 150- and 225-lb N rates. The old NT treatment (now sidedress at 8-lf) showed much lower NO_3-N concentrations even though 150 lb N/A had been applied annually. Very little NO_3-N was left in the profile from the manure treatments applied in 1987 and 1988. Temporal variation in NO_3-N concentration within any particular treatment from April through November was slight, indicating that NO_3 from the 1992 treatments had not leached to these depths by November.

Table 3. Nitrate-N concentration in the soil water at 5' and 7.5' in Olmsted Co. in 1992.

Nitrogen		Nitrate-N Conc. in Water					
		5'			7.5'		
Rate	Time/Method	4/14	7/17	11/12	4/14	7/17	11/12
lb/A		mg/L[1/]					
0	–	1^{2}	3^{3}	2^{3}	1^{2}	1^{2}	2^{2}
60	Spring Preplant	9^{3}	9^{3}	-	4^{1}	7^{2}	4^{1}
90	Spring Preplant	11^{2}	13^{2}	-	18	16^{3}	17^{3}
120	Spring Preplant	21^{3}	24^{3}	27^{2}	37^{3}	36^{2}	32^{2}
150	Spring Preplant	13^{3}	14^{2}	14^{2}			
60 + 30	PP + SD (8 lf)	12	15^{3}	13^{3}			
60 + 60	PP + SD (8 lf)	12^{3}	13^{3}	14^{3}			
90	SD (8 lf)	4^{1}	6^{2}	8^{3}			
3700 Gal. Man.	Annual	3^{3}	8^{1}	-	3^{3}	4^{3}	4^{3}
8650 Gal. Man.	Every other year	6^{2}	8	5^{3}	4^{2}	2^{3}	5^{1}

1/ All values are an average of four replications unless noted by a superscript which denotes number of samples in average.

<u>Goodhue Co.</u>

Corn grain production was greatly affected by both N rate and tillage in 1992 (Table 4). Grain yield was optimized at the 60- to 90-lb rate of N with disk tillage. Yields were sometimes 4 to 8 bu/A higher with some of the split and sidedress applications, but this probably was not statistically significant. Grain yield was substantially lower for each of the NT treatments compared to the disk treatments. Averaged over the 60, 90 and 120-lb N rates, yields from NT were 35.7 bu/A poorer than with disk tillage. This difference was accompanied by grain moisture being 6.5 points higher with NT. Delayed crop growth was seen throughout the season with NT due perhaps to the slow start it got early in the season. Weed growth was not a factor in any of the plots.

Table 4. Corn production following soybeans as affected by N treatments in Goodhue Co. in 1992.

	N Treatment[1/]		Grain	
Tillage	Rate	Time	Yield	Moisture
	lb/A		bu/A	%
Disk	0		115.2	31.9
"	30	Preplant (PP)	137.1	30.1
"	60	"	146.7	33.7
"	90	"	147.8	31.5
"	120	"	152.2	31.6
"	150	"	156.0	31.1
"	30 + 30	PP + Sidedress (12" high)	147.4	32.8
"	30 + 60	"	154.8	30.7
"	30 + 90	"	155.2	32.6
"	0 + 60	"	155.3	31.5
"	0 + 90	"	151.0	33.0
"	0 + 120	"	151.7	32.6
No Till	0	Preplant (PP)	81.2	38.9
"	60	"	108.2	39.7
"	90	"	108.1	39.4
"	120	"	123.3	37.2

1/ As ammonium nitrate

Nitrate-N concentrations in the soil water for the April and August samplings reflect the past history from 1987-91 (Table 5). The October sampling began to show lower NO_3-N concentrations in all six treatments and probably reflects the lower N rates applied in 1992. Also, similar to previous years, NO_3-N concentrations were higher with the chisel/disk systems compared to NT and with the sidedress N treatment.

<u>Winona Co.</u>

Alfalfa yield, whole plant N concentration, and N uptake in this first production year were not influenced significantly by the tillage or N rate treatments used in 1987-90 (Table 6). The significant tillage x N rate interaction shown for the third cutting and total yield is not explainable at this time.

Table 5. Nitrate-N in the soil water at 5' in Goodhue Co. in 1992.

1987-90 Treatment		1992 Treatment		Nitrate-N Conc. in Soil Water		
Tillage	N rate	Tillage	N rate	4/10	8/6	10/27
	lb/A		lb/A		mg/L[1/]	
Chisel	0	Disk	0	7^{3}	12^{2}	1^{2}
"	100	"	60	9^{3}	12^{3}	8^{3}
"	150	"	90	16^{3}	21^{3}	14^{3}
NT	100	NT	60	14	9	3
NT	150	NT	90	11^{3}	11	8
Chisel	150 (SD)	Disk	60 (SD)	18	17^{3}	11^{3}

1/ All values are an average of four replications unless noted by a superscript which denotes number of samples in average.

Nitrate-N concentrations in the soil water at 5' on April 24 still showed some relationship to the previous N rates, which were last applied in June of 1990 (Table 7). By June 11, average NO_3-N concentrations for all treatments were less than 4 ppm. This illustrates the scrubbing ability of alfalfa to remove NO_3 from the soil profile. High ET demand by the alfalfa reduced available soil water to levels where obtaining water in the suction cup samplers was extremely difficult in the fall. The four samples obtained in November averaged <1.5 ppm at the 5' depth.

Nitrate-N concentrations in April were lower for all treatments at the 7.5' depth compared to the 5' depth (Table 7). This was no longer true in June as some NO_3 had leached from the 5' zone into the 7.5' zone. In November, the four samples obtained averaged <1.5 ppm; again indicating either uptake by the alfalfa or leaching out of the soil profile.

Soil NO_3-N in the top 5' or 7' shown in Table 8 also indicates the phenomenal scavenging ability that alfalfa has to remove NO_3 from the soil. Amounts found showed some relationship to previous N rates but ranged from only 15 to 36 lb NO_3-N/A in the 0-5' profile in early June. These amounts were down from amounts as high as 284 lb/A 13 months earlier (May, 1991). Nitrate-N amounts as high as 417 lb/A in the 0-7' profile in May 1991 were reduced to less than 80 lb/A in June 1992. Additional samples taken on October 1 indicated very little additional scrubbing of NO_3 from the rooting profile. These data suggest that alfalfa can be used very effectively to scrub NO_3 from the soil profile if NO_3 has accumulated following continuous corn. However, we cannot discount the fact that some NO_3 may also have leached out of the soil profile in this study.

Table 7. NO_3-N concentration in the soil water at 5' and 7.5' as influenced by previous tillage and N rates in Winona Co. in 1992.

				Nitrate-N Concentration in Water					
				5'			7.5'		
No.	Tillage	N Rate	Time/Method	4/24	6/11	11/25	4/24	6/11	11/25
		lb/A				ppm[1/]			
1	CP	0	Spr., preplant	4.0^{2}	-	-			
3	CP	100	"	6.8	1.6^{2}	0.8^{2}	5.5^{2}	-	-
4	CP	150	"	5.9^{3}	1.1^{2}	-	5.4^{2}	4.2^{2}	-
5	CP	200	"	17.9^{2}	3.3^{2}	-	4.1^{2}	12.5^{2}	-
7	NT	100	"	-	-	-	-	-	-
8	NT	150	"	3.5^{2}	-	1.4^{2}	1.6^{2}	2.1^{2}	-
9	NT	200	"	5.6^{3}	1.2^{3}	-	3.1^{2}	4.2^{2}	1.1^{2}
11	CP	50 + 100	Spr. PP + SD	18.2^{3}	0.6^{2}	-	5.2^{3}	11.1^{3}	0.5^{2}
12	CP	150	Sidedress	5.0^{2}	-	-			

1/ Superscript indicates the number of samples in the mean if less than four.

Table 8. Nitrate-N content in the soil profile in June and October, 1992 as influenced by previous tillage and N rates in Winona Co.

				Nitrate-N in Soil Profile			
				June 9		October 1	
No.	Tillage	N Rate	Time/Method	0-5'	0-7'	0-5'	0-7'
		lb/A			lb/A		
1	CP	0	Spr., preplant	14.7	20.0	38.0	63.2
4	CP	150	"	19.2	37.9		
5	CP	200	"	20.9	50.8	22.1	44.6
6	NT	0	"	17.2	24.7		
8	NT	150	"	35.5	78.3		
9	NT	200	"	22.8	40.2		
11	CP	50 + 100	Spr. PP + SD	18.9	40.6		
12	CP	150	Sidedress	22.5	59.0	23.0	38.8

Table 6. Effect of previous tillage and N rates on alfalfa yield and N uptake in Winona Co. in 1992.

Previous tillage	Previous N rate	Harvest 1 Whole plant N	Harvest 1 Alfalfa yield	Harvest 1 N uptake by crop	Harvest 2 Whole plant N	Harvest 2 Alfalfa yield	Harvest 2 N uptake by crop	Harvest 3 Whole plant N	Harvest 3 Alfalfa yield	Harvest 3 N uptake by crop	Total yield	Total N uptake
	lb/A	%	TDM/A	lb/A	%	TDM/A	lb/A	%	TDM/A	lb/A	TDM/A	lb/A
CP	0	3.91	1.949	152.5	3.58	1.131	81.2	3.35	0.983	65.6	4.064	299.4
CP	200	4.22	2.004	169.6	3.75	1.238	92.7	3.28	1.208	79.5	4.450	341.8
NT	0	3.84	2.033	156.5	3.64	1.155	84.2	3.24	1.168	75.3	4.353	316.2
NT	200	3.98	1.819	144.5	3.78	1.132	85.0	3.26	1.138	74.2	4.090	303.7
MAIN EFFECTS												
Tillage												
CP		4.06	1.977	161.1	3.67	1.184	87.0	3.32	1.096	72.6	4.257	320.6
NT		3.91	1.926	150.5	3.72	1.143	84.6	3.25	1.152	74.8	4.222	309.9
Signif. Level (%):		44	42	54	20	53	33	56	67	40	22	58
N Rate (lb/A)												
0		3.87	1.991	154.5	3.62	1.143	82.8	3.30	1.074	70.4	4.21	307.7
200		4.10	1.912	157.1	3.77	1.185	88.8	3.27	1.173	76.9	4.27	322.7
Signif. Level (%):		60	61	14	58	54	71	22	90	86	37	73
INTERACTION												
Tillage x N Rate												
Signif. Level (%):		26	84	69	6	73	66	34	96	91	97	94
CV (%):		13.	9.1	18.	9.9	9.4	13.	5.4	9.6	11.	5.8	8.1

MATCHING PLANT POPULATION AND FERTILIZER MANAGEMENT FOR PROFITABLE CORN PRODUCTION[1/]

D. Allan, G. Rehm, J. Johnson, A. Scobbie, D. Schmitz, and D. Hicks[2/]

ABSTRACT: Total dry matter production, yield, nutrient concentration and uptake, and root density and distribution were compared at two sites with plant population density and fertilizer treatment as the study variables. Grain yields improved by approximately 20-30 bushels per acre with fertilization when soil test values were in the low range. The cool growing season emphasized the importance of starter fertilizer. Lower rates applied in a starter produced yields equivalent to those produced by higher broadcast rates. Unexpectedly, higher yields were not associated with higher populations. There were no strong interactions between fertilizer treatment and planted population for early growth, early nutrient uptake, total dry matter production, and grain yield. This indicates that higher plant density may not require higher fertilizer rates or different management strategies. Potash fertilization at low soil test sites increased root density, while phosphorus fertilization resulted in lower root densities. Both P and K application encourage deeper development of roots early in the growing season.

Introduction

Corn plant populations used by Minnesota farmers have increased slightly during recent years. Research conducted in the Agronomy Department over the last five years showed marked increases in grain yield when populations were increased to 40,000 plants per acre with high 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 strategies that result in the most efficient use of fertilizer P and K over a wide range of plant densities when corn is grown on soils having both high and low soil tests for either P or K.

Specific objectives are to determine the effect of planted corn population and fertilizer management strategies on:

- total dry matter production and grain yield of corn
- nutrient uptake early in the growing season
- root density at 2 plant growth stages
- root distribution at 2 plant growth stages

Material and Methods

This research project is divided into two separate studies. The study which focused on potassium management was conducted in fields of cooperating farmers in Goodhue County. The study dealing with management of phosphate fertilizer was conducted at the Southwest Experiment Station at Lamberton. Each study will be described and discussed separately.

Potassium Study

An analysis of soil for K as well as soil uniformity at the site were the main criteria for selecting sites for this study. Two farmers were involved. The soil type was the same at each site but prior fertilizer history was dramatically different. The site having the high soil test value for K had been manured heavily in past years. However, manure had not been applied since 1990. The site having the low soil test value for K had not been manured in recent years and relatively low rates of K_2O had been applied in a starter fertilizer for corn when grown in the crop rotation.

[1/] Support for this project was provided by The Potash and Phosphate Institute, Potash Corporation of Saskatchewan, and Asgrow Seed. K. Piotrowski, D. Bublitz, A. Kendall, and N. Schoop provided assistance in root sample collection and analysis.

[2/] Assistant Professor, Professor, Scientist, and Technical Field Crew in the Soil Science Department, University of Minnesota, St. Paul, MN 55108. D. Hicks is Professor in the Department of Agronomy and Plant Genetics.

Soil samples were collected prior to fertilizer application at each site and the results are summarized in Table 1. For the high fertility site, two fertilizer treatments (control, 15 lb. K_2O/acre in a starter) were combined with five planted populations (23,000, 28,000, 33,000, 38,000, 43,000 plants/acre) in a randomized complete block design with four replications. At the low testing site, the same plant populations were combined with four fertilizer treatments (control, 40 lb. K_2O/acre in a starter, 100 lb. K_2O/acre broadcast, 200 lb. K_2O/acre broadcast) in a randomized complete block design with four replications.

The broadcast treatments were applied and incorporated before planting. All plots at both sites received a spring N application of 46-0-0 which was also broadcast and incorporated before planting. Nitrogen rates were based on the results of a preplant soil test and a previous crop of soybeans at the low fertility site. Nitrogen rates were 190 lb./acre at the low fertility site and 150 lb./acre at the high fertility site. All plots at the low fertility site received a broadcast application of 100 lb. 0-46-0 per acre.

Phosphorus Study

This study was initiated at the Southwest Experiment Station in Lamberton in 1991. In 1992, treatments were reapplied to the plots used in 1991. The experimental design and plant populations were the same as used in Goodhue County. At the high fertility site, the phosphate rate for the starter was 23 lb. P_2O_5 per acre. Phosphate was broadcast at rates of 100 and 200 lb. P_2O_5/acre and used at a rate of 40 lb. P_2O_5/acre in a starter at the low fertility site. All treatments at both sites received 190 lb. N/acre as 46-0-0. All treatments at the low fertility site received a broadcast application of 150 lb. 0-0-60 per acre. All broadcast fertilizers were incorporated before planting.

General Procedures

Asgrow RX578 was planted at both sites. Corn was planted on May 2 at Lamberton and May 7 at Goodhue County. Appropriate herbicides and insecticides were used at both locations.

Detailed soil samples were collected to determine root density. For this sampling, cores were taken at a distance of 3, 6, and 12 inches from the row. Cores were taken directly opposite a plant and perpendicular to the row. The cores at each distance from the row were divided into 0-3 inches, 3-6 inches, 6-12 inches and 12-24 inches. This sampling scheme was repeated 4 times in a plot and these cores were composited before analysis. The soil samples for measurement of root density were taken from selected treatments. At the low fertility sites (both potassium and phosphorus) samples were taken from the control and the two broadcast rates at the planted populations of 23,000 and 33,000 plants per acre. At the high fertility sites, samples were taken from the control treatment at the planted populations of 23,000 and 33,000 plants per acre.

The selected treatments were sampled twice for root measurement. The samples were collected at 46 and 60 days after planting at Goodhue County and 51 and 68 days after planting at Lamberton. Whole plant samples were collected from all plots for the 1st sampling. These samples were dried, weighed, ground, and analyzed for K or P. Total dry matter production was measured at physiological maturity. A 35-foot section of row was harvested with a PTO driven forage harvester.

Results and Discussion

Potassium Study

The effects of planted population and application of potash fertilizer on early corn growth, K concentration in young plants, K uptake by young plants, total dry matter production, grain moisture at harvest and grain yield at the Goodhue County sites are summarized in Tables 3 through 10.

Dry matter production by corn plants at 46 days after planting is reported as pounds of dry matter per acre (Table 5). This value was calculated from plant weight and emerged plant population data. As would be expected, this value increased with both plant population and fertilizer use (Tables 3 and 4). Application of K_2O produced substantial increases in early growth, but there were no differences between the three K_2O treatments.

The concentration of potassium in the young corn plants was increased by potash application at the low testing site (Table 4 and 6). The planted population had no significant effect on this measurement and there was no interaction between planted population and the use of potash fertilizer. The use of 40 lb. K_2O per acre in a starter produced higher concentrations than the broadcast application of 100 lb. potash per acre. The potassium concentration in the whole plant tissue was not affected by treatment at the high testing site. This can be explained by the high soil test value for potassium (248 ppm).

Potassium uptake by the young plants was significantly affected by both planted population and potash fertilization at the low K site (Table 4 and 7). Uptake increased curvilinearly with planted population. As would be expected, uptake was enhanced by potash fertilization. The uptake from 40 lb. K_2O per acre in a starter was equivalent to uptake from the broadcast application of 100 lb. K_2O per acre. The uptake was not affected by treatment at the high K site. These results are consistent with the potassium concentration data.

Dry matter yields from both sites are summarized in Table 8. In general, the dry matter yields were higher at the site having the high soil test value for K. For the low K site, dry matter production was significantly affected by fertilizer treatment, but not plant population (Table 4). Total dry matter production was not affected by either planted population or fertilizer application at the site having the high soil test value for potassium.

The moisture content of the grain at harvest was not affected by fertilizer treatment (Table 3, 4 and 9). Grain moisture, however, did increase as planted population increased. This was true for both (high K test, low K test) sites. This would be expected in a year when grain moisture was high and slow in-field drying was a problem.

The grain yield at the site having the low K test was improved by the application of potash fertilizer (Table 4 and 10). The planted population, however, had no significant effect on yield. The yields resulting from the use of 40 lb. K_2O per acre in a starter fertilizer were equivalent to yields produced by the broadcast application of either 100 or 200 lb. K_2O per acre. There was also no significant fertilizer treatment by planted population interaction at this site (Table 4). The yields were lower than anticipated which can be attributed to the very cool growing season and slight damage from a frost on June 21. The application of potash, regardless of placement and rate, increased grain yield by approximately 30 bu. per acre.

In contrast to the site having the low K test, grain yields were significantly affected by plant population at the site having the high K test. The response was curvilinear. A planted population of 28,000 plants per acre appeared to be optimum. The use of 15 lb. K_2O per acre in a starter had no significant effect on yield and the plant population by fertilizer treatment interaction was not significant.

The measurement of root density for all samples collected during the growing season is not complete, but the available data are summarized in the Tables 11-14. Values for mean root length density are quite low, probably due to the cold soil conditions which inhibited root growth. At the Goodhue County sites, frost damage was apparent at the 1st sampling date. The low mean values and contribute to high CV's of about 80-100%.

The root density at the low K site was significantly affected by plant population with a higher density at a planted population of 33,000 plants per acre (Table 11). This observation was for the sampling at 46 days after planting (5 collars, 7-8 leaf stage). The average root density was also higher for the 33,000 plants per acre population for this sampling at the high fertility site.

At the second sampling (59 DAP, 6-7 collar, 8-10 leaf), the trend was the same for the high fertility site (Pr>F = .08). At the low fertility site, however, there were no significant differences due to plant population (Pr>F = .11). In situations where plant population had a significant effect on root density, there was never a significant interaction with the position from which the sample was collected. The absence of the significant interaction indicates that planted population does not change the pattern of root development at 46 days after planting.

The broadcast application of 200 lb. K_2O per acre produced a highly significant increase in root density for the first sampling at the low fertility site (Table 12). Increases in density were also noted for the 59 DAP sampling at the high fertility site. For the data sets where root measurements have been completed, there were no significant interactions between fertilizer use and the position from which the sample was taken (Tables 13, 14). However, there does appear to be a trend for fertilization to result in higher root densities below the 6" depth.

Phosphorus Study

Effects of planted population and application of phosphate fertilizer on early corn growth P concentration and uptake, total dry matter production, grain moisture at harvest, and grain yield at the Lamberton site are summarized in Tables 15-22.

Whole plant weights are reported as pounds of dry matter per acre. Again, dry matter production at 50 days after planting (DAP) was affected by plant population at both sites (Tables 15-17). The whole plant weight at the low fertility site increased as rate of phosphate increased. Plant weights from the use of the starter were equivalent to those resulting from the broadcast application. The use of 23 lb. P_2O_5 per acre in a starter also increased the weight of the young corn plants at the high fertility site. There was no significant interaction between fertilizer treatment and plant population at either site in 1992 (Tables 15 and 16).

Phosphorus concentrations in corn plants sampled at 51 days after planting are summarized in Table 18. When the soil test for P was low, phosphorus concentration in the plant was significantly affected by both planted population and applied phosphate (Table 16). In general, the concentration decreased as plant population increased. The use of phosphate, as either a starter or broadcast application, produced a substantial increase in phosphorus concentration (Table 16). Neither planted population nor the use of 23 lb. phosphate per acre in a starter fertilizer increased the phosphorus concentration in corn at the site with the high soil test for phosphorus (Table 15).

The uptake of phosphorus at this stage of growth is reported in pounds per acre (Table 19). When the soil test level for phosphorus was low, uptake was significantly affected by both plant population and phosphate fertilizer application (Table 16). Considering the effect of these two factors on the concentration of phosphorus in plant tissue, these effects could be anticipated. For the soil with the high phosphorus test, uptake was affected by population (Table 15). This observation is consistent with the fact that dry matter production increased with plant population.

The total amount of dry matter produced at physiological maturity was affected by both planted population and fertilizer treatment at the low fertility site (Table 15 and 20). Dry matter yields increased as plant population increased through 43,000 plants per acre. Dry matter production was also increased by the use of phosphate fertilizer. The use of 40 lb. P_2O_5 per acre in a starter or a broadcast application of 100 lb. P_2O_5 per acre produced optimum dry matter. Dry matter production at the high fertility site was not affected by the application of phosphate fertilizer in the starter (Table 16). Dry matter production at this site was affected by plant population. In general, yields increased as plant population increased.

The use of phosphate fertilizer reduced the moisture content of the grain at harvest at both sites (Table 15, 16 and 21). At the low fertility site, moisture decreased as the rate of phosphate applied increased. The application of 23 lb. P_2O_5 per acre in the starter was adequate to reduce moisture content of the grain at the high fertility site. The reduction in the moisture content of the grain is an advantage of phosphate fertilization that is frequently overlooked.

Considering grain yields, the effect of planted population was not consistent with site (Table 22). The planted population had no significant effect at the low fertility site (Table 16). There was, however, a curvilinear response at the high fertility site. The planted population by fertilizer application interaction was not significant at either site.

When the phosphate applications are considered, yields at the low P site increased as the broadcast rate of phosphate increased from 100 to 200 lb. per acre. The yields resulting from the use of 40 lb. P_2O_5 per acre in a starter were equivalent to yields produced by the broadcast application of 100 lb. P_2O_5 per acre.

Measurement of root densities from selected treatments has not been completed at the time of preparation of this report. The root density data that are available are summarized in the Tables 23-25.

For the first sampling (51 DAP; 6-7 collar; 7-9 leaf), root densities were much higher at the site with the low phosphorus soil test (Table 23). Planted population had no significant effect on root density at the low P site, but was significant at the high P site. The higher population was associated with higher root densities.

At Goodhue County, it was apparent that potash fertilization increased root density. This was not the case at the Southwest Experiment Station. When sampled 51 DAP, root densities were much higher at the low P site and the use of 200 lb. P_2O_5 per acre did not affect the density measurement (Table 24). Although root densities in the top 6 inches were higher in the control treatment, the densities tended to increase in the 6-12 and 12-24 inch depth increments with fertilizer application (Table 25). Although standard statistical analysis showed that this interaction was not significant, the large amount of variability in the measurement data may be masking true treatment effects.

Table 1. Soil test values for K at the experimental sites in Goodhue County in 1992.

Depth	Site: High K	Site: Low K
inches	---- ppm K ----	
0-6	248	77
6-12	106	79
12-24	96	97
24-36	88	84

Table 2. Soil test values for P (0-6 inches) at the experimental sites at the Southwest Experiment Station.

Time	Treatment in 1991	Site: High P	Site: Low P
		---- ppm P ----	
spring 1991	-	22	6
spring 1992	-	24	6
spring 1992	40 lb. P_2O_5/acre (starter)	-	4
spring 1992	100 lb. P_2O_5/acre (broadcast)	-	7
spring 1992	200 lb. P_2O_5/acre (broadcast)	-	14
spring 1992	23 lb. P_2O_5/acre (starter)	26	-

Table 3. Combined statistical analysis for early plant growth, percent K, K uptake, biomass at maturity, grain moisture content and grain yield at the Goodhue County high K site, 1992.

Source of Variation	df	Early Plant Growth	Percent K	K Uptake	Biomass at Maturity	Grain Moisture	Grain Yield
K Rate	1	*	NS	*	NS	NS	NS
Population	4	*	NS	+	NS	*	**
K x P	4	NS	NS	NS	NS	NS	NS
CV		23.5	5.3	26.5	10.9	6.2	4.7

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

Table 4. Combined statistical analysis for early plant growth, percent K, K uptake, biomass at maturity, grain moisture content and grain yield at the Goodhue County low K site, 1992.

Source of Variation	df	Early Plant Growth	Percent K	K Uptake	Biomass at Maturity	Grain Moisture	Grain Yield
K Rate	3	**	**	**	**	NS	**
Population	4	**	NS	+	NS	**	NS
K x P	12	NS	NS	NS	NS	NS	NS
CV		21.5	22.5	32.0	10.7	2.2	10.2

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

Table 5. Dry weight of young corn plants at 46 days after planting at the Goodhue County sites as affected by planted population and use of potash fertilizer.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low K Site:	- - - - - - lb. dry matter/acre - - - - - - -				
control	228.0	322.8	244.1	265.6	311.2
40 lb. K_2O/acre(starter)	315.9	316.8	339.4	427.6	452.9
100 lb. K_2O/acre(broadcast)	337.7	350.6	374.3	466.2	461.6
200 lb. K_2O/acre(broadcast)	370.0	368.1	287.0	408.9	431.2
High K Site:					
control	437.2	614.3	598.4	615.5	723.0
15 lb. K_2O/acre(starter)	500.4	382.3	443.3	585.4	610.1

Table 6. The effect of planted population and potash fertilizer use on the potassium concentration in young corn plants at the Goodhue County sites.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low K Site:	- - - - - - - - - - - % K - - - - - - - - - - -				
control	1.09	1.19	1.03	1.06	1.04
40 lb. K_2O/acre(starter)	2.20	2.40	2.29	2.17	2.22
100 lb. K_2O/acre(broadcast)	1.86	1.46	1.71	2.06	1.90
200 lb. K_2O/acre(broadcast)	2.63	2.44	2.15	2.36	2.18
High K Site:					
control	4.41	4.57	4.53	4.48	4.55
15 lb. K_2O/acre(starter)	4.61	4.50	4.51	4.49	4.50

Table 7. The effect of planted population and potash fertilizer use on the potassium uptake by young corn plants at the Goodhue County sites.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low K Site:	- - - - - - - - - lb. K/acre - - - - - - - - - -				
control	2.5	4.2	2.6	3.0	3.2
40 lb. K_2O/acre(starter)	6.9	7.8	7.6	9.0	9.7
100 lb. K_2O/acre(broadcast)	6.1	5.2	6.4	9.4	6.9
200 lb. K_2O/acre(broadcast)	10.1	8.8	6.2	9.5	9.4
High K Site:					
control	19.5	28.2	27.1	27.5	33.2
15 lb. K_2O/acre(starter)	23.3	17.3	20.0	26.3	27.3

Table 8. The effect of planted population and potash fertilizer application on dry matter production at physiological maturity at Goodhue County.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low K Site:	- - - - - - ton dry matter/acre - - - - - - -				
control	6.6	6.3	5.8	6.3	6.0
40 lb. K_2O/acre(starter)	6.2	7.9	7.3	7.3	7.1
100 lb. K_2O/acre(broadcast)	5.9	6.9	6.6	7.5	7.1
200 lb. K_2O/acre(broadcast)	7.0	6.9	6.7	7.3	8.0
High K Site:					
control	7.2	7.8	7.9	8.3	7.9
15 lb. K_2O/acre(starter)	6.9	7.8	8.2	7.3	7.2

Table 9. The effect of planted population and fertilizer treatment on the moisture content of grain at harvest at the Goodhue County sites.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low K Site:			% H_2O		
control	34.7	36.6	36.2	38.7	38.6
40 lb. K_2O/acre(starter)	34.2	35.8	36.7	36.7	37.7
100 lb. K_2O/acre(broadcast)	34.4	35.9	36.2	36.5	37.3
200 lb. K_2O/acre(broadcast)	33.9	35.5	36.0	37.6	37.9
High K Site:					
control	33.5	34.5	34.3	36.1	36.2
15 lb. K_2O/acre(starter)	33.4	34.4	35.5	35.3	35.9

Table 10. The effect of planted population and fertilizer treatment on corn grain yield at the Goodhue County sites.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low K Site:			bu./acre		
control	116.2	114.0	113.2	112.2	115.0
40 lb. K_2O/acre(starter)	147.2	140.1	141.4	147.5	136.3
100 lb. K_2O/acre(broadcast)	132.5	124.0	137.5	140.7	143.0
200 lb. K_2O/acre(broadcast)	142.5	141.5	140.2	138.7	139.1
High K Site:					
control	133.3	151.9	156.0	152.6	148.8
15 lb. K_2O/acre(starter)	141.4	152.7	148.2	157.3	155.0

Table 11. Mean root density as affected by planted population and relative soil test level for K at 46 and 59 days after planting (DAP).

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/acre		cm/cm^3		
23,000	.09*	.17	.16	.32
33,000	.14	.26	.21	.27
Pr>F	.09	.01	.08	.11

* Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Table 12. Mean root density 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/acre	cm/cm^3	
High	-	.12*	.19
Low	0	.15	.20
"	100	-	.36
"	200	.27	.28

* Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Table 13. Root density as affected by K_2O application and planted population at 46 DAP at the low fertility site.

K_2O Applied	Population	Distance From Row	Depth of Sample (inches) 0-3	3-6	6-12	12-24
lb./acre	plants/acre	inches	- - - - -	cm/cm^3	- - - - -	
0	23,000	3	.05	.41	.10	.005
	"	6	.14	.29	.08	.01
	"	12	.01	.11	.02	.02
200	23,000	3	.21	.44	.17	.06
	"	6	.35	.46	.22	.05
	"	12	.12	.38	.12	.02
0	33,000	3	.20	.52	.17	.09
	"	6	.15	.82	.06	.02
	"	12	.08	.11	.13	.006
200	33,000	3	.39	.60	.22	.04
	"	6	.49	.97	.41	.05
	"	12	.14	.32	.19	.01

Table 14. Root density at 59 DAP at various positions as affected by fertilizer application at the low K site.

K_2O Applied	Distance From Row	Depth of Sample (inches) 0-3	3-6	6-12	12-24
lb./acre	inches	- - - - - - -	cm/cm^3	- - - - - - -	
0	3	.32	.25	.35	.07
	6	.17	.46	.15	.05
	12	.09	.24	.19	.08
100	3	.46	.63	.46	.09
	6	.40	.44	.28	.13
	12	.37	.65	.26	.09
200	3	.28	.61	.41	.12
	6	.17	.57	.30	.09
	12	.13	.30	.31	.06

Table 15. Combined statistical analysis for early plant growth, percent P, P uptake, biomass at maturity, grain moisture content and grain yield at the Southwest Experiment Station, Lamberton, high P site, 1992.

Source of Variation	df	Early Plant Growth	Percent P	P Uptake	Biomass at Maturity	Grain Moisture	Grain Yield
P Rate	1	NS	NS	NS	NS	*	NS
Population	4	**	NS	**	*	NS	**
P x Pop	4	NS	NS	NS	NS	NS	*
CV		14.1	6.8	16.9	9.9	4.1	4.8

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

Table 16. Combined statistical analysis for early plant growth, percent P, P uptake, biomass at maturity, grain moisture content and grain yield at the Southwest Experiment Station, Lamberton, low P site, 1992.

Source of Variation	df	Early Plant Growth	Percent P	P Uptake	Biomass at Maturity	Grain Moisture	Grain Yield
P Rate	3	**	**	**	+	**	+
Population	4	**	*	**	**	NS	NS
P x Pop	12	NS	NS	NS	NS	NS	NS
CV		14.9	10.3	19.6	12.5	6.1	9.5

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

Table 17. The effect of planted population and phosphate fertilizer application on early growth of corn at the Southwest Experiment Station.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low P Site:			lb./acre		
control	1912	2471	2609	3078	3240
40 lb. P_2O_5/acre(starter)	3013	3804	4688	5220	5300
100 lb. P_2O_5/acre(broadcast)	3579	3535	3574	4479	4503
200 lb. P_2O_5/acre(broadcast)	3829	3860	4675	5556	4870
High P Site:					
control	2609	3662	4048	4092	4288
23 lb. P_2O_5/acre(starter)	3274	3675	4603	4612	4868

Table 18. The effect of planted population and phosphate fertilizer application on the phosphorus concentration in young corn plants at the Southwest Experiment Station.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low P Site:			% P		
control	.278	.290	.232	.270	.254
40 lb. P_2O_5/acre(starter)	.320	.322	.297	.296	.276
100 lb. P_2O_5/acre(broadcast)	.357	.389	.341	.351	.333
200 lb. P_2O_5/acre(broadcast)	.444	.464	.474	.433	.425
High P Site:					
control	.466	.456	.428	.450	.461
23 lb. P_2O_5/acre(starter)	.458	.445	.455	.456	.448

Table 19. The effect of planted population and phosphate fertilizer application on phosphorus uptake by young corn plants at the Southwest Experiment Station.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low P Site:			lb. P/acre		
control	5.7	7.4	6.4	8.6	8.6
40 lb. P_2O_5/acre(starter)	9.5	12.2	14.2	15.4	14.6
100 lb. P_2O_5/acre(broadcast)	12.8	13.9	12.4	15.7	15.2
200 lb. P_2O_5/acre(broadcast)	16.9	17.9	22.2	24.1	20.9
High P Site:					
control	12.5	16.8	17.5	18.3	19.8
23 lb. P_2O_5/acre(starter)	15.5	16.5	21.0	21.0	22.0

Table 20. The effect of planted population and phosphate fertilizer application on total dry matter production at physiological maturity at the Southwest Experiment Station.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low P Site:			ton dry matter/acre		
control	6.3	7.3	7.4	8.1	8.3
40 lb. P_2O_5/acre(starter)	8.8	8.5	7.6	8.5	9.0
100 lb. P_2O_5/acre(broadcast)	8.0	8.5	9.2	10.0	9.6
200 lb. P_2O_5/acre(broadcast)	8.1	8.0	9.3	9.1	9.9
High P Site:					
control	6.8	7.7	8.4	8.2	8.6
15 lb. P_2O_5/acre(starter)	7.6	8.0	8.3	8.3	8.8

Table 21. The effect of planted population and phosphate fertilizer application on the moisture content of grain at harvest at the Southwest Experiment Station.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low P Site:			% H_2O		
control	27.3	25.8	26.6	28.6	27.8
40 lb. P_2O_5/acre (starter)	24.4	22.7	22.8	24.1	24.0
100 lb. P_2O_5/acre (broadcast)	27.1	26.3	25.2	25.1	25.7
200 lb. P_2O_5/acre (broadcast)	25.4	26.0	24.5	23.6	24.7
High P Site:					
control	23.8	23.2	23.2	23.6	24.8
15 lb. P_2O_5/acre (starter)	23.1	23.3	22.9	22.4	22.7

Table 22. The effect of planted population and phosphate fertilizer application on grain yield at the Southwest Experiment Station.

Treatment	Planted Population 23,000	28,000	33,000	38,000	43,000
Low P Site:			bu./acre		
control	116.1	126.4	122.6	121.6	124.1
40 lb. P_2O_5/acre (starter)	132.5	146.6	146.1	161.1	145.2
100 lb. P_2O_5/acre (broadcast)	143.3	138.2	152.1	159.4	147.6
200 lb. P_2O_5/acre (broadcast)	154.9	160.0	159.2	162.6	154.7
High P Site:					
control	134.7	138.2	147.0	139.9	123.5
15 lb. P_2O_5/acre (starter)	133.5	148.6	143.4	153.0	136.3

Table 23. Mean root density as affected by planted population and relative soil test level for P at 51 and 68 days after planting at the Southwest Experiment Station Site.

Planted Population	Time of Sampling and Soil Test Level: 51 DAP High P	51 DAP Low P	68 DAP High P	68 DAP Low P
plants/acre		cm/cm^3*		
23,000	.18*	.84	.74	NA
33,000	.37	.61	.51	NA
Pr>F	.02	.14	.09	-

NA = Measurements not completed

* Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Table 24. Mean root density as affected by soil test level and fertilizer phosphate use at 51 and 68 days after planting at the Southwest Experiment Station.

Soil Test Level	P_2O_5 Applied	Sampling Time: 51 DAP	68 DAP
	lb./acre	cm/cm^3	
High	0	.28*	.63
Low	0	.79	-
"	200	.66	-

* Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Table 25. Root density as affected by P_2O_5 application and planted population at 51 days after planting at the Southwest Experiment Station.

P_2O_5 Applied	Planted Population	Distance From Row	Depth of Sample (inches) 0-3	3-6	6-12	12-24
lb./acre	plants/acre	inches	- - - - -	cm/cm^3	- - - - -	
0	23,000	3	2.87	1.62	.17	.18
	"	6	2.07	1.30	.20	.03
	"	12	.98	1.24	.33	.20
200	23,000	3	1.80	1.75	.45	.32
	"	6	.60	.63	.45	.24
	"	12	.52	1.11	.64	.07
0	33,000	3	1.72	1.99	.16	.17
	"	6	.70	.62	.58	.06
	"	12	.65	1.09	.14	.05
200	33,000	3	.74	.72	.40	.25
	"	6	.17	1.29	.28	.26
	"	12	1.37	.79	.64	.11

EFFECTS OF NUTRIENT SOURCES, APPLICATION TIMING AND RATE ON ALFALFA PRODUCTION AND SUBSEQUENT CORN CROPS

M.A. Schmitt, C.C. Sheaffer and G.W. Randall[1/]

This is an annual report of a long-term research project investigating the effects of manure and fertilizer on alfalfa establishment and production, soil N contents, and the resulting N effects the alfalfa/manure treatment combinations provide for subsequent corn crops. The 1992 growing season was the fourth year of the study.

Corn was the only crop grown in 1992. At two of the sites, corn was being grown for the second year following alfalfa plowdown while at the other site corn was grown where the alfalfa was plowed the previous fall. Previous Bluebook reports provide the 1989, 1990, and 1991 data.

Objectives

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

Specific objectives are:

1. Evaluate the effects of plowdown and topdress fertilizer applications, commercial and manure fertilizer sources, and rates of nutrient applications on alfalfa nutrient uptake, forage quality, stand density, and dry matter production.

2. Monitor soil N forms from the manure treatments while the alfalfa was growing to assess potential for excessive nitrate accumulation.

3. Determine the N fertilizer replacement equivalent (credit) for alfalfa/manure treatment combinations for the corn crops grown in the years after the alfalfa is plowed.

4. Compare and evaluate the overall economic feasibility of the fertility treatments in a 5-year rotation.

In 1992, issues associated with objective 3 are addressed.

Materials and Methods

A long-term project was started to examine the effects of manure fertilization on alfalfa. Trials were established at University of Minnesota Agricultural Experiment stations at Rosemount and Waseca. At Rosemount, hog manure was used on a shallow Waukegon silt loam soil lying on outwash gravel subsoil. At Waseca, dairy manure was used on a Nicollet clay loam soil. Two plot areas were established at Rosemount to offset potential confounding effects of years. The two Rosemount sites were direct seeded with alfalfa on April 25, 1989 (designated Rosemount-South) and April 24, 1990 (designated Rosemount-North). The Waseca plot area was direct seeded on May 16, 1989.

Nutrient application rates were based on the estimated two-year nutrient needs of alfalfa and the prevalent range of manure application rates commonly used by farmers. Three rates of manure (3000, 6000, and 12000 gal/acre) were broadcast and incorporated immediately prior to establishment of the alfalfa. Three inorganic commercial fertilizer treatments were also used--applied to give equivalent phosphorus (P) and potassium (K) rates as contained in the three rates of manure. Including a control, there was a total of seven fertility treatments replicated four times in a randomized, complete-block design. Total N application based on 3000, 6000, and 12000 gal/acre treatments and manure-N analysis was 231, 462, and 924 lb N/A at Rosemount-South, 159, 318, and 636 lb N/A at Rosemount-North, and 108, 216, and 432 lb N/A at Waseca.

[1/] Schmitt is Extension Soil Fertility Specialist, Department of Soil Science, St. Paul; Sheaffer is Agronomist, Department of Agronomy and Plant Genetics, St. Paul; and Randall is Soil Scientist, Southern Experiment Station, Waseca, all with the University of Minnesota.

Dependent variables associated with the alfalfa phase of this study were related to forage productivity. Dry matter yield was measured at each harvest and plant samples were collected at each harvest for total nutrient analysis. Stand density measurements and weed pressure estimates also were made. After the second year, before the alfalfa was plowed, subplots were undercut and crown counts, crown and taproot dry matter yields and N contents measured. The plots were subdivided at this time, with one half of the plot having its last cut of alfalfa harvested and the other half of each plot having its late summer regrowth plowed under. Thus, the plot design is a split plot.

Corn production practices were followed according to optimum management principles. No N fertilizers were added to the plots. At the time of alfalfa plowdown, broadcast applications of P and K were made to exceed corn crop removal amounts for the next several years. This was done to eliminate the effect of added P and K in the manure confounding the N focus. The corn is harvested from 2-20 ft rows within each subplot.

Fertilizer N equivalency plots were established so that the corn yield response to manure- and/or alfalfa-N could be compared to corn response to fertilizer N. The fertilizer N plots were established where corn followed alfalfa, followed second-year corn after alfalfa, and where continuous corn was being grown. Rates of N were 0 to 180 lb N/acre in 30 lb increments.

Soil samples were taken on the control plots and plots where manure had been applied as a preplant treatment for alfalfa. Samples were collected in early April, mid May, and early June from depths to 3 ft in 1-ft increments. These samples were then analyzed for nitrate-N and ammonium-N.

Results

Corn Production after Alfalfa-Objective 3

There was no effect of alfalfa's preplant manure or fertilizer treatments on grain yields when corn was grown following plowdown at Rosemount (North) in 1992 (Table 1). This is consistent with the other two sites' results in 1991. Although no response to fertilizer N was measured as a function of preplant manure and fertilizer treatments, there was a significant yield difference between the subplots where fall regrowth was either removed or left on the field. On average, subplots that had their fall regrowth left on the field yielded 8 bu/A more than subplots where the regrowth was removed.

Yields from corn that followed alfalfa in the N equivalency plots indicate no grain response to fertilizer N (Table 2). Thus, the grain yields from plots that had been fertilized with manure or fertilizer in 1989 obtained their N needs from the alfalfa N credit and any possible additional N from manure would not add to yield.

Although there were no statistical differences among treatments, soil nitrate-N measurements from one-foot samples taken in June indicate slight increases where manure had been applied at this Rosemount-North location (Table 3). At the Rosemount-South and Waseca sites, second-year corn following alfalfa was grown in 1992. At both of these sites, yield levels were lower than expected (Table 4). At the Rosemount site, a soil rootworm problem created a root pruning and lodging problem that lowered yield and confounded the N responses because it was observed that lodging decreased as fertilizer N rate increased. At Waseca, as well as at Rosemount to some degree, early season N deficiencies were observed on all plots probably due to the unseasonably cool conditions decreasing mineralization of alfalfa- and manure-N.

At Rosemount-South, second-year corn after alfalfa yields did significantly increase with increasing manure rates (Table 4). The before-mentioned rootworm damage did not affect the N equivalency plots, thus comparing the manured plots and the N equivalency plots is not recommended. The soil nitrate data measured in June for the top foot of soil indicates very low amounts of N (Table 3). The soil nitrate-N concentrations, increased by 25% between the low and high manure rate treatments.

At Waseca, corn was grown for the second consecutive year and yields were increased on plots that had received preplant alfalfa treatments of fertilizer or manure compared to the control (Table 4). Because the Waseca site was responsive to P and K fertilizer, significantly higher alfalfa yields had been produced with P and K fertilizer. Because a blanket application of P and K was made to all plots, the corn yield response would be due to N from alfalfa rather than P and/or K. Stand counts for all treatments was greater than five plants per square foot, thus the recommended N credit amount would have been the same for all treatments. Soil nitrate data indicate little residual effect of manure-N at this time (Table 3). Based on the relatively low amounts of manure-N applied at this site, the persistency of soil nitrate at this time is not expected.

The generalized effect of crop rotation and corn yields at Rosemount is exhibited in Table 2. The N equivalency plot data confirms the benefit of having alfalfa in the rotation based on corn yields. Corn yields following alfalfa were around 170 bu/A without any response to added N fertilizer. For second-year corn yields, yields were in the 135 bu/A range with 90+ lb N/A necessary. With a continuous corn system, corn yields plateaued around 125 bu/A and needed 120+ lbs N per acre. Due to the leveling of the yields, it is evident that rotational factors other than just N are contributing to lower yields.

Summary

Regardless of whether manure has been applied to alfalfa or not, corn grain yields following the alfalfa do not respond to added fertilizer N. In the second year of corn following alfalfa, there is some residual effects of manure based on N applied in the manure. Manure applied to alfalfa will increase the soil nitrate N concentrations for several years after application. The increase in soil nitrate-N and its persistence is a function of manure application rate. Fertilizer applications of P and K that affect alfalfa yields can have an effect on subsequent corn grain yields. As the number of years of corn increase following alfalfa, fertilizer N needs increase while optimum yields decrease.

Appreciation is acknowledged to the following people who all contributed significantly to the conduct of this experiment in 1992; Andy Scobbie and Doug Swanson at St. Paul, Brian Anderson at Waseca, and Dave Sandstrom at Rosemount.

Table 1. Corn grain yields following alfalfa as affected by preplant nutrient applications to alfalfa and fall cutting management at Rosemount-North, 1992.

Treatment	4th Cut Removed	No 4th Cut	Average
	- - - - - - -	bu/acre	- - - - - - -
Control	162	163	163
Manure-Low	158	167	163
-Medium	161	168	165
-High	167	178	173
Fertilizer-Low	164	168	166
-Medium	160	165	163
-High	154	174	164
Average	161	169	
	- - - - - - -	Pr.>F	- - - - - - - -
Source of variation:			
Preplant treatment			0.3985
Regrowth removal	0.0002		
Interaction			0.7370

Table 2. Corn grain yield response to fertilizer N as affected by previous two years' crops at Rosemount, 1992.

Fertilizer N Rate	Previous Crops[1/] A-A-C	A-C-C	C-C-C
- - lb N/A - - -	- - - - - - - -	bu/A	- - - - - - - -
0	170	104	77
30	172	116	88
60	169	116	99
90	170	132	112
120		132	125
150		138	122
180		138	119
Treatments(Pr.>F)	0.9914	0.0005	0.0001
LSD	-	10.5	9.8

[1/] Abbreviations for crops are corn (C) and alfalfa (A). Current crop is underlined.

Table 3. Nitrate-N concentrations from top foot of soil when corn was 6-12 inches tall as affected by previous manure treatments at Rosemount and Waseca, 1992.

Treatment	Rosemount-South A-C-C	Rosemount-North A-A-C	Waseca A-C-C
	- - - - - - - - - - - -	ppm NO_3-N	- - - - - - - - - - - -
Control	5.8	17.9	4.0
Manure-Low	6.1	19.7	4.0
-Medium	6.5	19.1	4.3
-High	7.5	20.4	5.1
	- - - - - - - - - - - -	P.>F	- - - - - - - - - - - -
Treatments	0.0403	0.6551	0.4318
-Linear	0.0063	-	-
-Quadratic	0.7105	-	-

Table 4. Second-year corn after alfalfa grain yields as affected by preplant manure and alfalfa treatment applied in 1989 at Rosemount and Waseca, 1992.

Treatment	Rosemount-South	Waseca
	- - - - bu/A - - - -	
Control	71	50
Manure-Low	77	65
-Medium	86	60
-High	96	62
Fertilizer-Low	-	60
-Medium	-	66
-High	-	69
	- - - - Pr.>F - - - -	
Treatments	0.0142	0.7735
Contrasts:		
Control vs. Others	0.0113	-
Manure vs. Fertilizer	-	-
Manure-Linear	0.0195	-
Fertilizer-Linear	-	-

EVALUATION OF LIMING MATERIALS AND RATE OF APPLICATION FOR ALFALFA PRODUCTION ON IRRIGATED SANDY SOILS.

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

ABSTRACT: This report provides a summary of a study designed to evaluate the use of lime for alfalfa production on irrigated sandy soils. The study established in 1990 is designed to evaluate the effect of liming materials and rate of application on alfalfa yield and soil pH change. Lime has increased alfalfa yield. All sources are equal if applied to supply the same amount of ENP per acre. This project will be continued in 1993.

The cost of lime needed for profitable alfalfa production is substantial in many parts of Minnesota. There are some alternative materials that might be used for this purpose and there was a need to evaluate these materials.

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 each applied at three rates (4,321, 8,690, 12,960 lb. ENP/acre). The Pel-Lime was also applied at a rate of 2,160 lb. ENP/acre to verify advertising claims. Treatments were arranged in a randomized complete block design with 4 replications. A control treatment was used but it was not included as part of the complete factorial.

All liming materials as well as adequate rates of phosphate, potash, and sulfur were broadcast and incorporated before seeding. Alfalfa was seeded at a rate of 16 lb./acre in late April without a companion crop. Irrigation water, as needed, was applied during each growing season.

Alfalfa yields were recorded in 1990, 1991, and 1992. Two cuttings were taken in 1990 while three cuttings were taken in both 1991 and 1992. Yields are reported as tons of dry matter per acre.

Soil samples (0-6 inches) were collected prior to lime application and the results are listed in Table 1. Each plot was sampled to a depth of 6 in. in the fall of 1990, the spring of 1992, and the fall of 1992 for pH measurement.

RESULTS AND DISCUSSION:

The alfalfa yields measured in 1990, 1991, and 1992 are summarized in Table 2. In 1990, alfalfa yields were quite variable and this is to be expected in the establishment year. In this first year of production, neither the liming material nor the rate of application had a significant effect on dry matter yield.

In 1991, all liming materials increased alfalfa production when compared to the control. A rate of 4,321 lb. ENP per acre was adequate. Considering sources, all had an equal effect on yield. The yield produced by the Pel-Lime applied at a rate of 2,160 lb. ENP per acre was not significantly different from the yield of the control (no lime applied).

Table 1. Relevant soil properties for the experimental site used for the lime source study. Wadena County.

pH	5.4
phosphorus (Bray & Kurtz #1), ppm	66
potassium, ppm	144
exchangeable calcium, ppm	995
exchangeable magnesium, ppm	128
sulfur, ppm	5.8
organic matter, %	3.0

The results for 1992 are similar to those reported for 1991. The source and rate of application had no significant effect on yield. All yields were significantly higher than the yield from the control treatment. The yield from the Pel-Lime treatment, which received 2,160 lb. ENP per acre, was not significantly different than the yield from the control.

[1/] Extension Soil Scientist, Junior Scientist, Assistant Scientist, Respectively.

Table 2. The effect of lime source and rate of application on the yield of irrigated alfalfa.

Liming Material	ENP Rate	1990	Year 1991	1992	Total
	lb./acre	- - - - - - -	ton dry matter/acre	- - - - - - - -	
	0	1.45	4.17	4.10	9.72
Ag-Lime	4,321	1.62	5.05	4.64	11.31
	8,640	1.62	4.88	4.91	11.41
	12,960	1.47	4.96	4.64	11.07
finely ground Ag-Lime	4,321	1.75	4.87	4.53	11.15
	8,640	1.76	4.91	5.08	11.75
	12,960	1.39	5.11	4.63	11.13
sugarbeet lime	4,321	1.71	5.02	4.72	11.45
	8,640	1.54	4.97	4.49	11.00
	12,960	1.56	5.22	5.03	11.81
Pel-Lime	2,160	1.39	4.44	4.41	10.24
	4,321	1.54	4.96	4.64	11.14
	8,640	1.53	4.68	4.73	10.94
	12,960	1.40	4.73	4.44	10.57

The yield totals for the 3 years reflect the results that were measured in 1991 and 1992.

Soil samples were collected from each plot and pH was measured. These results are summarized in Table 3. These results are quite different from what might be expected. To begin with, the pH values measured in the fall of 1990 did not go as high as expected. The application of 12,960 lb. ENP per acre, regardless of source, was expected to raise the soil pH higher than 6.6.

Secondly, all pH values dropped to values that were lower than expected by the spring of 1992. At the present time, the data collected do not provide an explanation for this drop.

Table 3. The effect of lime source and rate of application on soil pH in an irrigated alfalfa field.

Liming Material	ENP Rate	Fall 1990	Sampling Time Spring 1992	Fall 1992
	lb./acre	- - - - - - -	pH	- - - - - - -
-	-	5.6	5.5	5.5
Ag-Lime	4,321	6.0	5.7	5.7
	8,640	6.1	6.0	5.9
	12,960	6.1	5.9	6.2
finely ground Ag-Lime	4,321	6.2	5.8	5.8
	8,640	6.2	5.9	5.8
	12,960	6.5	6.1	5.9
sugarbeet lime	4,321	6.2	5.9	5.6
	8,640	6.4	6.1	5.7
	12,960	6.6	6.3	5.8
Pel-Lime	2,160	5.8	5.5	5.6
	4,321	5.9	5.8	5.7
	8,640	6.2	5.9	5.7
	12,960	6.2	5.9	5.6

SUMMARY:

A the present time, the data collected from this study lead to the following general conclusions. This study will be continued in 1993 and data collected during that growing season may alter these conclusions somewhat.

1. If applied at equivalent rates of ENP per acre, several liming materials seem to have an equal effect on the production of irrigated alfalfa.

2. When compared to the control, all liming materials produced a substantial increase in alfalfa production.

3. Use of Pel-Lime at a less than recommended rate produced less than optimum alfalfa yields.

4. For all lime sources and rates of application, soil pH values are dropping faster than predicted.

LIME REQUIREMENTS OF FIVE FORAGE LEGUMES GROWN ON AN IRRIGATED SANDY SOIL

George Rehm, Dan Schmitz, Andy Scobbie, Craig Sheaffer, and Neal 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 5 legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover) to the application of Ag-lime (0, 2, 4 ton/acre). Total forage produced during the 1992 growing season was affected by both legume and lime use. A rate of 2 ton Ag-Lime per acre was optimum for the 1992 growing season. Plans call for continuing this study in 1993.

There is general agreement that lime is needed for optimum yields when legumes are gown on acid soils. The amount of lime needed, however, may vary with individual legumes. Therefore, this study was conducted to determine the response of birdsfoot trefoil, cicer milkvetch, kura clover, and red clover to the addition of Ag-Lime. 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 of 1991. Soil samples (0-6 inches) were collected prior to planting and the results of the analysis are summarized in Table 1. Ag-Lime at rates of 2 and 4 tons/acre was broadcast and incorporated prior to seeding. An appropriate control (no lime applied) was also used. Adequate amounts of phosphate, potash, and sulfur were also broadcast to the entire plot area and incorporated with the Ag-Lime.

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

pH	5.6
phosphorus (Bray & Kurtz #1)	49 ppm
potassium	126 ppm
sulfate - sulfur	1.7 ppm
organic matter	2.4

Five forage legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover) were seeded on May 6, 1991. These legumes were allowed to establish during the 1991 growing season and no harvests were recorded. The sulfur, phosphate, and potash were topdressed to the established stands in early spring of 1992. The alfalfa was harvested 3 times. All other legumes were harvested twice. First cutting yields were reduced substantially by dry weather during the first part of the growing season. The irrigation system did not function properly and moisture was very limited on this sandy soil

The rates of lime and the 5 legumes were combined in a complete factorial design with 4 replications. A split plot treatment arrangement was used. The various rates of lime were the main plots. The legumes were the sub-plots.

Results and Discussion:

Total yield of each forage for the 1992 growing season is summarized in Table 2. The effect of lime use on the yield of individual cuttings was not consistent and yields are not summarized in this report.

When all legumes are considered, the legume , itself, as well as the rate of lime applied, had a significant effect on forage yield (Table 2). Alfalfa and red clover produced the largest amount of dry matter. Lowest yields were produced by the cicer milkvetch and the kura clover. Birdsfoot trefoil yields were intermediate.

[1/] Extension Soil Scientist, Junior Scientist, Assistant Scientist, Professor, and Extension Specialist-Forage Crops, respectively.

Table 2. The effect of rate of Ag-Lime on the total yield of five forage legumes.

Legume	Ag-Lime Applied (ton/acre) 0	2	4
	- - - - ton dry matter/acre - - - -		
alfalfa	3.02	3.80	3.50
birdsfoot trefoil	2.83	3.01	3.09
cicer milkvetch	1.96	2.19	2.40
kura clover	1.68	2.08	1.97
red clover	3.02	3.55	3.89

Considering the rate of lime applied, the use of 2 ton/acre was adequate for optimum yield in 1992. An increase in rate from 2 to 4 ton/acre had no effect on yield. Added response to lime should be measured in 1993.

POTASSIUM FERTILIZATION AND GROWTH OF FORAGE LEGUMES

George Rehm, Dan Schmitz, Andy Scobbie, Craig Sheaffer, and Neal Martin[1/]

ABSTRACT: This study was conducted because there was a need to determine the potassium requirements for several forage legumes grown on the sandy soils of North-Central Minnesota. Four rates of K_2O (0, 75, 150, 225 lb./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 the plant tissue was measured. Potassium uptake was computed from this information. Even though the soil test for potassium was considered to be low (87 ppm) there was no yield response to applied potash in 1992. Potassium concentrations in the tissue increased and potassium uptake increased with rate of K_2O applied. This study will be continued in 1993.

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. However, there is very little information that describes the potassium requirements for these legumes. Therefore, this study was conducted to determine the response of other legumes to potash fertilization.

Experimental Procedure:

This study was conducted in the field of a cooperating farmer in Todd County starting in the spring of 1991. 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)	92 ppm
K	87 ppm

Four Rates of K_2O (0, 75, 150, 225 lb./acre) were used. These rates were applied to alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, and red clover. These two factors were combined in a complete factorial design with four replications.

The experimental area was corn in 1990 and a disk was used to prepare a uniform seedbed prior to seeding. The legumes were seeded on May 6, 1991. The legumes 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 April of 1992 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.

Results and Discussion:

When total dry matter production for the 1992 growing season is considered, the legume, but not rate of K_2O applied, had a significant effect on production (Table 2). Alfalfa produced the largest amount of dry matter. Total yield from red clover was significantly lower than the yield of alfalfa but significantly higher than the yield of other legumes. Yields from birdsfoot trefoil and cicer milkvetch were equal but lower than the yield from alfalfa and red clover. The kura clover produced the lowest yield.

[1/] Extension Soil Scientist, Junior Scientist, Assistant Scientist, Professor, and Extension Specialist-Forage Crops, respectively.

Table 2. Total yield of five forage legumes as affected by rate of potash applied in 1991 and 1992.

Legume	K_2O Applied (lb./acre) 0	75	150	225
	- - - - - - - - - -	- - ton dry matter/acre - -	- - - - - - - - - -	
alfalfa	6.7	6.5	6.6	6.3
birdsfoot trefoil	4.6	4.9	4.7	4.7
cicer milkvetch	4.8	4.8	4.8	4.8
kura clover	2.5	2.3	2.3	2.6
red clover	5.7	5.8	6.0	5.3

Except for the second cutting of the kura clover, the application of K_2O had no significant effect on the yield of individual cuttings of all legumes. The soil test for potassium of 87 ppm is considered to be in the low range and a response to potash fertilization would be expected. This anticipated response, however, was not observed or measured in 1992. Apparently, the soil was able to supply the amount of K needed for production of these forage legumes.

The concentration of K in the plant tissue was significantly affected by the rate of K_2O applied (Table 3). This effect was significant for nearly all cuttings of all legumes. In general, the K concentration increased as the rate of applied K_2O increased. These data provide a good illustration of the luxury consumption of K.

Table 3. Potassium concentration in the tissue of forage legumes as affected by rate of K_2O applied in 1991 and 1992.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		- - - - - - - - - -	- - % K - -	- - - - - - - - - -	
alfalfa	1	.230	.281	.294	.326
	2	.262	.274	.285	.323
	3	.246	.266	.273	.302
birdsfoot trefoil	1	.198	.260	.274	.298
	2	.209	.232	.250	.266
cicer milkvetch	1	.250	.287	.315	.339
	2	.282	.323	.348	.409
kura clover	1	.188	.209	.217	.261
	2	.199	.209	.241	.253
red clover	1	.203	.248	.253	.251
	2	.175	.208	.220	.237

Potassium uptake for the various legumes is summarized in Table 4. In general, uptake increased as rate of applied K_2O increased. This reflects the positive effect of rate of applied K $_2$O on the K concentration of the various legumes.

When the legumes are considered, uptake was highest when alfalfa was grown. Uptake was high when the cicer milkvetch is considered. Because of the lower yields, lowest K uptake was associated with the kura clover.

Since rate of applied K_2O had no significant on forage yield, the impact of applied K_2O on K uptake has limited meaning.

Table 4. Potassium uptake by forage legumes as affected by rate of potash applied in 1991 and 1992.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		lb. K/acre			
alfalfa	1	143	161	163	179
	2	89	97	105	110
	3	94	100	106	108
	Total:	326	358	374	397
birdsfoot trefoil	1	83	124	128	134
	2	107	116	115	131
	Total:	190	240	243	266
cicer milkvetch	1	108	131	150	145
	2	148	161	167	218
	Total:	256	293	317	363
kura clover	1	63	47	58	70
	2	39	46	49	64
	Total:	102	93	107	134
red clover	1	99	123	141	113
	2	112	136	140	141
	Total:	211	259	281	254

SULFUR FERTILIZATION AND GROWTH OF FORAGE LEGUMES

George Rehm, Dan Schmitz, Andy Scobbie, 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 3 rates of fertilizer S (0, 25, 50 lb./acre) on the yield of 5 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. Current plans are to continue this study in 1993 to measure yield and S uptake.

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 sulfur requirements of several alternative legumes have not been clearly identified. Therefore, this study was conducted to determine the response of birdsfoot trefoil, cicer milkvetch, kura clover, and red clover to sulfur fertilization. Alfalfa was included as a standard for comparison.

Experimental Procedure:

This study was started in the field of a cooperating farmer in Wadena County in the spring of 1991. Soil samples (0-6 inches) were collected prior to planting and the results of the analysis are summarized in Table 1. Adequate amounts of Ag-Lime, phosphate, and potash were broadcast to the plot area and incorporated with a disk prior to planting.

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

pH	5.6
phosphorus (Bray & Kurtz #1)	49 ppm
potassium	126 ppm
sulfate - sulfur	1.7 ppm
organic matter	2.4

Three rates of S (0, 25, 50 lb./acre) were applied to five legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover) in a complete factorial design with four replications. A moldboard 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 the appropriate use of post-emergence herbicides.

The sulfur rates were reapplied to the established plots in the spring of 1992. Granular gypsum was used to supply the sulfur in both 1991 and 1992. Adequate rates of phosphate and potash were also topdressed to the established stand in the spring of 1992.

The alfalfa was harvested three times. The other legumes were harvested twice. Whole plant samples were collected from each plot at each harvest to be analyzed for sulfur. This analysis had not been completed at the time of preparation of this report.

Results and Discussion:

The total dry matter yields for the 1992 growing season are summarized in Table 2. Forage yield was significantly influenced by legume, but not by the rate of fertilizer S applied. Considering the legumes, the alfalfa and red clover produced the largest amounts of dry matter. The cicer milkvetch and kura clover produced the lowest amount of dry matter. Yields of birdsfoot trefoil were intermediate.

[1/] Extension Soil Scientist, Junior Scientist, Assistant Scientist, Professor, and Extension Specialist-Forage Crops, respectively.

The lack of a response to fertilizer S is surprising for this sandy soil. Apparently, the amount of SO_4-S released from the mineralization of soil organic matter was adequate for the reduced yields measured in this study.

Table 2. The effect of rate of sulfur applied on the yield of five forage legumes.

Legume	S Applied (lb./acre)		
	0	25	50
	---- ton dry matter/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

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 second year of work to determine In-season nitrogen needs of 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 N A^{-1}; 0 to 2 foot nitrate-N plus fertilizer) and five topdress N applications (0, 15, 30, 45, and 60 lb N A^{-1}) at tiller growth stage. Preliminary results indicate in some instances the topdress application of N did improve grain yield. Plant parameter measured (NIR total N, Kjeldahl total N, and NIR crude protein) were not affected by the soil N levels at tillering. The soil nitrate-N test for the 0 to 2 depth did characterize the soil N levels.

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 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 50 to 60 percent of the N fertilizer in the fall and determine how much of the remainder to 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 test, or a chlorophyll meter to adjust N fertilizer application to spring wheat during the growing season.

Nine experimental sites were established in western Minnesota in 1992 (Table 1). The initial residual soil nitrate-N at the sites ranged from 14 to 73 lb A^{-1} at the 0 to 2 foot depth. To meet the objective the treatments included a factorial design of three soil NO_3^--N levels (0 to 2 feet) (50, 100, and 150 lb A^{-1}) and five topdress N application rates (0, 15, 30, 45, and 60 lb A^{-1}). The soil N levels were established by applying N fertilizer preplant. This was urea (46-0-0) at all sites except the Hamre site where ammonium nitrate (34-0-0) was used and the lowest N soil N level was 73 lb A^{-1} instead of 50 lb A^{-1}. Marshall hard red spring wheat was seeded at 100 lb A^{-1} in six inch rows with a double disk press wheel drill. Topdress N application of ammonium nitrate (34-0-0) 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. Grain yield , moisture, and protein concentrations were determined on these samples. The grain yield and protein were then corrected to 13.5 % moisture content.

---

[1] This is report is for the second 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, St. Paul, MN, 55108. N. Martin is a Professor in the Department of Agronomy and Plant Genetics at the University of Minnesota, St. Paul, MN, 55108. S.D. Evans and G. Nelson are Professor and Assistant Scientist at the West Central Experiment Station, University of Minnesota, Morris, MN, 56267. B.J. Holder and J. Cameron are Associate Professor and Field Plot Technician at the Northwest Experiment Station, Crookston, MN, 56716.

Table 1. Site location and preplant soil nitrate-N 0-2 ft in 1992.

Site	County	Preplant soil nitrate-N 0-2ft.
		lb A^{-1}
Anderson	Marshall	55
Cassavan	Red Lake	30
Hamre	Becker	73
Houglum	Norman	34
Ness	Norman	14
Sands	Marshall	24
Seeger	Red Lake	29
Morris E	Stevens	52
Morris N	Stevens	16

Grain Yields

Small grain growing conditions were excellent. The air temperatures were cooler than normal which made for a longer grain fill period and substantially later harvest. An early season dry period did cause moisture stress for early planted plots but the moisture was plentiful the rest of the growing season.

At all sites but one, Cassavan, there was a significant grain yield response to the treatments. At this time there is no explanation for this lack of yield response (Tables 2, 3, and 4). At the Seeger site, wild oat infestation caused variable results which is reflected in the coefficient of variability (C.V). The Ness site was affected by lack of early season precipitation. The response was negative to the 150 soil N level at the Hamre location. The rest of the sites; Anderson , Houglum, and Morris N, grain yields responded positively ranging from 4.3 to 6.7 bu A^{-1} to increasing soil N levels.

Topdress N did not affect grain yield at Cassavan, Hamre, Seeger, and Morris N locations. Grain yields were maximized at the 30 lb N A^{-1} topdress N rate at the Anderson site with a 9.5 bu A^{-1} increase over the 0 lb N A^{-1} treatment. At the Houglum site a 9.6 bu A^{-1} increase occurred between 0 and 60 lb N A^{-1} topdress N treatment. The grain yield at the Ness location was increased 5 bu A^{-1}.

Table 2. Grain yield (13.5 % moisture basis) at sites with no statistical significant interactions in 1992.

	Anderson	Cassavan	Hamre	Houglum	Ness	Seeger	Morris N
Soil N	------------------------------ bu/A ------------------------------						
lb A^{-1}							
50	60.8	52.7	47.9	45.8	37.4	54.4	64.6
100	65.3	53.4	48.1	49.6	36.5	61.9	66.7
150	67.5	52.4	44.6	50.1	36.2	62.5	69.3
Topdress N							
0	59.9	53.0	47.8	42.7	34.2	55.1	66.9
15	62.9	52.7	47.9	48.2	35.8	55.6	67.2
30	69.4	52.2	47.3	48.6	36.9	61.3	67.5
45	66.7	54.2	45.7	50.4	37.4	61.9	66.1
60	63.7	52.1	45.7	52.3	39.2	65.7	66.6
Statistical Analyses							
Soil N (SN)	**	NS	*	**	NS	NS	*
Topdress N (TN)	*	NS	NS	**	**	NS	NS
SN x TN	NS	NS	NS	NS	NS	NS	NS
C.V. (%)	11.6	6.4	8.3	8.2	6.1	18.3	5.4

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

There was a significant interaction between soil N level and topdress N for grain yield at the Sands and Morris E sites (Tables 3 and 4). At these sites topdress N application did not increase grain yields at the 100 and 150 soil N levels. Topdress N did increase grain yields at the 50 soil N level. The yields were maximized at 30 and 15 lb N A^{-1} at the Sands and Morris E sites, respectively.

Table 3. Grain yield (13.5 moisture basis) at Sands and Morris E sites in 1992.

	Topdress N (lb A^{-1})				
Soil N	0	15	30	45	60
lb A^{-1}	Grain yield (bu A^{-1})				
	Sands				
50	52.2	61.8	71.0	72.6	73.3
100	72.4	69.3	74.8	67.2	69.8
150	64.0	69.4	68.0	73.8	67.0
	Morris E				
50	58.0	64.8	62.2	64.5	63.8
100	62.6	64.7	66.7	67.0	68.1
150	68.0	63.6	64.9	67.7	63.5

Table 4. Statistical analyses for grain yield at Sands and Morris E locations in 1992.

	Sands	Morris E
Soil N (SN)	NS	NS
Topdress N (TN)	**	NS
SN X TN	*	*
C.V. (%)	9.8	5.0

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

Grain protein

Soil N level increased grain protein at four sites in 1992 (Table 5). The increases were 0.9, 0.8, 0.8, and 1.2% at the Hamre, Houglum, Ness, and Seeger sites, respectively. There were no significant responses at Cassavan, Morris E, and Morris N. Top dress did not significantly increase grain protein at any sites reported in Table 5.

There was significant interaction between soil N and topdress N application at the Anderson and Sands locations (Table 6 and 7). The interaction is not consistent with treatments at the Anderson site and a biological explanation is not possible. At the Sands site topdress N treatment maximized grain protein at the 45, 0, and 0 lb N A^{-1} amounts in the soil N levels of 50, 100, and 150, respectively.

Diagnostic measurements

Chlorophyll was not affected by soil N treatments (Table 8). The time of measurement (tillering) may be too early in plant development for chlorophyll to reflect N status. Soil nitrate-N from 0-1 foot was significantly increased by soil N level at all sites but Ness. At the 1 to 2 foot depth, nitrate-N was significantly increased only at the Anderson, Cassavan,Houglum,and Sands locations. The total nitrate-N in 0 to 2 foot depth was significantly affected (P=0.10) at all locations in 1993. At this time the 0 to 2 foot nitrate-N sample reflects the soil N levels that we were trying to effect with our treatments.

The Kjeldahl N measurements in young plants were affected by soil N treatments at only the Anderson site. At the Anderson site, the increase occurred between the 50 and 100 soil N levels. The NIR total N and crude protein were significantly increased at the Seeger location. This increase only occurred between the 50 and 100 soil N levels. Total N determined by NIR was affected at the Sands site with a small increase between the 50 and 100 soil N levels and a larger increase between 100 and 150 soil N levels.

Table 5. Grain protein concentration (13.5 % moisture basis) at sites with no statistical significant interaction in 1992.

	Cassavan	Hamre	Houglum	Ness	Seeger	Morris E	Morris N
Soil N	------------------------------ % ------------------------------						
lb A^{-1}							
50	13.0	14.0	12.6	13.6	11.4	11.2	11.4
100	13.0	14.2	13.0	14.0	11.9	11.0	11.8
150	13.6	14.9	13.4	14.4	12.6	11.4	11.8
Topdress N							
0	13.3	14.3	13.0	13.6	11.3	11.0	11.6
15	12.8	14.0	12.4	14.0	12.0	11.1	11.6
30	13.0	14.1	13.0	14.1	12.2	11.3	11.7
45	13.7	14.8	13.3	14.0	12.4	11.3	11.6
60	13.2	14.6	13.2	14.3	12.1	11.3	11.8
Statistical Analyses							
Soil N (SN)	NS	**	*	**	**	NS	NS
Topdress N (TN)	NS	NS	NS	NS	NS	NS	NS
SN X TN	NS	NS	NS	NS	NS	NS	NS
C.V. (%)	6.6	5.7	7.1	4.2	5.8	3.4	3.3

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

Table 6. Grain protein concentration (13.5 % moisture basis) at Anderson and Sands site in 1992.

	Topdress N (lb A^{-1})				
Soil N	0	15	30	45	60
lb A^{-1}	Grain protein concentration (%)				
	Anderson				
50	12.3	11.4	12.2	12.0	13.0
100	12.1	12.1	12.2	13.7	12.6
150	12.1	13.1	12.7	12.3	13.2
	Sands				
50	10.0	10.7	11.1	10.9	12.8
100	11.1	12.4	10.6	12.8	12.1
150	12.7	12.4	12.4	12.5	12.5

Table 7. Statistical analyses for grain protein concentration at Anderson and Sands locations in 1992.

	Anderson	Sands
Soil N (SN)	NS	**
Topdress N (TN)	++	NS
SN X TN	*	++
C.V. (%)	6.5	9.6

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

Table 8. Diagnostic measurements (chlorophyll meter, soil nitrate-N, plant total N, and plant crude protein N) made tiller stage of growth in 1992.

						Tiller plant analyses		
		Chlorophyll meter	Soil nitrate-N			Total N		Crude protein
Site	Soil N		0-1 ft.	1-2 ft.	0-2 ft.	Kjeldahl	NIR	NIR
	lb N A^{-1}	units	---------- lb A^{-1} ----------			---------- % ----------		
Anderson	50	37.1	21	17	38	5.18	5.60	33.48
	100	37.5	40	28	68	5.62	5.88	35.28
	150	39.7	63	29	92	5.60	5.96	35.81
Statistic			**	*	**	*	NS	NS
Cassavan	50	39.8	32	28	60	5.25	5.60	33.49
	100	40.8	61	35	96	5.47	5.71	34.10
	150	40.6	98	40	138	5.50	5.80	34.50
Statistic			**	*	**	NS	NS	NS
Hamre	73	39.6	85	44	129	6.08	6.03	36.24
	100	39.4	142	49	191	6.03	6.12	36.65
	150	38.6	150	53	203	5.82	5.85	35.30
Statistic			**	NS	**	NS	NS	NS
Houglum	50	41.8	56	20	76	5.11	5.35	32.25
	100	42.0	110	37	147	5.43	5.51	32.79
	150	42.4	178	46	224	5.34	5.37	32.08
Statistic			**	**	**	NS	++	NS
Ness	50	42.3	60	19	79	6.21	6.28	36.22
	100	42.2	96	36	132	6.32	6.23	35.97
	150	41.0	118	22	140	5.99	6.28	36.30
Statistic			NS	NS	++	NS	NS	NS

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

Table 8. (continued)

Site	Soil N	Chlorophyll meter	Soil nitrate-N			Tiller plant analyses		
						Total N		Crude protein
			0-1 ft.	1-2 ft.	0-2 ft.	Kjeldahl	NIR	NIR
	lb N A^{-1}	units	---------- lb A^{-1} ----------			---------- % ----------		
Sands	50	42.8	58	24	77	5.70	5.81	35.01
	100	43.9	81	39	120	5.90	5.87	35.05
	150	44.9	169	59	228	5.92	6.00	35.53
Statistic			**	**	**	NS	++	NS
Seeger	50	37.9	20	27	47	4.77	4.82	29.00
	100	38.5	79	22	103	5.04	5.40	32.02
	150	39.0	154	39	193	5.32	5.41	31.76
Statistic			**	NS	**	NS	*	*
Morris E	50		52	35	87	5.83	5.90	36.07
	100		70	39	109	6.10	6.03	36.21
	150		88	34	122	5.87	5.98	36.23
Statistic			**	NS	*	NS	NS	NS
Morris N	50		45	18	63	6.35	5.77	35.00
	100		107	32	139	6.62	5.76	35.10
	150		121	22	143	6.41	5.71	34.62
Statistic			*	NS	*	NS	NS	NS

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

CALIBRATION AND CORRELATION OF SOIL N TESTS FOR IMPROVED N RECOMMENDATIONS[1]/

M.A. Schmitt, G.W. Randall, A.J. Scobbie, and S.K. White[2]/

Soil testing, which allows site specific fertilizer recommendations, offers a means of improving nitrogen (N) management for corn production for a given soil/crop/climate. Research throughout the Corn Belt has shown that soil N tests have great potential for refining N rate decisions.

The primary objective of this project is to develop an N soil test that will enable farmers to apply optimum rates of N for corn under a wide variety of soil, crop, and climatic conditions. To meet this objective, an evaluation of different tests or combination of tests, based on sampling time and depth as well as form of N, will be made for measuring and/or assessing available N before and during the growing season for use in predicting fertilizer N requirements for corn.

METHODS AND MATERIALS

Fourteen experimental sites were established in conjunction with participating organizations in 1992 (Table 1). The sites were located primarily on farmer-cooperator fields in south-central, southeastern, and east-central Minnesota on soils derived from glacial till, loess, and glacial outwash, respectively. All sites had well-documented fertilization and manure records and had a range of previous crops. This is the final year of a 4-yr study.

There were ten treatments at most locations. The treatments included a control plot, six preplant N rates (30, 60, 90, 120, 150, 180 lb N/acre) and three split-applied N rates (30 lb N/acre preplant with 30, 60, or 90 lb N/acre sidedressed). Where alfalfa was the previous crop, treatments were 0 lb N/acre preplant with 30, 60, or 90 lb N/acre sidedressed. Urea was broadcast and incorporated for the preplant applications and placed in subsurface bands 3 to 4 in. deep midway between the rows when sidedressed. The sidedress treatments were applied in mid to late June when the corn was 6-12 in. tall.

Soil samples were collected four times during the year: 1) preplant, approximately 2 weeks before planting, 2) 2 to 3 weeks after planting, when the corn was in the 1-2 leaf stage (V1) of growth, 3) about 5 to 6 weeks after planting, when the corn was approximately 12 in. tall (V4), and 4) after grain harvest. The control plots were sampled at each sampling time. The 60- and 150-lb N preplant and the 30+90-lb N split treatments were sampled at the V1 and V4 stages and after harvest. Soil samples were collected in 1-foot increments to a depth of 4 feet for the preplant and postharvest samplings and to a depth of 3 feet for the in-season samplings. The 4-foot samples were collected from 2 cores taken with a hydraulic probe while the in-season samples were collected using hand probes and contained at least 6 cores per sample.

All soil samples were analyzed for ammonium-N and nitrate-N using a Wescan autoanalyzer. Selected treatments were also analyzed for hydrolyzable-N using a phosphate-borate buffer extractant.

Stover and grain yields were measured from each plot after physiological maturity or a killing frost. Total Kjeldahl N was determined in the stover and grain, and nitrate-N was determined in the basal stalk section of the corn plants from selected treatments after maturity. Rainfall and temperature records were recorded from mid-April through July at each site or taken at a nearby weather reporting station.

A randomized complete block design with 4 replications was used at all sites. Plot size ranged from 10 to 15 ft wide (all with 30-in. rows) by 40 to 60 ft long. Statistical analyses of plant data were performed using analysis of variance procedures. Three sets of comparisons were made and are reported in Tables 2 and 3: (a) control and preplant N treatments, (b) preplant compared to split treatments at same N rates, and (c) an overall analyses where all treatments were compared. Treatment differentiations were made using least significant differences (LSD) for preplant N treatments when the Pr>F was less than 10%.

---

[1]/ This project has received direct support from Farmland Industries, Tennessee Valley Authority-National Fertilizer and Environmental Research Center, Greater Minnesota Corporation-Agricultural Utilization Research Institute, USDA-Cooperative States Research Service, and Minnesota Corn Growers Association.

[2]/ Schmitt, Scobbie, and White are Extension Soil Fertility Specialist, Assistant Scientist, and Research Fellow, respectively, St. Paul, and Randall is Soil Scientist, Southern Experiment Station, Waseca, all with the University of Minnesota.

RESULTS AND DISCUSSION

Grain and stover yields

In 1992, grain yield response to fertilizer N occurred at 13 of the 14 locations (Table 2). Corn yields were generally lower than normal due to the cool season and an early frost. Corn was the previous crop at the one non-responsive site (Dakota-2), which had received heavy applications of manure in the past. The 3 sites with second-year corn following alfalfa had optimum preplant N rates ranging from 60 to 120 lb N/acre with grain yield responses of 25 to 61 bu/acre. (Within a location, yield responses were calculated by comparing the average yield of the control plots to the average yield of the plots that received the optimum preplant N rate). Yield responses following small grains (2 sites) ranged from 24 to 53 bu/acre with optimum N rates of 90 and 150 lb N/acre. When following soybeans (3 sites), corn yield responses ranged from 31 to 57 bu/acre with optimum N rates ranging from 60 to 120 lb N/acre. The site which had alfalfa as the previous crop responded to the 30-lb rate of sidedress-applied N.

There were no differences when comparing rates of N applied as split or preplant treatments for 9 of the 13 sites (Table 2). At 3 of the sites, there was an advantage to split N application compared to the preplant application. One of these sites (Sherburne) was on an irrigated, sandy soil and split N treatments are a recommended practice, one site (Wabasha) was in no-till where the preplant N was subject to losses before uptake, and one site (Stevens) had a significant response that is unexplainable at this time. Yield was reduced 11 bu/acre with the split application compared to preplant application at the Blue Earth site.

Stover yield response to fertilizer N occurred at 12 of the 14 locations in 1992 (Table 3). Corn and soybeans were the previous crops at the 2 non-responsive sites. The site that was non-responsive to fertilizer N for grain yield was also non-responsive for stover yield. Split application of N significantly increased stover yields at 3 locations (2 of them on loess sites and 1 on an outwash site) and decreased stover yields at 1 till site.

Soil N concentrations in control plots

Nitrogen transformations in plots that received no preplant N additions can be characterized by following the change in N soil test levels during the season. Because N transformations can be dependent on inherent soil properties, the sites are categorized by soil parent material.

Table 4 lists nitrate-N concentrations that were consistently highest in the top ft of soil and generally increased with each successive sampling from April through June. While nitrate-N can be from residual N from a previous year and accumulate in lower soil levels, the location and low concentrations in 1992 indicate that the nitrate-N was from mineralization of organic N. At the Dakota-2 and Carver sites, there were some significant nitrate-N concentrations in the lower soil depths, most likely from previous documented manure applications. Although most preplant nitrate-N concentrations were low, those sites on loess and glacial till soils generally had the higher concentrations by June.

Ammonium-N concentrations were fairly consistent regardless of the time of sampling and although the highest concentrations were measured in the top foot, there were not large differences in concentrations. Rarely were any differences of 3.0 ppm ammonium-N measured within any given site. The unusually high ammonium-N concentrations at the preplant sampling in Goodhue County are currently unexplainable.

Hydrolyzable-N is a fraction of the soil's organic N that is released during the growing season--an estimate of potentially available N from organic matter, manure, and legumes. Because this value is a portion of the relatively large organic N pool, the lack of concentration differences between sampling times is expected. There is, however, a relationship between organic matter content of the soil and hydrolyzable-N, which is evident when comparing sites with different soil parent materials.

1992 SUMMARY

Grain yield response to applied fertilizer N occurred at 13 of 14 sites in 1992. The lone non-responsive site had a recent history of manure applications. Preplant and split applications of N performed equally well at most sites, the exceptions being where the splits were, for the most part, better than preplant only applications and would have been the recommended application practice for these particular conditions.

Low soil nitrate-N concentrations were characteristic of the year, regardless of previous fertilization/manure history, previous crops, or parent material. This observation can be primarily attributed to the above-average rainfall received during the fall of 1991 throughout the corn-growing regions of Minnesota.

INTERPRETIVE PROJECT SUMMARY, 1989-1992

The primary objective of this project has been to develop an N test that will aid in the refinement of current University of Minnesota N recommendations. Individual year results provide information that are applicable for that year, however, when data is used for predictive uses, multiple years must be combined to develop recommendations. The following discussion briefly outlines how the data was used to select an N test to be used in the corn-growing regions of Minnesota that currently do not use a soil N test.

Model Selection

The components of a soil N test that were evaluated throughout the course of this project were sampling time, sampling depth, and form of N to measure. This projected was conducted at 58 sites located in 19 counties in Minnesota. The initial analysis used was to correlate grain yields with all possible combinations of time, depth, and N form. The most commonly suggested combinations and their correlations to grain yield are listed in Table 5. Simple correlations indicate no cause-and-effect nor quantify any relationship. From the results in Table 5, nitrate had stronger correlation coefficients than the other N forms. For the sampling depths and times, no differentiations based on simple correlations are clear.

The next step used was to evaluate sampling time and depth as well as N form using statistical models. Using a model that represents the yield response to N, these three factors can be compared in terms of model fit and the amount of errors made using the model by comparing the predicted responsiveness with actual site results. Table 6 contains the model information used in selecting the N form, sampling depth, and sampling time for a recommended N test.

In agreement with the simple correlation data, nitrate-N is the clear choice as the N form to measure. Thus, while ammonium-N and hydrolyzable-N may be very important N forms in supplying N to crops, they are not as useful in developing predictive models.

Based on predictive models for nitrate and comparing sampling depths at preplant and when the corn is approximately 12-in. tall, the model fit is better for the 2-ft sample compared to the 1-ft sample. Additionally, at the preplant sampling time, the 3-ft model does not provide a better fit compared to the 2-ft model. Sampling to a depth of 2 ft combines the improved predictability of the data and the feasibility of acceptance by those taking soil samples. A 2-ft sample should also contain the majority of N released from the soil's organic N pool as well as any N leftover from a previous year if used with an in-season sampling time.

Data for comparing the different times of sampling are not as easy to interpret. Assuming a 2-ft nitrate-N test, the early in-season sampling time provided a better model fit. In discerning the sampling time issue, we also considered logistical and theoretical implications. An early season N test will most likely measure residual (carryover) nitrate from the previous year, whereas a test taken during the growing season would include some recently mineralized N along with some possible residual N. Thus, the issue of legume, soil organic matter, and manure credits as part of a N recommendation could be complicated by the use of an in-season test.

If the soil N test is to be used in making a fertilizer recommendation, it is implied that a fertilizer application will need to be made after taking the test. Thus, samples collected after the corn is planted will require a sidedress, topdress, or fertigation N application. Yet, for many crop producers and fertilizer dealers, this situation is not ideal. In evaluating a) the data, b) the implications of sampling time on subsequent fertilizer applications, and c) the issue of crediting legumes and manures, the preplant sampling time was selected for south-central, southeastern, and east-central Minnesota.

Preplant, 2-ft, Nitrate-N Test Model

Figure 1 plots the relative grain yield (control plot yield as a percent of the highest responsive N rate yield for each site) and the preplant, 2-ft, nitrate-N concentration. Errors in using this model occur when there is a non-responsive site (indicated by a "star") with an N test value less than the critical value. When this occurs, the crop producer would be adding fertilizer N and there would be no grain yield response. Because several of these sites were making this error, we graphed the same site information, but now indicating the previous crops for each site (Figure 2). This indicated that whenever alfalfa was the previous crop, low soil nitrate-N values were measured and no yield response to N was measured. Because this is consistent with research in the Upper Midwest, we made the decision to exclude the use of the preplant, 2-ft, nitrate-N test when alfalfa is the previous crop. Our current University of Minnesota recommendations, which recommend no N for most situations when alfalfa was the previous crop, are very appropriate and need no refining. When alfalfa is excluded as a previous crop, the soil N test model (Figure 3) resulted in a better model fit (0.49 vs. 0.41), less errors, and a critical value of 15.9 ppm.

The University of Minnesota has been recommending a spring preplant, 2-ft nitrate-N test for over the past year. When alfalfa is the previous crop or when fertilizer has been added the previous fall, the test should not be used. Based on preliminary results, the critical value of 175 lb nitrate-N/acre was used as a "switch" to indicate when fertilizer N was not needed. The current results indicate that 175 lb N/acre may be too high. Further calibration statistics are being conducted and refinement of this test will be forthcoming. Note that this test is not developed for western Minnesota--a region that has had a soil nitrate test/recommendations in place for numerous years.

Table 1. Characteristics of the 14 sites used for the soil N test evaluation study in 1992.

Ident. Code	County/Site	Cooperator	1990 Crop	1991 Crop	Parent Material	Soil Type	Texture
A	Waseca-1	AES[1/]	soybeans	corn	till	Webster	clay loam
B	Waseca-2	AES[1/]	alfalfa	alfalfa	till	Webster	clay loam
C	Blue Earth	Hiniker	soybeans	soybeans	till	Cordova/ Minnetoka	clay loam
D	Stevens	AES[1/]	heat	oats	till	Nutley	clay
E	Dodge	Jorgenson	corn	soybeans	loess	Mount Carroll	silt loam
F	Goodhue	Foss	corn	soybeans	loess	Port Byron	silt loam
G	Olmsted-1	Lawler	alfalfa	corn	loess	Mount Carroll	silt loam
H	Olmsted-2	Bourquin	alfalfa	corn	loess	Mount Carroll	silt loam
I	Sherburne	AES[1/]	lupine	rye	outwash	Hubbard	loamy sand
J	Dakota-1	Beskau	corn	corn	outwash	Wadena	loam
K	Dakota-2	Conzemius	soybeans	corn	loess	Port Byron	silt loam
L	Chisago	Holmquist	corn	corn	till	Nebish	loam
M	Wabasha	Bremer	soybeans	corn	loess	Fayette	silt loam
N	Carver	Dreier	alfalfa	corn	till	Lester	loam

[1/] Agricultural Experiment Stations (AES).

Table 2. Corn grain yields as a function of N application rate and method, 1992.

N Treatment[1]	Waseca-1 Corn	Waseca-2 Alfalfa[2]	Blue Earth Soyb	Stevens Oats	Dodge Soyb	Goodhue Soyb	Olmsted-1 Corn	Olmsted-2 Corn	Sherburne Rye	Dakota-1 Corn	Dakota-2 Corn	Chisago Corn	Wabasha Corn	Carver Corn
	Location and Previous Crop													
lb/acre	bu/acre[3]													
0	105.8e	152.6b	106.9e	120.6d	104.9d	115.3c	77.2d	144.6c	94.6d	109.5d	149.2	90.6c	65.9d	110.9c
30	131.0d		132.5d	133.4c	123.2c	137.2b	105.9c	160.7b	102.4cd	146.0c	148.1	103.5bc	71.4d	124.3c
60	146.0bc		143.9cd	135.0bc	132.5bc	146.7ab	119.3bc	169.5ab	112.7cd	165.1b	151.6	120.2a	83.5c	123.2c
90	141.8cd		155.7bc	144.1ab	139.7ab	147.8ab	138.0a	164.8ab	121.4bc	176.3ab	149.8	116.5ab	88.7bc	135.1bc
120	156.0ab		163.9ab	148.5a	144.6a	152.2a	128.2ab	171.9ab	116.0bcd	177.3ab	151.2	121.4a	98.7ab	171.1a
150	163.6a		168.6a	152.7a	144.0a	156.0a	136.5ab	175.7a	148.0a	183.2a	159.2	124.2a	102.8a	175.8a
180	154.9abc		161.2ab	145.0ab	137.5ab	[4]	139.7a	172.9ab	137.9ab	186.5a	155.7	122.2a	94.6ab	168.2ab
Pr>F	0.000		0.000	0.003	0.000	0.002	0.000	0.008	0.010	0.000	0.177	0.011	0.000	0.014
LSD(0.10)	13.4		12.7	10.4	11.4	14.6	18.3	12.3	22.7	16.7		14.0	10.7	34.2
CV(%)	7.7		7.0	6.0	7.0	8.3	12.4	6.0	15.4	8.4	4.1	9.9	10.1	19.4
SP 60	136.1	174.7a	141.0	140.3	132.9	147.4	137.7	170.4	124.8	150.2	150.3	123.9	94.7	143.1
90	150.5	173.4a	136.8	151.3	141.8	154.9	127.9	168.0	136.7	173.0	154.6	129.7	101.8	133.3
120	149.8	181.3a	153.3	151.9	137.8	155.2	139.9	165.3	166.5	184.5	156.3	137.3	102.5	165.4
PP Ave.[5]	147.9		154.5	142.5	138.9	148.8	128.5	168.6	117.2	172.9	150.8	119.6	90.3	143.2
SP Ave.[5]	145.5		143.7	147.8	137.5	152.5	135.1	167.9	142.7	169.2	153.6	130.3	99.4	147.2
PP vs SP														
Pr>F	0.555		0.016	0.070	0.757	0.411	0.248	0.775	0.001	0.564	0.527	0.219	0.040	0.609
All trts														
Pr>F	0.000	0.005	0.000	0.000	0.001	0.001	0.000	0.004	0.000	0.000	0.473	0.010	0.000	0.005
CV(%)	7.7	4.8	7.5	5.2	8.0	8.0	11.4	5.4	12.6	8.4	4.9	12.2	9.6	17.0

[1] Nitrogen applications were made preplant (PP) and split (SP = preplant + sidedress).
[2] At this location, the split rates were 0 + 30, 0 + 60, and 0 + 90 lb N/acre.
[3] Grain yields are statistically similar if the same letter follows different treatment means within each location.
[4] At this location, there was no 180-lb N rate.
[5] Yields averaged over the 60, 90, and 120-lb N/acre rates.

Table 3. Corn stover yields after physiological maturity as a function of N application rate and method, 1992.

N Treatment[1]	Waseca-1 Corn	Waseca-2 Alfalfa[2]	Blue Earth Soyb	Stevens Oats	Dodge Soyb	Goodhue Soyb	Olmsted-1 Corn	Olmsted-2 Corn	Sherburne Rye	Dakota-1 Corn	Dakota-2 Corn	Chisago Corn	Wabasha Corn	Carver Corn
	Location and Previous Crop													
lb/acre	-----	-----	-----	-----	-----	-----	T/acre[3]	-----	-----	-----	-----	-----	-----	-----
0	2.22e	2.60b	2.37c	2.25b	2.42c	3.18	2.24c	2.76c	1.58c	2.86d	2.96	3.07b	2.10c	2.34d
30	2.68cd		3.28b	2.27b	3.06b	4.05	2.70b	3.19b	1.94bc	3.51c	3.03	3.07b	2.55b	2.89bc
60	2.60d		3.16b	2.37b	3.13b	3.59	2.76b	3.26ab	2.08bc	3.63bc	3.06	3.31b	2.83ab	2.65cd
90	2.98abc		3.89a	2.77a	3.78a	3.58	3.34a	3.42ab	2.21abc	4.21a	3.22	3.23b	2.83ab	2.92bc
120	2.87bcd		3.94a	2.81a	3.26ab	3.99	3.27a	3.42ab	2.35ab	4.13a	3.03	3.39b	2.84ab	3.19ab
150	3.27a		3.89a	2.85a	3.57ab	4.08	3.40a	3.63a	2.87a	4.02ab	3.00	3.80a	2.89a	3.63a
180	3.17ab		3.94a	3.03a	3.36ab	[4]	3.33a	3.35ab	2.44ab	3.87abc	3.26	3.35b	2.85ab	3.26ab
Pr>F	0.001		0.001	0.002	0.017	0.132	0.000	0.031	0.091	0.000	0.673	0.058	0.004	0.004
LSD(0.10)	0.34		0.54	0.32	0.57		0.28	0.38	0.67	0.40		0.38	0.31	0.47
CV(%)	9.7		12.5	10.0	14.3	13.3	7.6	9.5	24.5	8.8	2.3	9.3	9.5	12.9
SP 60	2.69	3.64a	2.99	2.57	3.25	4.14	2.88	3.48	2.23	3.64	3.13	3.24	2.95	2.95
90	2.85	3.32a	2.98	2.84	3.40	4.04	3.21	3.68	2.65	3.77	3.14	3.54	3.02	2.79
120	2.95	3.30a	3.39	2.81	2.91	3.87	3.25	3.44	2.92	3.84	3.26	3.64	3.08	3.08
PP Ave.[5]	2.82		3.66	2.65	3.39	3.72	3.13	3.37	2.20	4.02	3.10	3.31	2.83	2.92
SP Ave.[5]	2.83		3.12	2.74	3.19	4.01	3.11	3.53	2.60	3.75	3.18	3.47	3.02	2.94
PP vs SP														
Pr>F	0.890		0.002	0.418	0.333	0.024	0.871	0.400	0.058	0.156	0.613	0.379	0.068	0.898
All trts														
Pr>F	0.000	0.013	0.000	0.001	0.043	0.066	0.000	0.146	0.014	0.001	0.856	0.329	0.001	0.005
CV(%)	9.3	10.8	11.3	9.9	15.3	11.3	7.3	11.9	20.7	9.0	9.9	12.8	9.2	12.6

[1] Nitrogen applications were made preplant (PP) and split (SP = preplant + sidedress).
[2] At this location, the split rates were 0 + 30, 0 + 60, and 0 + 90 lb N/acre.
[3] Grain yields are statistically similar if the same letter follows different treatment means within each location.
[4] At this location, there was no 180-lb N rate.
[5] Yields averaged over the 60, 90, and 120-lb N/acre rates.

Table 4. Soil N concentrations as a function of sampling depth and time for all plots that received no preplant N, 1992.

Site[1/]	Sampling Time[2/]	NO_3-N 0-1'	NO_3-N 1-2'	NO_3-N 2-3'	NH_4-N 0-1'	NH_4-N 1-2'	NH_4-N 2-3'	Hydrolyzable-N[3/] 0-1'	Hydrolyzable-N[3/] 1-2'	Hydrolyzable-N[3/] 2-3'
		ppm N								
Outwash										
Sherburne	Preplant	1.2	1.1	0.8	3.3	3.0	2.6	28.0	14.0	4.9
	1-2 leaf	3.1	0.9	3.8	1.9	1.5	1.6	28.3	11.1	3.7
	6-12" tall	5.1	2.0	2.2	3.7	3.2	3.5	35.5	18.0	9.6
Dakota-1	Preplant	3.4	4.5	2.0	2.6	2.3	2.2	40.9	16.4	4.7
	1-2 leaf	4.5	3.9	3.9	3.8	2.3	2.3	41.1	17.3	5.8
	6-12" tall	6.9	5.5	4.2	2.5	2.0	1.6	51.0	24.0	9.3
Loess										
Dodge	Preplant	2.2	2.4	1.1	4.1	4.5	2.2	47.1	18.3	8.3
	1-2 leaf	7.2	4.9	3.1	5.4	4.1	3.1	43.2	22.6	12.4
	6-12" tall	8.6	6.5	6.1	4.6	3.8	3.6	43.0	21.6	13.7
Goodhue	Preplant	4.7	2.6	2.2	47.8	31.6	16.6	134.1	70.6	35.8
	1-2 leaf	12.3	5.2	4.0	5.3	3.1	2.9	52.8	29.9	16.3
	6-12" tall	14.4	14.8	3.9	6.5	4.5	3.0	60.1	31.8	14.6
Olmsted-1	Preplant	3.0	2.1	2.0	5.4	3.2	2.9	51.5	29.5	16.0
	1-2 leaf	5.7	3.3	2.7	4.7	2.7	2.4	63.6	33.3	16.9
	6-12" tall	9.8	5.9	4.4	5.0	3.1	2.4	48.1	28.1	16.8
Olmsted-2	Preplant	3.4	1.9	1.9	5.5	3.0	3.4	45.2	20.9	12.4
	1-2 leaf	10.1	4.3	4.0	5.9	3.2	2.9	51.2	27.9	21.6
	6-12" tall	17.4	6.2	4.7	5.1	3.0	3.1	51.3	24.5	17.0
Dakota-2	Preplant	5.3	7.4	6.5	4.5	3.1	3.0	58.5	20.2	8.4
	1-2 leaf	6.5	11.4	12.6	4.5	3.3	3.2	54.6	24.6	12.8
	6-12" tall	11.0	9.4	9.8	3.8	2.8	2.4	63.1	32.3	12.7
Wabasha	Preplant	3.4	2.8	3.9	3.4	3.0	3.0	48.7	18.1	11.6
	1-2 leaf	8.5	3.0	3.1	3.3	2.6	2.9	39.2	14.3	9.8
	6-12" tall	13.4	4.7	3.4	3.7	2.6	3.1	38.7	15.7	10.5
Till										
Waseca-1	Preplant	3.2	3.0	3.9	4.9	2.6	2.8	66.1	11.2	7.0
	1-2 leaf	8.7	4.8	4.0	5.3	2.5	2.4	77.2	19.5	12.0
	6-12" tall	6.5	3.8	4.0	5.0	1.6	1.5	73.3	15.6	10.0
Waseca-2	Preplant	5.4	2.4	1.5	6.6	3.6	3.6	65.1	14.7	5.7
	1-2 leaf	11.9	5.5	3.5	9.2	3.7	2.6	76.7	29.3	15.6
	6-12" tall	11.1	6.1	5.0	6.7	2.6	1.5	73.8	25.4	15.4
Blue Earth	Preplant	2.8	2.2	3.1	5.1	3.2	2.8	70.2	21.3	6.8
	1-2 leaf	7.9	3.5	3.4	6.6	2.3	1.9	65.9	29.0	13.6
	6-12" tall	8.8	3.8	3.5	4.3	1.4	0.9	60.9	25.3	8.2
Stevens	Preplant	10.5	5.7	1.5	6.5	2.6	2.2	57.2	16.9	8.3
	1-2 leaf	15.1	4.8	2.1	4.2	3.0	2.5	46.6	14.7	7.0
	6-12" tall	20.4	5.4	1.9	2.5	2.4	1.9	44.3	14.7	6.0
Chisago	Preplant	4.7	3.2	1.8	3.3	3.6	4.4	34.5	10.0	8.7
	1-2 leaf	14.9	3.8	3.9	3.0	2.8	3.3	34.0	12.6	9.0
	6-12" tall	15.0	6.5	5.2	6.2	5.8	5.5	46.8	17.5	15.1
Carver	Preplant	4.4	4.3	4.0	4.3	2.6	3.0	53.0	24.3	18.5
	1-2 leaf	5.9	6.2	4.9	4.6	4.6	4.0	59.0	30.6	24.3
	6-12" tall	7.7	6.2	5.7	7.0	3.4	3.9	58.2	29.3	23.3

[1/] Sites are also categorized by soil's parent material.
[2/] Sampling times were preplant, and at the 1-2 leaf and 6-12" tall growth stages.
[3/] Includes ammonium-N.

Table 5. Effect of depth and time of sampling on correlation of N form and grain yield for all plots at 54 sites that received no N, 1989-92.

Time	Depth	NO_3-N	NH_4-N	Hyd-N
	- ft -		r[1/]	
Preplant	0-2	0.52	-0.01^{NS}	0.24
Preplant	0-3	0.52	-0.01^{NS}	0.24
1-2 Leaf	0-1	0.49	0.31	0.38
1-2 Leaf	0-2	0.54	0.32	0.40
6-12" Tall	0-1	0.48	0.25	0.37
6-12" Tall	0-2	0.46	0.28	0.41

[1/] All coefficients are statistically significant at the 10% probability level except those designated with NS.

Table 6. The effect of sampling time, sampling depth, and N form on linear-plateau models with relative grain yields as the dependent variable from 49 sites (excluding where alfalfa was the previous crop), 1989-1992.

Sampling Time[1/]	Sampling Depth	N Form	R^2	Critical Value	Error Rate
	-ft-			lb N/acre	-%-
PP	0-2	**NO_3-N**	0.49	127	22
PP	0-2	**NH_4-N**	NF[3/]	--	--
PP	0-2	**Hydrol-N[2/]**	0.12	210	54
PP	**0-1**	NO_3-N	0.36	78	22
PP	**0-2**	NO_3-N	0.49	127	22
PP	**0-3**	NO_3-N	0.49	174	20
V4	**0-1**	NO_3-N	0.41	51	31
V4	**0-2**	NO_3-N	0.44	160	20
PP	0-2	NO_3-N	0.49	127	22
V1	0-2	NO_3-N	0.57	160	26
V4	0-2	NO_3-N	0.44	160	20

[1/] Abbreviations for sampling time are: PP, preplant; V1, 1-2 leaf corn; V4, 6-12 in. corn.
[2/] Phosphate-borate extractable hydrolyzable N.
[3/] The data did not statistically fit a model.

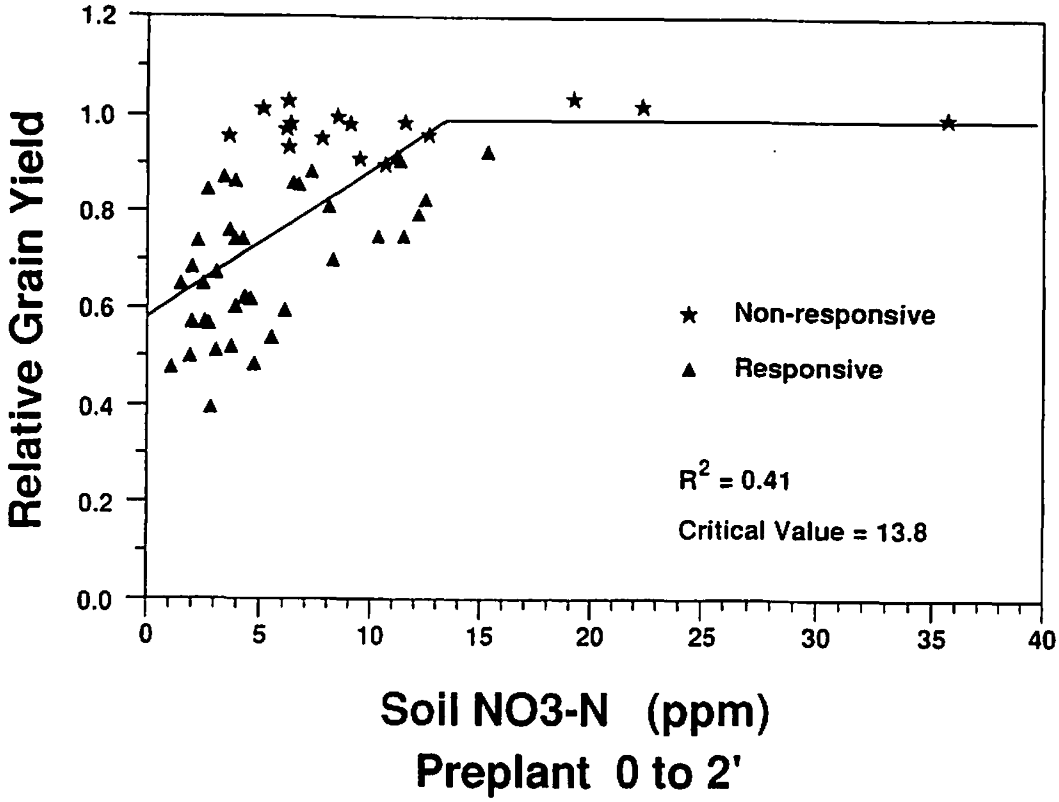


Figure 1. Relationship between soil NO_3-N and relative grain yield for all 1989-92 locations showing those sites that responded to fertilizer N.

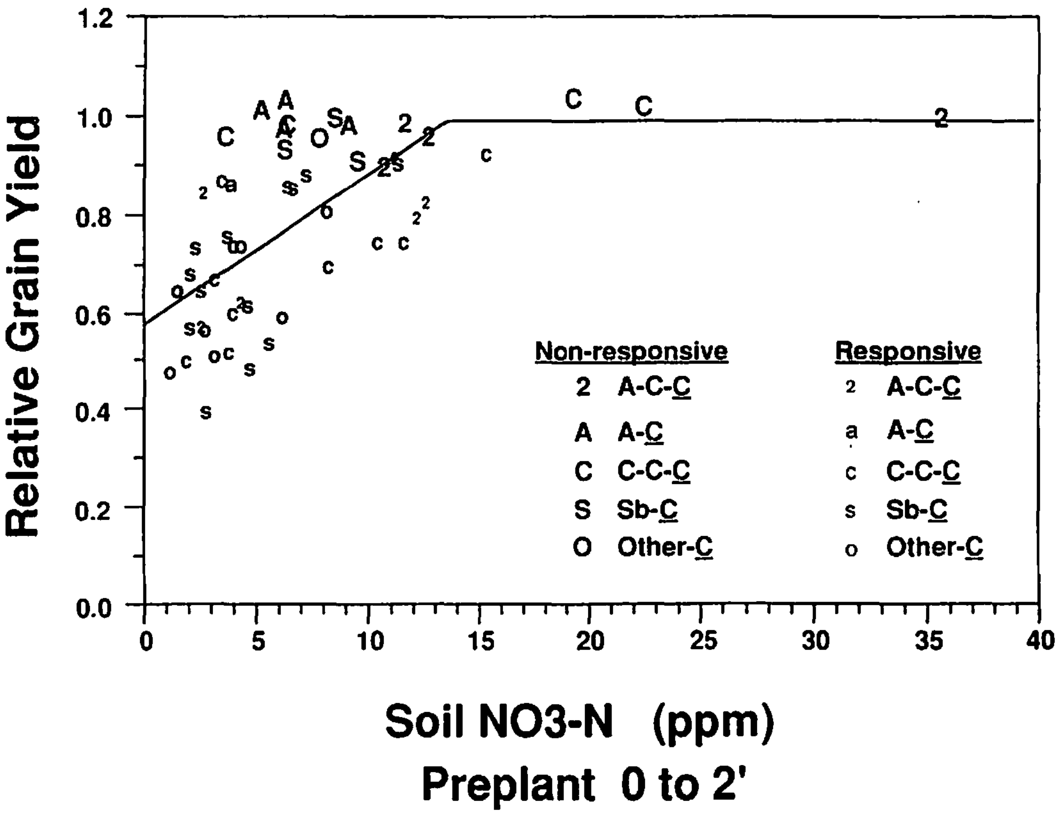


Figure 2. Relationship between soil NO_3-N and relative grain yield for all 1989-92 locations showing the previous crop at each site.

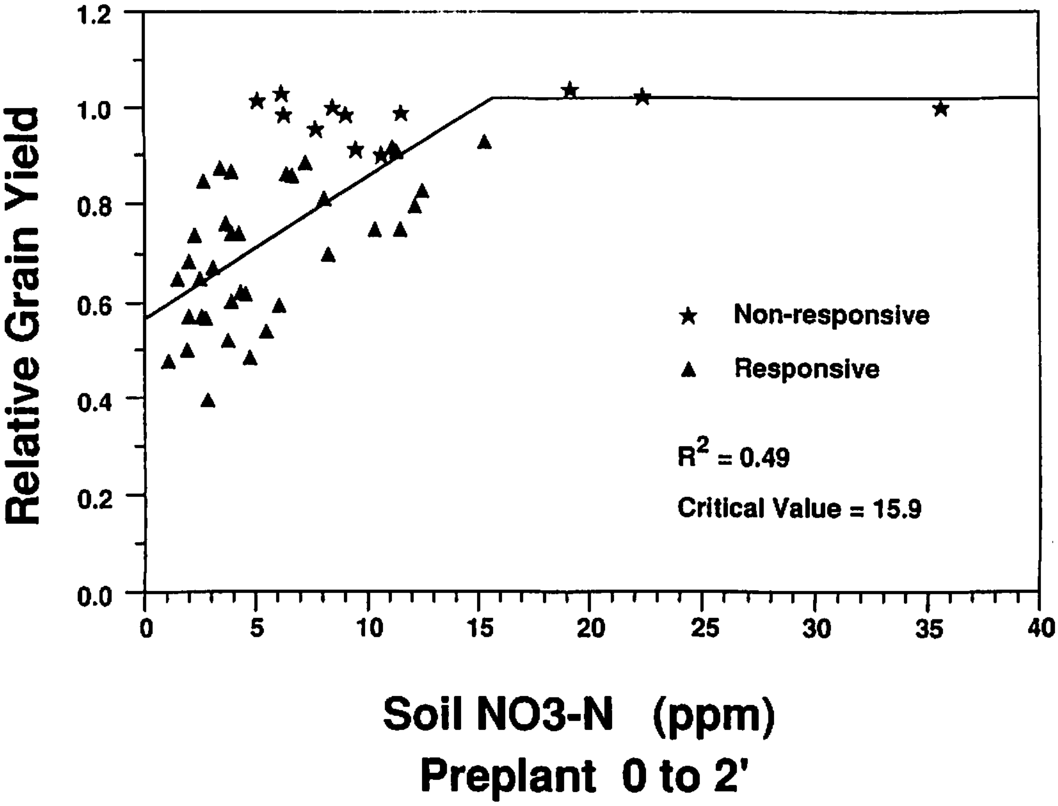


Figure 3. Relationship between soil NO_3-N and relative grain yield for those 1989-92 sites where alfalfa was <u>not</u> part of the crop history.

IMPROVING FERTILIZER RECOMMENDATIONS FOR PRODUCTION OF EDIBLE BEANS IN MINNESOTA

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

ABSTRACT: There was a need to review and evaluate current fertilizer recommendations used for edible bean production. Therefore, trials were conducted to evaluate the response of this crop to rates of N and P_2O for fine-textured soils as well as potash and sulfur for sandy soils. Response to fertilizer N was related to residual NO_3-N in the soil. When carryover was low, fertilizer N produced substantial increases in the yield of both red kidney and navy beans. There was no response when residual NO_3-N was high (approximately 100 lb./acre). Response to phosphate fertilization was related to the soil test value for P. No response was recorded when the soil test was in excess of 20 ppm P. Substantial increases in production were recorded when the soil test for P was low (6 ppm). The application of both potash and sulfur had no effect on yield when red kidney beans were grown on irrigated sandy soils. This study will be continued in 1993.

Agricultural statistics continue to show that dry edible bean production is a major component of the farm economy of both North Dakota and Minnesota. As with other crops, profitability hinges on producing high yields with the most efficient use of inputs. Effective and efficient use of fertilizer has a direct impact on edible bean production.

In recent years, the wise use of nitrogen fertilizers has been a major concern in the production of most agronomic crops. Effective use of nitrogen fertilizer has a direct impact on both farm profitability and environmental quality. Current nitrogen fertilizer recommendations for edible bean production on fine-textured soils are based on yield goals and a measure of residual or carryover nitrate-nitrogen (NO_3-N). For production on sandy soils, recommendations for use of fertilizer nitrogen are based on a yield goal and the previous crop. These recommendations, however, have evolved from a limited amount of research data collected from Minnesota and North Dakota.

Effective use of phosphate fertilizer is also a concern for edible bean production throughout Western Minnesota. Yet, there have been few trials to document the importance of phosphate in a fertilizer program.

Questions about fertilizer use are not always limited to nitrogen and phosphate. Very little is known about the need for potassium and sulfur when this crop is grown on sandy soils. Current fertilizer suggestions for the use of these two nutrients are based on very limited information collected when average yields were lower. The rates of these two nutrients needed for optimum production must be determined when modern production practices are used.

Recognizing the need for new information with respect to fertilizer recommendations, this research project is designed to meet 3 objectives. These are:

1. To improve nitrogen fertilizer recommendations for edible bean production. For much of the production area, this means improving 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 potash and sulfur.

Experimental Procedure:

For this study, trials were conducted in farmers' fields in Renville, Yellow Medicine, and Cass Counties as well as the Irrigation Center at Staples. The details for the conduct of each trial are discussed separately.

[1/] Extension Soil Scientist, Assistant Scientist, Junior Scientist, and Plot Coordinator, University of Minnesota and Staples Irrigation Center, Respectively.

Nitrogen Trials

Three locations were used. Two were in Renville County and one was located in Yellow Medicine County. Initial plans called for a nitrogen trial to be conducted at the Irrigation Center. However, a substantial error in fertilizer application prevented the collection of useful data at this site.

Soil samples were collected from each location prior to fertilizer application. Soil was collected from depths of 0-6, 6-12, 12-24, and 24-36 inches. Routine soil testing procedures were used and the results are summarized in Table 1.

Five rates of nitrogen (30, 60, 90, 120, 150 lb. N/acre) were broadcast and incorporated before planting. The N was supplied as 46-0-0. An appropriate control (0 N applied) was also used. Each N rate was replicated 4 times in a randomized block arrangement of treatments. All plots received a uniform application of phosphate supplied as 0-46-0. The nitrogen and phosphate fertilizers were incorporated with a field cultivator prior to planting.

Table 1. Relevant soil test values for the experimental sites where the nitrogen and phosphate trials were conducted.

Soil Test Property	Depth	Renville(W)	Renville(M)	Yellow Medicine
	in.			
pH	0-6	7.2	7.4	7.7
P (Bray), ppm	0-6	26.0	24.7	6.0
K, ppm	0-6	170	178	132
NO_3-N, lb./acre	0-6	5.7	10.9	9.4
	6-12	6.7	18.7	4.1
	12-24	9.5	37.5	9.1
	24-36	12.9	32.4	9.5
	Total:	34.8	99.5	32.1

Red kidney beans were planted at one Renville County site. Navy beans were planted at the second Renville County site and the Yellow Medicine County site. Appropriate planting rates, herbicides, etc. were used at all sites.

Whole plant samples were collected in late August for a determination of total dry matter production. These plants were dried, weighed, ground and analyzed for N to determine the total amount of N absorbed by the crop. Yields were measured in early to mid-September and are reported on a basis of 18% moisture.

Phosphate Trials

These studies were conducted in the fields used for the nitrogen trials and were placed immediately adjacent to the nitrogen trials. The results of the soil samples for the nitrogen trials are also appropriate for the phosphate trials.

Three rates of phosphate (23, 46, 69 lb. P_2O_5/acre) were broadcast and incorporated before planting. An appropriate control (No applied phosphate) was also used. The treatments were replicated four times and arranged in a randomized complete block design. All plots received a broadcast application of 120 lb. N/acre supplied as 46-0-0. The phosphate and nitrogen fertilizers were incorporated with a field cultivator before planting.

The cultural practices used during the growing season and the sampling and harvesting techniques were identical to those used for the nitrogen trials.

Potash and Sulfur Trials

These trials were conducted on irrigated sandy soils at two locations in north-central Minnesota. Soil samples (0-6 inches) were collected from each site prior to fertilizer application. The results of the analysis of these samples are summarized in Table 2.

Table 2. Relevant soil test values for the experimental sites where the potash and sulfur trials were conducted.

Soil Test Property	Depth	Location: Irrigation Center	Location: Cass Co.
	in.		
pH	0-6	7.1	5.6
P (Bray), ppm	0-6	32	67
K, ppm	0-6	70	139
SO_4-S, ppm	0-6	2.6	1.7

Four rates of K_2O (60, 120, 180, 240 lb./acre) were combined with a control treatment (no K_2O applied) for the potash trial. The source of K_2O was 0-0-60. The treatments were replicated four times and were arranged in a randomized complete block design. Adequate rates of sulfur and phosphate were applied to all plots. The potash, sulfur and phosphate fertilizers were incorporated with a field cultivator prior to planting.

The sulfur trials were conducted immediately adjacent to the potash trials. Three rates of sulfur (10, 20, 30 lb. S/acre) were used with an appropriate control. The treatments were replicated four times and arranged in a randomized complete block design. Granular gypsum was used as the sulfur source.

Both trials received 120 lb. N/acre supplied as 46-0-0. A split application of N was used. The initial application was made approximately 2 weeks after emergence. The remainder was applied 2 weeks later. All nitrogen was incorporated with irrigation water.

Appropriate cultural practices for the production of red kidney beans were used at both sites. The sampling and harvesting techniques were identical to those described for the nitrogen trial.

Results and Discussion:

Nitrogen Trial

In 1992, N fertilization increased total dry matter production and edible bean yield at 2 of the 3 sites (Table 3). In both situations, the overall yields continued to increase as the rate of applied N increased. The response to fertilizer N appeared to be related to the amount of residual or carryover NO_3-N measured to a depth of 3 feet. At the Renville (W) location, where red kidney beans were grown, the residual NO_3-N was 34.8 lb./acre. The residual NO_3-N at the Yellow Medicine County site, where navy beans were grown, was 32 lb./acre. The residual of 99.5 lb. NO_3-N/acre at the Renville (M) site appeared to be adequate for good yields of navy beans.

Table 3. The effect of rate of applied N on total dry matter yield and bean yield.

N Applied	Renville (W) D.M. Yield	Renville (W) Bean Yield	Renville (M) D.M. Yield	Renville (M) Bean Yield	Yellow Medicine D.M. Yield	Yellow Medicine Bean Yield
lb./acre	ton/A	lb./A	ton/A	lb./A	ton/A	lb./A
0	2.03	2279	2.18	3260	1.36	1878
30	2.60	2706	2.10	3059	1.40	1771
60	2.56	2732	2.47	3322	1.70	2212
90	2.65	2758	2.44	3503	1.75	2144
120	2.76	3120	2.38	3327	1.73	2504
150	2.99	3079	2.38	3430	1.81	2428

The concentration of N in the whole plant tissue at maturity was not significantly affected by rate of applied N at all sites (Table 4). Total N uptake was computed from the dry matter yields and the N concentration data. The rate of N applied affected N uptake at the two Renville County sites (Table 4).

Table 4. The effect of rate of applied N on the N concentration in whole plant at maturity and N uptake.

	Location					
N	Renville (W)		Renville (M)		Yellow Medicine	
Applied	N Conc.	N Uptake	N Conc.	N Uptake	N Conc.	N Uptake
lb./acre	%	lb./A	%	lb./A	%	lb./A
0	1.97	78.4	1.93	84.3	1.55	43.2
30	2.00	104.1	1.97	82.2	1.45	41.3
60	2.22	113.4	1.82	89.9	1.84	61.5
90	1.88	99.7	2.04	99.2	1.68	58.3
120	1.87	102.9	1.96	92.9	1.57	55.1
150	1.87	111.5	2.25	108.4	1.51	54.8

In general, N uptake increased as rate of applied N was increased. A rather high amount of variability may have masked the uptake response to rate of applied N at the Yellow Medicine County site. The effect of rate of applied N on N uptake is consistent with the effect on yield. This suggests that absorbed N is being used to produce more dry matter and subsequently higher bean yields.

The impact of the residual NO_3-N on response to fertilizer N is important. The N recommendations in the future will be adjusted for the amount of residual NO_3-N measured to some appropriate depth.

Phosphate Trials

The response to phosphate fertilization was related to the soil test values for P (Table 5). In Yellow Medicine County (soil test P = 6.0 ppm), yield of navy beans increased as rate of applied phosphate increased. Total dry matter production at this site, however, was not significantly affected by phosphate fertilization. This absence of a significant effect is probably due to a large amount of variability in the data.

Table 5. The effect of rate of applied phosphate on total dry matter yield and bean yield.

	Location					
P_2O_5	Renville (W)		Renville (M)		Yellow Medicine	
Applied	D.M. Yield	Bean Yield	D.M. Yield	Bean Yield	D.M. Yield	Bean Yield
lb./acre	ton/A	lb./A	ton/A	lb./A	ton/A	lb./A
0	2.56	2685	1.99	2950	1.75	1841
23	2.84	2816	2.18	2893	1.85	2002
46	2.88	2956	1.98	3025	1.63	2194
69	2.90	2712	2.01	3034	1.84	2262

By contrast, use of phosphate did not increase the yield of navy beans at the Renville (M) site or the yield of red kidney beans at the Renville (W) site. The soil test value for P at both sites was in excess of 20 ppm indicating a relatively high level of available P in the soil.

The P concentration in the whole plant tissue at maturity was not significantly affected by phosphate fertilization at all sites (Table 6). As a result, there was no significant effect of phosphate fertilization on P uptake.

Table 6. The effect of rate of applied phosphate on the P concentration of whole plant at maturity and P uptake.

P_2O_5 Applied	Renville (W) P Conc.	Renville (W) P Uptake	Renville (M) P Conc.	Renville (M) P Uptake	Yellow Medicine P Conc.	Yellow Medicine P Uptake
lb./acre	%	lb./A	%	lb./A	%	lb./A
0	.295	15.0	.243	9.6	.146	5.1
23	.319	18.1	.263	11.2	.163	6.0
46	.336	19.4	.253	10.5	.171	5.5
69	.319	18.5	.280	11.0	.160	6.0

Potash Trials

The potash trials were conducted with red kidney beans. At both sites, the rate of applied K_2O had no significant effect on total dry matter yield, bean yield, and K uptake (Table 7). Potassium uptake was in the range of 100-120 lb./acre. The sandy soils were apparently able to supply the amount of K needed for optimum yield.

Table 7. The effect of rate of applied potash on yield and potassium uptake by red kidney beans.

K_2O Applied	Irrigation Center D.M Yield	Irrigation Center Bean Yield	Irrigation Center K Conc	Irrigation Center K Uptake	Cass Co. D.M. Yield	Cass Co. Bean Yield	Cass Co. K Conc	Cass Co. K Uptake
lb./acre	ton/A	lb./A	%	lb./A	ton/A	lb./A	%	lb./A
0	2.53	2552	2.38	120.6	2.49	2594	1.97	98.1
60	2.53	2383	2.12	106.8	2.44	2538	1.98	96.2
120	2.69	2449	2.25	120.5	2.28	2477	2.16	97.7
180	2.48	2389	2.43	119.7	2.33	2361	2.27	105.5
240	2.61	2384	2.59	134.4	2.30	2612	2.24	103.3

The K concentration in the whole plant tissue at maturity did increase with rate of applied K_2O. This increase was not related to yield and is an example of luxury consumption of K by crops.

Sulfur Trials

The application of S had no significant effect on both total dry matter production and bean yield at each site (Table 8). Even though the soils were sandy, the soil apparently was able to supply adequate S for optimum yield of the edible bean crop.

Table 8. The effect of rate of applied sulfur on dry matter yield and bean yield.

S Applied	Irrigation Center D.M. Yield	Irrigation Center Bean Yield	Cass Co. D.M. Yield	Cass Co. Bean Yield
lb./A	ton/A	lb./A	ton/A	lb.A
0	2.41	2309	2.22	2482
10	2.36	2433	2.37	2456
20	2.33	2649	2.22	2544
30	2.30	2366	2.22	2468

Plant samples collected at maturity will be analyzed for S, but results were not available at the time of preparation of this report.

NORTHERN CORNBELT SAND PLAINS MANAGEMENT SYSTEMS EVALUATION AREA, PRINCETON, MN[1]

J.A. Lamb, J.L. Anderson, R.H. Dowdy, G.N. Delin
K. Ault, D. Onken, M. Landon, and B. Giebink[2]

Abstract The Management Systems Evaluation Area (MSEA) site was established at Princeton, MN with the primary objective to evaluate the impact of an irrigated agricultural management system on ground water in a surficial sand and gravel aquifer.

Corn-soybean rotation, potato-sweet corn rotation, and continuous corn cropping systems are being evaluated. Preliminary results indicate that even in small areas crop yield and N uptake can vary and thus influence amount of chemicals that are moved to the ground water. Soil samples indicate herbicide concentrations decrease during the growing season and only moved to a maximum depth of 30 inches or less. Atrazine and metribuzin were not detectable in post harvest samples but alachlor was still present. At present the MSEA cropping systems have not influence herbicide concentrations in ground water. Potato and continuous corn production have increased nitrate + nitrite-N concentrations in the ground water.

The Management Systems Evaluation Area (MSEA) program was established as part of the Presidential initiative for water quality in 1990. Five MSEA programs were initiated in 1990 in the states of Nebraska, Ohio, Missouri, Iowa, and Minnesota. This is a multiagency project involving USDA-CSRS, USDA-ARS, USGS, EPA, USDA-ES, and USDA-SCS. The Minnesota MSEA (Northern Cornbelt Sand Plain MSEA) has established four research sites located near Arena, WI (Univ. of Wisconsin); Princeton, MN (Univ. of Minnesota); Aurora, SD (South Dakota State Univ.); and Oaks, ND (North Dakota State Univ.). This report will be for the primary site located near Princeton, MN. The specific objectives for the Minnesota MSEA are the following: 1) investigate the impacts of ridge-tillage practices in a corn and soybean cropping system on the rate of transport of atrazine, alachlor, and metribuzin in unsaturated and saturated zones, 2) determine the effects of nitrogen fertilizer management, 3) characterize water flow and relate these characteristics to transport and storage of agricultural chemicals, and 4) determine the relationship between ground water recharge and agricultural-chemical loading of ground water.

Materials and Methods:

Crop Production

The Northern Cornbelt Sand Plains (MSEA) Minnesota site was established in 1991. The 160 acre site is located three miles southwest of Princeton, MN. The major soil identified at the site by the soil survey is Zimmerman loamy fine sand (mixed, nonacid, frigid, Alfic Udipsamment). Three irrigated cropping systems are being studied i.) ridge-tillage corn-soybean rotation, ii.) full width tillage continuous corn, and iii.) full width tillage potato-sweet corn rotation. Each crop in the rotation is grown each year on cropping areas ranging in size from 4.4 to 6.6 acres. A 95 day relative maturity corn adapted for the region was planted at a rate of 34000 seed A^{-1} in late April of early May. Soybean and sweet corn were planted the second week of May at rates of 60 lb soybean seeds A^{-1} and 24000 sweet corn seeds A^{-1}. Early table market red potatoes were planted the first and second week of April. Nitrogen fertilizer was split applied to all crops except soybean at rates and times listed in Table 1. A 20 lb A^{-1} nitrogen credit for legumes (soybeans) was used in 1992 for rotation corn. During 1991 the crops were not irrigated but 25 inches of precipitation occurred during the growing season. In 1992, the check book method was used to schedule amounts and time of irrigation. Soil applied herbicides were applied at broadcast rate of 1.5 lb a.i. A^{-1} atrazine and 2.0 lb a.i. A^{-1} alachlor (Lasso) to continuous corn, rotation corn, and sweet corn. The atrazine and alachlor were applied

[1] This report contains information from the first two years of a five year study and should be consider preliminary. The funding source is from the Presidential Initiative for Water Quality.

[2] J.A. Lamb, J.L. Anderson, D. Onken, and B. Giebink are Associate Professor, Professor, Junior Scientist, and MSEA Education Coordinator with the Soil Science Department, University of Minnesota, St. Paul, MN. R.H. Dowdy and K. Ault are Research Leader and Support Scientist with USDA-ARS located in the Soil Science Department, University of Minnesota, St. Paul, MN. G.N Delin and M. Landon are with the Water Resources Division of USGS, Moundsview, MN.

broadcast to continuous corn and in a 10 inch band over the row at planting to the sweet corn and rotation corn. Soybeans had alachlor and metribuzin (Sencor) applied in a band at the broadcast rates of 2.0 lb a.i. A^{-1} and 0.5 lb a.i. A^{-1}, respectively. Metribuzin and metolachlor (Dual) were applied to potato broadcast after planting and before emergence at rates of 0.5 lb a.i. A^{-1} and 1.0 lb a.i. A^{-1}, respectively. Dry matter and yields were determined from 64 and 60, 50 X 60 ft cells in 1991 and 1992, respectively, in each of the cropping areas at harvest. Nitrogen concentrations were determined on the grain and dry matter and total N uptakes were calculated.

Table 1. Urea nitrogen applications made in 1991 and 1992 at Minnesota MSEA.

Crop	Application time	N applied	
		1991	1992
		-------- kg N A^{-1} --------	
Rotation Corn	Starter	20	20
Rotation Corn	V6	50	70*
Rotation Corn	V8	70	50
Continuous Corn	Starter	20	20
Continuous Corn	V6	50	70*
Continuous Corn	V8	70	60
Sweet Corn	Starter	20	20
Sweet Corn	V6	50	70*
Sweet Corn	V8	70	60
Potato	Starter	100	60
Potato	Cultivation	50	0
Potato	Hilling	50	70

* Nitrapyrin sprayed on urea as it was applied at rate of 0.5 lb A^{-1} a.i..

Soil Herbicide Movement

Each cropping area was soil sampled six times during the cropping season. The times are before herbicide application, immediately after application, two weeks after application, five weeks after application, eleven weeks after application, and post-corn harvest. Samples to a depth of three feet are obtained in noncontaminated sleeves and divided in six inch increments from the crop row and between crop rows. The samples were analyzed at the National Soil Tilth Lab, Ames Iowa for atrazine, alachlor, and metribuzin.

Ground Water Characterization

Water samples were taken from a series of multiport wells to determine the effect of agricultural farming system on ground water quality. These samples are taken four time a year; April, June, August, and October-November. The initial characterization of the research site was done April 1991 from sampling wells established on the perimeter of the site. By June 1991, the multiport wells were installed with one at the upgradient to ground water flow position of each cropping area, middle of cropping area, and down gradient of cropping area. This allows for monitoring of atrazine, alachlor, metribuzin, metolachlor, and nitrate + nitrite-N that is moving in under the cropping area, under the cropping area, and moving out under the cropping area.

Results and Discussion

Crop Production

Crop Yields

Corn grain yields in both 1991 and 1992 exhibited considerable variability across the small cropping areas, 4.4 A, Table 2. Continuous corn yields ranged from 91 to 163 bu A^{-1} in 1991 and 100 to 148 bu A^{-1} in 1992. Standard deviation for continuous corn decreased from 16 bu A^{-1} in 1991 to 11 bu A^{-1} in 1992 and is also reflected by the coefficient of variation (C.V.) Table 2. This decrease in variability is attributed to irrigation. Even though there was sufficient precipitation during 1991 growing season, some locations in the continuous corn cropping area were water stressed in June. Within cropping area, location of continuous corn grain yield variation for the two growing seasons were similar, but the range in grain yields in 1992 was smaller. Rotation corn was grown on cropping area D in 1991 and cropping area B in 1992. The standard deviation increased from 10 bu A^{-1} (C.V.= 6.4%) to 13 bu A^{-1} (C.V.=9.0%) Table 2. Areas B and D are spatially different in elevation relief and soil type. With only one year of data for each crop interpretation is difficult when comparing soybean grain yield variability in area B and D with corresponding corn grain variability, there was less in area B. Yield variability increased in cropping area D in 1992 (Table 2). This increase was the result of two early season frosts (June 1 and 21) which reduced soybean grain yields at lower elevations. Variability decreased from 1991 to 1922 for potatoes and sweet corn as indicated by lower C.V.s in 1992, Table 3.

Table 2. Statistical analyses of corn and soybean yields for 1991 and 1992.

Year	Crop	Cropping area	Mean	Minimum	Maximum	Std. Dev.	C.V.
			--------- bu A^{-1} ---------				%
1991	Soybean	B	33	22	39	3	10.8
1992	Corn	B	139	113	163	13	9.0
1991	Corn	D	147	124	177	10	6.4
1992	Soybean	D	25	18	34	4	14.6
1991	Corn	E	136	91	163	16	11.3
1992	Corn	E	126	100	148	11	8.3

Table 3. Statistical analyses of potato and sweet corn yields for 1991 and 1992.

Year	Crop	Cropping area	Mean	Minimum	Maximum	Std. Dev.	C.V.
			---------- Tons A^{-1} ----------				%
1991	Potato	A	9.4	6.2	13.1	1.3	13.9
1992	Sweet Corn	A	7.9	6.3	9.8	0.8	10.2
1991	Sweet Corn	C	5.8	4.1	7.4	0.7	12.2
1992	Potato	C	12.0	8.1	15.3	1.4	11.3

N Uptake

At this time data are only available for rotation corn (D) and continuous corn (E) Tables 4 and 5. Total plant dry matter, total N uptake at maturity, and grain yield were significantly correlated to each other, Table 6.

Table 4. Statistical analyses for total N uptake by corn in 1991.

Year	Crop	Cropping	Mean	Minimum	Maximum	Std. Dev.	C.V.
		area	------------ lb A^{-1} ------------				%
1991	Corn	D	125	107	146	8.6	6.9
1991	Corn	E	122	93	148	12.1	9.9

Table 5. Statistical analyses for total dry matter of corn in 1991.

Year	Crop	Cropping	Mean	Minimum	Maximum	Std. Dev.	C.V.
		area	----------- ton A^{-1} -----------				%
1991	Corn	D	6.6	5.6	7.4	0.4	6.1
1991	Corn	E	6.5	4.7	8.1	0.7	10.3

Table 6. Correlations and statistical probabilities for rotation and continuous corn grain yield, total dry matter, and total N uptake in 1991.

Cropping System	Correlation	r	Significance
Rotation Corn	Yield vs Total N Uptake	0.77	0.01
Rotation Corn	Yield vs Total Dry Matter	0.80	0.01
Rotation Corn	Total N Uptake vs Total Dry Matter	0.76	0.01
Continuous Corn	Yield vs Total N Uptake	0.83	0.01
Continuous Corn	Yield vs Total Dry Matter	0.84	0.01
Continuous Corn	Total N Uptake vs Total Dry Matter	0.79	0.01

Preliminary Results

Yield and N uptake variability exists in the cropping areas. This variability is exhibited by C.V.s of up to 15 % across an area as small as 4.4 A. Total dry matter, total N uptake, and grain yield for corn are highly correlated which means they vary similarly over the landscape. If constant rates of N fertilizer are applied and there is lower plant utilization of applied N there is a greater chance of excess N leaching to the ground water than if rates are varied according to yields found at different location in the cropping areas. Additional large field studies should be undertaken to confirm these results.

Soil Herbicide Results

Atrazine

At this time only the 1991 soil herbicide data is available. Where soil herbicides were band applied (soybean (area B), sweet corn (area C), and rotation corn (area D)) no chemicals were detected in between crop row soil samples. Soil atrazine concentrations in the continuous corn were greater in the row than between the row. Surface 0 to 6 inch depth concentrations after application were 537 ppb in the row and 128 ppb between row. Concentrations decreased to 16 ppb in the row and 10 ppb between the row from application time (5/15/91) to post harvest (11/26/91). The deepest depth that atrazine was detected was 24 to 30 inches eleven weeks after application in the row. Rotation corn soil atrazine concentration were similar to the continuous corn in row samples. No atrazine was detected between the row at any time in 1991. The deepest depth of detection was 12 to 18 inches at the eleven week sampling date. The row soil atrazine concentration in the sweet corn cropping area was greatest directly after application (714 ppb) and decreased to 12 ppb by post harvest. Again no atrazine was detected between the row.

Alachlor (Lasso)

Alachlor was applied to soybeans (area B), sweet corn (area C), rotation corn (area D), and continuous corn (area E) in 1991. The broadcast rate was 2.0 lb a.i. A^{-1}. Soybean, sweet corn, and rotation corn application were banded. No alachlor was detected in soil samples taken between the rows. In the row for the crops receiving banded application, alachlor did not move deeper than 30 inches. There were small amounts in the 0 to 6 inch depth (26 to 53 ppb) in the post harvest sample in the soybean and rotation corn cropping areas. Approximately 4 ppb was left in the 1991 sweet corn cropping area. Alachlor was detected in the row and between the in the continuous corn cropping area. The concentrations decreased with time but similar to soybean and rotation in the row. At post harvest there was still alachlor present in the 6 to 12 inch depth sample (9 ppb). Between row alachlor concentration were considerably lower than in the row. This is similar to what was reported for atrazine concentrations. Alachlor concentrations between the row decreased to 8.3 ppb in the 0 to 6 inch depth at post harvest. In both locations alachlor was not detected below 30 inches.

Metribuzin (Sencor)

Metribuzin was broadcast applied to potatoes in 1991. The concentration in the row and between were similar. Directly after application the concentration in the 0 to 6 inch depth increased to 115 ppb. Metribuzin was only detected in the 0 to 6 inch depth and was not detected by five weeks after application. The same trends occurred in the row of soybeans. The concentration after application in the 0 to 6 inch depth was less, 70 ppb. There were no detections in samples taken between the rows.

Preliminary Results

The use of banded application kept the herbicide only in the row. Atrazine, alachlor, and metribuzin concentration decreased to small detectable amounts during the growing season even in the surface soil. The deepest depth where herbicide was detected was 30 inches.

Ground Water

Initial Ground Water Characterization

Initial ground water samples were taken during April 1991. Fourteen wells were sampled between April 3 and April 18, 1991 around the perimeter of the research area. No detections of alachlor, metolachlor, or metribuzin were found, Table 7. Atrazine and nitrate + nitrite-N were detected. The median value for atrazine was below the reporting limit of 0.08 ppb. Nitrate + nitrite-N ranged from less than the reporting limit to 19.9 ppm with a median for the initial 14 well samples of 7.0 ppm.

Table 7. Contaminants measured in ground water at Princeton, MN sampled April 3 and April 18, 1991.

Contaminant	Number of water samples	Range	Median	Number of Detections
		----- ppb -----		
Atrazine	14	<0.08 - 0.17	<0.08	2
Alachlor	14	<0.08	<0.08	0
Metolachlor	14	<0.08	<0.08	0
Metribuzin	14	<0.08	<0.08	0
		----- ppm -----		
Nitrate + nitrite-N	14	<0.5 - 19.9	7.0	17

Effect of Cropping Systems

As of August 1992, cropping systems have not effected atrazine, alachlor, metolachlor, or metribuzin in the ground water. Table 8 indicates that nitrogen fertilizer use for potato production in 1991 has caused an elevation of nitrate + nitrite-N in the ground water. The N application was greater than recommended because of a problem in starter attachment calibration. The mid-plot well data indicates an elevation of nitrate + nitrite-N when compared to the upgradient values at the water table. The 1991 soybean, rotation corn, and sweet corn cropping areas had not been influenced by N fertilizer application. In 1992 a trend towards an elevated nitrate + nitrite-N concentrations under the continuous corn has been noted. Again the continuous corn received twice as much N fertilizer as the rotation corn.

Table 8. Water table nitrate + nitrite-N as effected by potato and continuous corn cropping systems.

Crop	Well	6/91	9/91	12/91	4/92	6/92	9/92
1991		------------------------ ppm ------------------------					
Potato	Upgradient	15	13	11	18	19	15
	Mid-plot	16	14	25	34	29	30
	Downgradient	13	11	47	19	30	29
Continuous corn	Upgradient	9	10	13	1	11	10
	Mid-plot	18	14	18	16	20	27
	Downgradient	6	10	8	15	13	17

Preliminary Conclusions

As of fall 1992, herbicide concentrations in the ground water have not been influenced by the MSEA cropping systems established in 1991. Fertilizer N use in the potato-sweet corn and continuous corn cropping systems have elevated nitrate + nitrite-N concentration in the ground water. The amount of N fertilizer applied is important in reducing the potential to contaminate ground water.

THE ANOKA SAND PLAIN WATER QUALITY DEMONSTRATION PROJECT: A SUMMARY OF RESULTS FROM NITROGEN MANAGEMENT DEMONSTRATIONS IN CORN AND POTATOES[1]

J.K. Jarman, J.S. King, M.J. Blaine, D.L. Schuster, and C.J. Rosen[2]

Abstract

This report summarizes the results of project-sponsored on-farm demonstrations of best management practices (BMP's) for corn and potato nitrogen applications. Field-length replicated strips were used to evaluate the effects of conventional practices and BMP's on crop yields and other parameters. Corn demonstrations were generally successful in illustrating the validity of using University N recommendations and legume and manure N credits. However, poor growing conditions in 1992 may have had adverse effects on corn yields and organic N mineralization, making it difficult to accurately assess the size of the N credits. Potato yields increased with nitrogen rate in one of two demonstrations, but not significantly. A petiole sap nitrate test was evaluated and appeared to be useful in monitoring potato plant N status during the growing season. Petiole sap nitrate-N levels were generally well correlated with potato yields.

Introduction

The Anoka Sand Plain Water Quality Demonstration Project is one of sixteen demonstration projects nationwide, begun in 1990 as part of the USDA Water Quality Program. It is in its fourth of five years. The overall goal of the project is to encourage voluntary adoption of best management practices that will reduce the potential for contamination of the sensitive Anoka Sand Plain aquifer from agricultural non-point sources. The project works directly with forty cooperating farmers in seven counties and a wide variety of practices are demonstrated in the areas of nutrient, manure, pest and irrigation management. A large effort is maintained in the area of N management for corn and potatoes, as these crops require large N inputs. The demonstrations described below focused on the use of legume and manure N credits, University of Minnesota N recommendations and nitrification inhibitors for corn, and N management and plant N monitoring for potatoes. It is anticipated that the results from this project will be used to encourage the adoption of these practices by farmers in other regions with similar soils, crops and climatic conditions.

CORN NITROGEN MANAGEMENT DEMONSTRATIONS

Procedures

With the exception of Demonstration No. 1, conducted in 1991, all demonstrations described here took place in 1992. The best management practices of using split and sidedressed N applications are already in wide use by corn producers in the Anoka Sand Plain, so demonstrations focused on comparing the farmer's usual N rates to those recommended by the University of Minnesoata or which included legume and manure N credits. In general, treatments consisted of varying sidedress N rates replicated two to four times in each field to evaluate differences in estimated total N supply. This approach was also used to evaluate the effects of the nitrification inhibitor N-Serve on corn yields. All demonstration fields were irrigated.

In all cases, non-treatment cultural practices for corn were identical between plot areas and will be included in more complete summaries of the project's 1990, 1991 and 1992 demonstrations. Other pertinent practices, including those affecting treatment results, are described in the individual demonstration discussions. Soil samples were taken to a depth of six inches in the spring prior to planting for routine analysis of pH, organic matter, P and K content. Preplant, pre-sidedress and post-harvest soil samples were taken from a 0-24" depth and analyzed for NO_3-N content. However, this nitrogen is not credited to corn N supply in these soils due to the high potential

[1]Support for this project is provided by the Minnesota Extension Service, the Soil Conservation Service, the Agricultural Stabilization and Conservation Service, the Anoka Sand Plain Association of Soil and Water Conservation Districts, and the cooperating farmers. Their support is greatly appreciated.

[2]J.K. Jarman, J.S. King and M.J. Blaine are Best Management Practice Consultants for the Anoka Sand Plain Project, P.O. Box 250, 12433 Pine St., Becker MN 55308. J.K. Jarman and J.S. King are also Assistant Scientists with the Agricultural Engineering Department, University of Minnesota; M.J. Blaine and D.L. Schuster are also Resource Conservationists with the Soil Conservation Service. C.J. Rosen is Extension Soil Scientist, University of Minnesota.

for leaching. Manure was analyzed for N, P_2O_5 and K_2O content and nutrient availabilities determined with current University of Minnesota recommendations. Application rates were calculated with spreader calibrations or based on storage and application tank capacities.

All corn producers utilized starter fertilizer applied in a band two inches below and two inches to the side of the seed at planting. Sidedressed N applications to corn were banded six inches from the row about four to six weeks after emergence. Ear leaf samples were taken from at least one treatment in each demonstration at about 50% silking. Twenty leaves from just below and opposite the ear were gathered from each of two rows and analyzed for N content. Yields were measured by weighing the grain harvested with a field combine or by hand from randomly chosen representative areas of the treatment strips or plots. Combined corn plots were usually four to six rows wide and varied in length, but were approximately 1/10 of an acre or more in area. Hand-harvested corn was picked from twenty foot lengths of two adjacent rows in each replicate. Grain moisture content was determined gravimetrically and yields are expressed on a 15.5% moisture basis. Grain yield standard deviations are included with the demonstration results.

Results and Discussion

Demonstrations of Recommended N Rates and Nitrification Inhibitors

Soils and crop nutrient information is shown in Table 1 and results in Table 2.

Table 1. Soils and crop nutrient information for N rate and N-Serve demonstrations.

Demonstration number	1	2	3
County	Sherburne	Sherburne	Sherburne
Soils Information			
Soil type	Hubbard sandy loam	Hubbard loamy sand	Hubbard loamy sand
Subgroup	Udic haploboroll	Udorthentic haploboroll	Udorthentic haploboroll
Family	Sandy, mixed	Sandy, mixed	Sandy, mixed
pH	6.4	6.4	6.4
Organic matter	2.9 %	1.8 %	2.0 %
Phosphorus	28 ppm	34 ppm	48 ppm
Potassium	104 ppm	144 ppm	149 ppm
Sulfate-S	NA	1 ppm	1 ppm
Nitrate-N			
Preplant	NA	14 lb/A	16 lb/A
Presidedress	58 lb/A	36 lb/A	40 ppm
Post-harvest	21 lb/A	NA	NA
Crop Nutrient Information			
Corn yield goal	180 bu/A	200 bu/A	200 bu/A
Recommended N rate	220 lb/A	220 lb/A	220 lb/A
Previous legume crop			Soybeans, 65 bu/A
N credit			40 lb/A
Starter fertilizer			
Form[1]	Dry (13-6-23-12)	Dry	Dry
Units applied[2]	26-12-46-24	28-40-24-15	28-40-24-15
Sidedressed fert.			
Form	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)
Applied N rate			
Normal	170 lb/A	180 lb/A	180 lb/A
Demo. plots	140, 180 or 220 lb/A	140, 150, 190, 220 or 230 lb/A	140, 150, 190, 220 or 230 lb/A
Topdressed fert.			
Form		Potash (0-0-60)	Potash (0-0-60)
Units applied		90 lb/A K_2O	90 lb/A K_2O
Fertigation			
Form		Liquid (28-0-0)	Liquid (28-0-0)
Applied N rate		10 lb/A	10 lb/A
Irrigation water			
N concentration	9.6 ppm	24.8 ppm	24.8 ppm
Applied N rate	NA	45 lb/A	45 lb/A

[1] Percent N-P_2O_5-K_2O-S   [2] Lb/A N-P_2O_5-K_2O-S

The nitrification inhibitor N-Serve was applied to the indicated treatments (Table 2) at a rate of 1 pt/A at the same time as N sidedressing. Corn yields in Demonstration No. 1 were unaffected by differences in total N supply or the presence or absence of N-Serve. Ear leaf N concentrations indicate that actual N supply may have increased with N rate, although all reflected an adequate N supply.[3] The University of Minnesota recommendation for yields in this range is 200 lb N/A, yet yields of about 168 bu/A were obtained with a minimum of 166 lb N/A. This may have been due to better than average growing conditions in 1991.

Demonstration Nos. 2 and 3 were on adjacent areas of one field, where corn followed corn on one half of the field (Demo. No. 2) and soybeans on the other half (Demo. No. 3). A comparison should not be made between these two areas, however, because a longer season variety was used on the half following corn. This resulted in lower yields than the other variety (following soybeans), due to the short, cool growing season of 1992. In both cases, however, a maximum yield was obtained with a rate close to the University recommendation (in Demo. No. 2, this included an N credit from the previous soybean crop). All but the middle sidedressed N rate received N-Serve, and so it is difficult to determine whether these yields would have been obtained at these rates in its absence. Since both producers in these demonstrations already sidedress the majority of their corn N, a nitrification inhibitor would be expected to provide little benefit in their programs.

Table 2. Results from N rate and N-Serve demonstrations.

Demo. No.	Replications	N-Serve	Sidedress N Rate	Total N Supply	Grain Yield	Std. Dev.[1]	Grain Moisture	Ear Leaf
			lb/A	lb/A	bu/A		%	% N
1	3	With	140	166	167.7	3.5	15.0	3.00
	3	Without	140	166	167.3	3.8		3.08
	3	"	180	206	169.0	2.0		3.14
	3	"	220	246	168.2	2.7		3.29
2	2	With	140	218	162.6	3.3	23.7	3.27
	2	"	150	228	157.8	1.1	25.1	3.03
	2	Without	190	268	158.2	1.3	25.2	3.03
	2	With	220	298	157.1	1.3	25.5	3.03
	2	"	230	308	162.0	2.3	23.3	3.18
3	3	With	100	218	179.9	3.8	21.4	3.25
	3	"	110	228	178.8	2.4	21.8	3.36
	2	Without	150	268	183.3	2.6	20.9	3.28
	3	With	180	298	188.6	10.8	21.0	3.26
	3	"	290	308	181.2	2.5	21.4	3.51

[1] Standard deviation for grain yield

[3] Ear leaf N concentrations of 2.75% or more are generally accepted as indicating the presence of sufficient N supply to optimize corn yields.

Demonstration of Alfalfa N Credits with Different Tillage Systems

Soils and crop nutrient information is summarized in Table 3. The producer in this demonstration incorporated an alfalfa stand of unknown plant density in the spring of 1992, using a moldboard plow on one half of the field and a chisel plow on the other half. Each tillage operation was followed by discing. With a yield goal of 120 bu/A, University of Minnesota 1992 recommendations called for no additional N applied following a good stand of alfalfa (150 lb/A N credit) or 75 lb N/A following a poor stand (75 lb/A N credit). In the results of a five-year study on an irrigated sandy soil in Staples, Minnesota,[4] higher intensity tillage resulted in higher yields of first year corn after alfalfa when no additional fertilizer N was supplied. Applied N made up the yield difference between tillage systems in the first year but not in subsequent years.

Table 3. Soils and crop nutrient information for alfalfa N credit demonstration.

Demonstration number	4		
County	Mille Lacs		
Soils Information		**Crop Nutrient Information**	
Soil type	Sartell fine sand	Corn yield goal	120 bu/A
Subgroup	Typic Udipsamment	Recommended N rate	150 lb/A
Family	Frigid	Legume crop	Alfalfa
pH	6.9	Plants/ft^2	NA
Organic matter	1.6%	N Credit	75-150 lb/A
Phosphorus	49 ppm	Starter fertilizer	
Potassium	161 ppm	Form[1]	Dry (20-20-7-6)
Sulfate-S	1 ppm	Units applied[2]	32-32-11-10
Nitrate-N		Sidedressed fertilizer	
Preplant	26 lb/A	Form	Anhyd. NH_3 (82-0-0)
Presidedress	84 lb/A	Applied N Rate	
Post-harvest	12 lb/A	Normal	80 lb/A
		Demo. plots	0, 40 or 80 lb/A
		Irrigation water	
		N concentration	0.7 ppm
		Applied N Rate	Negligible

[1] Percent N-P_2O_5-K_2O-S [2] Lb/A N-P_2O_5-K_2O

Table 4. Results from alfalfa N credit demonstration.

Replications	Sidedress N Rate	Total N Supply[1]	Grain Yield	Std. Dev.[2]	Grain Moisture	Ear Leaf N	Grain N	Grain N Uptake
	lb/A	lb/A	bu/A		%	%	%	lb/A
Moldboard								
4	0	182	105.4	11.0	27.7	1.93	1.26	62.4
4	40	222	116.1	8.1	27.9	(not	1.40	76.4
4	80	262	123.0	7.4	28.0	done)	1.34	77.5
Chisel								
4	0	182	100.0	18.2	27.2	1.76	1.26	59.2
4	40	222	104.4	12.4	27.5	(not	1.25	61.3
4	80	262	103.9	8.4	27.4	done)	1.27	62.0

[1] Assumes 150 lb/A N credit from alfalfa [2] Standard deviation for grain yield

In this demonstration, similar yields (Table 4) were obtained in the two tillage systems when no additional fertilizer N was applied, and these yields indicate that the alfalfa supplied the effects

[4] Moncrief, J.F., M.J. Wiens, N. Krause, and B.J. Johnson. 1992. Tillage effects on N available to irrigated corn from alfalfa: A five-year summary. p. 96-99. In Field Research in Soil Science. Univ. of Minnesota Misc. Publ. 75-1992.

of at least 90 lb N/A in both tillage systems (this equals University recommendations of 120 lb N/A for 100 bu/A corn minus 30 lb N/A in the starter). It is not likely that the alfalfa N supply was much greater than this, as corn yields in the moldboard area increased with sidedressed N rate. Alfalfa N mineralization, as well as corn yields in general, were most likely limited by cool conditions throughout the 1992 growing season. Chisel-plowed corn did not respond to additional N. Factors such as cooler soil temperatures and much higher weed pressure than in the moldboard-plowed area had additionaly adverse effects on yields. Both ear leaf and grain N concentration indicated that neither system supplied sufficient N to maximize corn yields in this particular year.[5] This demonstration will be repeated in 1993 to estimate second year alfalfa N credits from the two tillage systems.

Demonstrations of Pulse Legume N Credits

Table 5 lists soils and crop nutrient information for these demonstrations. The University of Minnesota corn N recommendations in 1992 allowed a 40 lb/A N credit for soybeans, but no credit was given for edible beans, a legume crop grown in this area in rotation with potatoes and corn. The 1993 soybean N credit is still 40 lb/A, but this year a 20 lb/A N credit is suggested for edible beans.

Table 5. Soils and crop nutrient information for pulse legume N credit demonstrations.

Demonstration number	5	6	7
County	Stearns	Mille Lacs	Sherburne
Soils Information			
Soil type	Estherville sandy loam	Sartell fine sand	Pierz sandy loam
Subgroup	Typic hapludoll	Typic udipsamment	Udic argiboroll
Family	Sandy, mixed, mesic	Frigid	Coarse, loamy, mixed
pH	6.6	6.7	6.7
Organic matter	3.3 %	1.2 %	1.8 %
Phosphorus	25 ppm	38 ppm	39 ppm
Potassium	147 ppm	97 ppm	158 ppm
Sulfate-S	3 ppm	1 ppm	1 ppm
Nitrate-N			
Preplant	36 lb/A	20 lb/A	6 lb/A
Presidedress	88 lb/A	30 lb/A	40 lb/A
Post-harvest	32 lb/A	20 lb/A	NA
Crop Nutrient Information			
Corn yield goal	150 bu/A	170 bu/A	150 bu/A
Recommended N rate	180 lb/A	220 lb/A	180 lb/A
Previous legume crop	Navy beans	Soybeans	Soybeans
N credit	Unknown	40 lb/A	40 lb/A
Starter fertilizer	Liquid	Dry	Dry
Form[1]	9-18-9 + 0-0-30	NA	16-11-15-12
Units applied[2]	5-10-12	35-30-35-10	21-15-20-16
Sidedressed fertilizer			
Form	Anhyd. NH_3 (0-0-82)	NH_4NO_3 (28-0-0)	Anhyd. NH_3 (82-0-0)
Applied N rate			
Normal	120 lb/A	50 lb/A	136 lb/A
Demo. plots	120, 150 or 180 lb/A	0, 50 or 100 lb/A	0, 100, 140 or 180 lb/A
Fertigation			
Form		NH_4NO_3 (28-0-0)	
Applied N rate		87 lb/A	
Irrigation water			
N concentration	4.7 ppm	NA	NA
Applied N rate	Negligible	NA	NA

[1] Percent N-P_2O_5-K_2O-S [2] Lb/A N-P_2O_5-K_2O-S

[5] Grain N concentrations of 1.4 to 1.6% usually indicate adequate corn N supply.

Results of these demonstrations are shown in Table 6. In Demonstration No. 5 (corn after navy beans), corn yields of 130 to 140 bu/A were obtained with as little as 125 lb/A fertilizer N (the University recommended 150 to 180 lb N/A for these yields). This indicates that an edible bean N credit of at least 20 lb/A is realistic.

Corn yields in Demonstration No. 6 (following soybeans) did increase with N supply, although these differences may not be significant. The ear leaf and grain N concentrations of the corn with 0 lb/A sidedressed N indicated inadequate N supply. It is possible that the cool conditions of 1992 resulted in less soybean N mineralization than in a more normal year. However, a large amount of the total N supply was topdressed through the irrigation system, and some of this N may have been applied beyond the period of maximum corn N uptake (application dates between July 17 and August 4). This premise is supported by the fact that the highest N rate (262 lb/A, including soybean N credit) resulted in a yield of only 143 bu/A, though weather could also have been a factor. In this situation, it is difficult to judge the size of the legume N credit.

Yields in Demonstration No. 7 were likely limited by soil moisture rather than N supply, as late season rainfall was below normal and less than three inches of irrigation water was applied. No conclusion may be made regarding the soybean N credit since the 100 lb/A sidedress N rate (121 lb/A total N supply without the credit) should have been adequate to produce yields of 107 to 114 bu/A, and ear leaf N concentrations of 2.7% or greater seem to confirm this.

Table 6. Results of pulse legume N credit demonstrations.

Demo. No.	Reps.	Sidedress N Rate	Total N Supply	Grain Yield	Std. Dev.[1]	Grain Moisture	Ear Leaf N	Grain N	Grain N Uptake
		lb/A	lb/A	bu/A		%	%	%	lb/A
5	3	120	125	141.3	2.0	28.1	3.25	(not	(not
	3	150	155	140.1	5.8	30.5	(not	done)	done)
	3	180	185	129.3	8.2	32.2	done)		
6	3	0	162	126.6	4.2	25.2	1.78	1.27	75.6
	3	50	212	136.1	3.7	28.7	2.44	1.41	90.2
	3	100	262	143.2	6.0	27.5	3.01	1.45	97.6
7	3	0	61	52.8	7.5	27.9	2.41		
	3	100	161	107.4	3.6	27.1	2.70	(not	(not
	3	140	201	113.8	4.4	27.5	2.75	done)	done)
	3	180	241	114.5	10.4	27.9	2.71		

[1] Standard deviation for grain yield

Demonstrations of Combined Manure and Pulse Legume N Credits

Table 7. Soils and crop nutrient information for manure N credit demonstrations.

Demonstration number	8	9	10
County	Stearns	Stearns	Wright
Soils Information			
Soil type	Estherville sandy loam	Estherville sandy loam	Hubbard loamy sand
Subgroup	Typic hapludoll	Typic hapludoll	Udorthentic haploboroll
Family	Sandy, mixed, mesic	Sandy, mixed, mesic	Sandy, mixed
pH	6.6	6.3	7.0
Organic matter	3.3 %	2.5 %	1.0 %
Phosphorus	25 ppm	52 ppm	61 ppm
Potassium	147 ppm	134 ppm	108 ppm
Sulfate-S	3 ppm	4 ppm	1 ppm
Nitrate-N			
Preplant	36 lb/A	32 lb/A	14 lb/A
Presidedress	88 lb/A	36 lb/A	68 lb/A
Post-harvest	32 lb/A	28 lb/A	21 lb/A

--- Continued ---

--- Table 7 continued ---

Demonstration No.	8	9	10
Crop Nutrient Information			
Corn yield goal	150 bu/A	160 bu/A	160 bu/A
Recommended N rate	180 lb/A	200 lb/A	200 lb/A
Manure type	Dairy, liquid	Swine, solid	Dairy, solid
Application rate	3 Mgal/A	6 T/A	17.4 T/A
Application method	Broadcast	Broadcast	Broadcast
Incorporation	Within 4 days	Within 4 days	None (daily haul)
Analysis[1]	48-19-33	16-10-12	13-8-20
Availability[2]	17-70-75	30-80-85	20-80-85
Nutrient credits[3]	25-40-75	29-48-61	46-117-293
Previous legume crop	Navy beans	Soybeans	Soybeans
N credit	Unknown	40 lb/A	40 lb/A
Starter fertilizer			
Form[2]	Liquid (9-18-9 and 0-0-30)	Dry (14-16-13-11)	Dry (20-16-9-8)
Units applied[3]	5-10-12	19-22-18-15	20-16-9-8
Sidedressed fertilizer			
Form	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)
Applied N rate			
Normal	120 lb/A	100 lb/A	120 lb/A
Demo. plots	90, 120 or 150 lb/A	100 or 140 lb/A	0, 30, 60, 90 or 120 lb/A
Irrigation water			
N concentration	4.7 ppm	<0.5 ppm	NA
Applied N rate	Negligible	Negligible	NA

[1] Lb/T (solid) or lb/Mgal (liquid) $N-P_2O_5-K_2O$ (as-is basis)   [2] Percent $N-P_2O_5-K_2O-(S)$ [3] Lb/A $N-P_2O_5-K_2O-(S)$

Three demonstrations were conducted on soybean or edible bean fields to which manure had been applied prior to corn planting (Table 7, above). These fields had probably also been manured prior to project involvement, and soil P and K levels were high to very high. Very little P or K was therefore required or used in the starter fertilizers. A conservative estimate of manure nutrient availability was used in Demonstration No. 8 since the cooperator was unsure of the presence of these nutrient credits. A corn yield of 127 bu/A (Table 8, below) was achieved with an estimated total N supply of 120 lb/A (including 25 lb/A from the manure only). The beans and/or the manure appear to have contributed up to 30 lb N/A more than was credited, as yields of this size normally require about 150 lb N/A. Additional fertilizer N did not increase yields, which may have been limited by weather or other factors.

Table 8. Results of combined manure and pulse legume N credit demonstrations.

Demo. No.	Replications	Sidedress N Rate	Total N Supply	Grain Yield	Std. Dev.[1]	Grain Moisture	Ear Leaf N
		lb/A	lb/A	bu/A		%	%
8	3	90	120	126.8	10.7	28.8	(not
	3	120	150	124.5	8.8	29.1	done)
	3	150	180	127.9	1.7	27.4	
9	3	100	188	144.2	1.2	20.2	3.09
	2	140	228	152.0	0.1	19.3	(not done)
10	1	0	106	102.8	---	24.4	1.92
	3	30	136	138.3	3.6	22.5	2.40
	3	60	166	130.5	4.0	22.6	2.50
	3	90	196	132.2	3.8	22.9	2.51
	3	120	226	141.3	8.0	22.5	2.34

[1] Standard deviation for grain yield

Corn yields did increase with sidedressed N rate in Demonstration No. 9, but this difference may not be significant as ear leaf N at the lower rate was more than adequate. The manure and soybean N credit estimates were probably accurate since the yield at the lower N rate (144 bu/A) was about what would be expected with the total N supplied (188 lb/A). The nitrification inhibitor N-Serve was applied to this field at the rate of 1 pt/A, but its effects cannot be evaluated without a control treatment. Other non-manured demonstration plots have not shown yield improvements with the use of N-Serve.

The results seem inconclusive in the demonstration of daily haul manure and soybean N credits (No. 10). Yields at the lower N rates do reflect the estimated N supplies, but ear leaf N at all rates indicates lower than optimum supply. Again, yields at the upper N rates were probably limited by weather conditions. It is likely that the manure contributed nitrogen to the corn, but it is difficult to accurately assess the size of a credit from daily haul manure as bedding content may be high, applications are difficult to spread evenly and it is almost never incorporated in a timely manner.

Demonstration of Poultry Manure N Credits

This demonstration was conducted for a broiler operation with a high level of manure production but limited acreage on which to spread it. As a consequence, soil P and K levels were very high (Table 9). Poultry manure also has a higher N content than other livestock manures. Manure application, combined with starter N and a normal sidedressed N application of 190 lb/A, resulted in this field receiving approximately 360 lb N/A in 1992.

Table 9. Soils and crop nutrient information for poultry manure N credit demonstration.

Demonstration number	11	**Crop Nutrient Information**	
County	Sherburne	Manure type	Poultry, solid
		Application rate	7 T/A
Soils Information		Application method	Broadcast
Soil type	Hubbard sandy loam	Incorporation	Within 12 hours
Subgroup	Typic haploboroll	Analysis[2]	74-59-30
Family	Sandy, mixed	Availability[3]	30-80-85
pH	6.2	Nutrient credits[4]	155-330-179
Organic matter	2.3 %	Starter fertilizer	
Phosphorus	100+ ppm[1]	Form[3]	Dry (12-12-12-12)
Potassium	149 ppm	Units applied[4]	18-18-18-18
Sulfate-S	1 ppm	Sidedressed fertilizer	
Nitrate-N		Form	Anhyd. NH_3 (82-0-0)
Preplant	28 lb/A	Applied N rate	
Presidedress	252 lb/A	Normal	190 lb/A
Post-harvest	65 lb/A	Demo. plots	0, 140 or 190 lb/A
		Irrigation water	
		N concentration	6 ppm
		Applied N rate	Negligible

[1] Soil P content was greater than analysis limit of 100 ppm
[2] Lb/T (solid) or lb/Mgal (liquid) $N-P_2O_5-K_2O$
[3] Percent $N-P_2O_5-K_2O-(S)$
[4] Lb/A $N-P_2O_5-K_2O-(S)$

Table 10. Results of poultry manure N credit demonstration.

Replications	Sidedress N Rate	Total N Supply	Grain Yield	Std.Dev.[1]	Grain Moisture	Ear Leaf N
	lb/A	lb/A	bu/A		%	%
4	0	173	146.3	13.2	23.2	(not
5	140	313	165.1	8.5	22.3	done)
5	190	363	166.2	4.9	22.7	

[1] Standard deviation for grain yield

With a yield goal of 185 bu/A and manure N supply of about 155 lb/A, only 50 to 70 lb/A of additional N should have been needed. An average yield of 146 bu/A was achieved with just the manure and starter N, indicating the accuracy of the N credit estimation (Table 10, above). Sidedressing an extra 140 lb N/A resulted in only a 20 bu/A yield increase, but without incremented N treatments below this level, it cannot be determined at what total N rate yields would have been maximized. It was obvious however that the poultry manure provided a very large and very real N credit.

POTATO N MANAGEMENT AND PETIOLE N MONITORING DEMONSTRATIONS

Procedures

Demonstration No. 12 was conducted with the help of Carl Rosen, Extension Soil Scientist at the University of Minnesota, and focused mainly on evaluating the use of petiole sap nitrate testing with the Cardy Nitrate meter[6] to monitor potato plant N status and predict in-season N needs. Demonstration No. 13 was conducted separately by the project but with the same goals and methods. Nitrogen rate treatments consisted of different total rates and time-of-application splits based on normal field operations, University of Minnesota recommendations and either reduced starter N (Demo. No. 12) or reduced N at hilling (Demo. No. 13). Each treatment was replicated three times. Nitrogen application amounts for both demonstrations are shown in Table 11. All nitrogen applied up to hilling was ammonium nitrate (34-0-0) in Demonstration No. 12 and a low pressure liquid ammonium nitrate + ammonia solution (38-0-0) in Demonstration No. 13. All post-hilling N applications were as 28-0-0 (UAN) through the irrigation systems.

Table 11. Nitrogen application amounts for potato N management demonstrations.

Demo. No.	Treatment	Nitrogen Applications: Planting	Emergence	Hilling	Post-Hill	Total N Applied
		lb/A				lb/A
12	1. Univ. of MN rec.	32	50	80	51	213
	2. Reduced starter	32	80	50	51	213
	3. Grower treatment	64	80	50	51	245
13	1. Univ. of MN rec.	25	95	95	NA	215[1]
	2. Reduced hilling	25	95	120	NA	240
	3. Grower treatment	25	95	140	NA	260

[1] Does not include post-hilling N applications for Demo. No. 13.

The potato variety in each demonstration was Russett Burbank. Both demonstration fields were irrigated to provide adequate water supplies. Non-treatment cultural practices consisted of the producer's customary planting, hilling, pesticide application, vinekill and harvest practices, and were the same between the N management treatments. Soil samples for NO_3-N analysis were taken as with the corn demonstrations. Potato petiole samples from the most recently matured leaf were collected every 7-10 days starting on 6/3/92. Thirty petioles were collected in three areas within each treatment (total of 90 petioles per treatment). For each area, 15 petioles were crushed with a Hach press[7] for sap analysis. Sap nitrate was determined using the Cardy nitrate meter. For Demonstration No. 12 only, the remaining 15 petioles were dried for conventional petiole nitrate analysis. Potatoes were hand-dug from thirty foot lengths of three rows per replicate and separated into quality and size grades before weighing. Potato yields are expressed on an as-is basis.

Results and Discussion

The N treatments tested in Demonstration No. 12 had little effect on potato yields (Table 12, below). Rainfall during the 1992 growing season was very timely with only one leaching event occurring in July. Had more leaching rains occurred earlier in the season, the University recommendations treatment (more N at hilling than at emergence) may have been more beneficial. The results of this demonstration clearly suggest that high amounts of starter nitrogen are not needed

[6] Spectrum Technologies, Inc., 12010 S. Aero Dr., Plainfield, IL 60544

[7] Hach Co., P.O. Box 389, Loveland, CO 80539.

for optimum potato yields, provided that nitrogen is available at later stages of growth.

Table 12. Yield results of potato N management demonstrations.

Demo. No.	Treatment	Total N	< 3 oz.	3-12 oz.	> 12 oz.	Culls	Total
		lb/A	cwt/A				lb/A
12	1 (U of M)	213	35	432	58	54	579
	2 (Red. St.)	213	37	404	84	44	570
	3 (Grower)	245	38	423	53	49	563
13	1 (U of M)	215[1]	59	292	41	77	469
	2 (Red. Hil.)	240	57	339	30	113	539
	3 (Grower)	260	68	361	34	84	547

[1] Does not include post-hilling N applications for Demo. No. 13.

Petiole nitrate-N values for Demonstration 12 are shown in Table 13. Sap nitrate-N correlated well with conventional petiole analysis, suggesting that the sap test is a useful indicator of plant N status. Petiole nitrate-N generally followed rate of nitrogen applied, with the grower N treatment having highest petiole nitrate-N levels. However, for all treatments, these levels were on the low side throughout the growing season compared to established sufficiency ranges.[8] Additional treatments would be needed to determine whether higher N rates than those used in this demonstration would have increased yields. At least in this year, good yields were achieved with petiole nitrate-N levels lower than those suggested for sufficiency ranges. Additional research is still required to determine the practicality of using the sap test.

Table 13. Petiole nitrate-N values for Demonstration 12.

Date	6/3	6/10	6/17	6/24	7/1	7/8
	ppm NO_3-N					
Petiole sap[1]						
Trmt. 1	837	1000	1050	733	577	560
2	947	920	1027	743	423	320
3	973	1027	1200	1053	927	970
Petiole tissue[2]						
Trmt. 1	20764	21252	21749	13138	8039	3766
2	22991	19302	20308	12242	5235	2440
3	23560	21285	23445	19452	15991	12307

Date	7/15	7/22	8/5	8/12	8/19
	ppm NO_3-N				
Petiole sap[1]					
Trmt. 1	417	557	563	596	297
2	520	223	490	360	300
3	697	457	860	616	453
Petiole tissue[2]					
Trmt. 1	3951	1375	2808	4303	2610
2	2709	1388	3204	2252	707
3	6685	2409	5289	6332	1783

[1] Critical range for petiole sap NO_3-N: 6/15-7/1, 1200-1500 ppm
7/1-7/15, 800-1100 ppm
7/15-8/15, 400- 700 ppm

[2] Critical range for petiole tissue NO_3-N: 6/15-7/1, 17000-22000 ppm
7/1-7/15, 11000-15000 ppm
7/15-8/15, 6000-15000 ppm

[8] The critical ranges for petiole nitrate-N are those levels which have been found to correlate with optimum potato yields.

Potato yields in Demonstration 13 did increase with N rate (Table 12), mainly due to increases in yields in the 3-12 oz. size grade. However, these differences were not statistically significant, possibly due to large variability between individual replication yields (statistical analysis not shown). Petiole sap nitrate-N values (Table 14) for the grower N treatment tended to fall within the indicated sufficiency ranges, while those of the other two treatments fell below these levels. This is in contrast to the previous demonstration, where hilling N applications were smaller and petiole nitrate-N levels were below the critical values in all treatments.

Table 14. Petiole nitrate-N values for Demonstration No. 13.

Date	6/3	6/10	6/17	6/24	7/1	7/8
	ppm NO_3-N					
Trmt. 1	(not	937	1037	1167	1366	767
2	done)	1007	1167	1233	1333	833
3	860	980	1233	1233	1466	913
Date	7/15	7/22	7/29	8/6	8/13	8/20
	ppm NO_3-N					
Trmt. 1	1016	723	426	426	210	337
2	953	727	563	280	343	213
3	1233	930	736	540	303	320

Critical range for petiole sap NO_3-N: 6/15-7/1, 1200-1500 ppm
7/1-7/15, 800-1100 ppm
7/15-8/15, 400- 700 ppm

NITROGEN SPECIFIC MANAGEMENT BY SOIL CONDITION[1]

J.A. Vetsch, G.L. Malzer, P.C. Robert, and D.R. Huggins[2]

Abstract: Recent advances in technology has brought about considerable interest in developing the methodology for making variable N (site-specific) rate applications within a field. The objectives of this study were to evaluate yield variability within production fields, determine yield response to applied fertilizer N and differential N loss as influenced by soil conditions. This report contains results from the second year of a research project originated in 1991 to evaluate site-specific application of anhydrous ammonia to corn. Preliminary analysis by soil map unit shows considerable yield variability in segmented harvest areas between and within map units at both sites. Economic analysis of variable rate application suggests potential improvement over conventional application.

Introduction: Nitrogen specific management by soil condition (NSMSC) has evolved from recent advances in geographic information system technology and renowned interest in improving best management practices for nitrogen. Nitrogen specific recommendations, based on yield goal and soil conditions of production fields, are stored on a computer as digitized maps. The applicator's computer reads the digitized map and applies the specific N rate. Implementation of NSMSC may increase yields by better evaluating yield potentials of fields, increase profits by lowering inputs and improve water quality by identifying areas of potential N loss. This paper contains data from the second year of study to evaluate NSMSC. Anhydrous ammonia was applied in strips across production corn fields and the response to fertilizer was measured on a 'field scale'. The objectives of this study were to evaluate the variability in yield potentials within production fields, determine yield response to applied fertilizer N and differential N loss as influenced by soil conditions and ascertain what measurable soil conditions are best suited for making site specific N recommendations.

Materials and Methods: Experimental sites for 1992 were chosen at the Southwest Experiment Station, Lamberton (dryland) and the Malcolm and Steve Olson Farm, Becker (irrigated) of 19 and 29 acres respectively. The sites selected represented soil variability common to the respective areas. Experimental measurements for both sites include: an improved soil survey, grid soil sampling (analyzed for NO_3-N, NH_4-N, total N, carbon, mineralizable N and soil water), corn grain yield, grain moisture and N accumulation in grain. Soil sample grid size was 90 by 50 feet and 140 by 50 feet, samples were taken to a depth of 4 and 3 feet at Lamberton and Becker, respectively. Soil samples were separated into one foot increments for analysis. A summary of the sites soil characteristics are presented in Tables 1 and 2.

Table 1. Soil data for Nitrogen Specific Management by Soil Condition Lamberton 1992.

Soil Series	Symb	Acre	Text	Slope	T.C.	NO_3-N	Subgroup
				%	%	lbs/A	
Canisteo	86	4.9	cl	0-2	2.3	23	Mollic Haplaquoll
Delft-Web*	884	0.6	cl	0-2	2.2	38	Typic Haplaquoll
Normania	446	6.2	l	0-2	1.9	21	Aquic Haplustoll
Ves B	421B	2.0	l	2-6	1.6	23	Udic Haplustoll
Ves-Swan**	954C2	0.7	l	6-12	0.9	19	Entic Hapludoll
Seaforth	423	2.8	l	0-2	2.0	30	Auqic Calciustoll
Ves-E-S***	999B2	1.7	l/s	2-6	1.1	12	Hapludoll/Udorthent

Symb Soil series symbol
Text Soil texture
T.C. Total Carbon (values for one foot depth)
NO_3-N Residual Nitrate (values for zero to two foot depth)
* Delft Webster Complex
** Ves Swanlake Complex
*** Ves Esterville Storden Complex

[1] The assistance and financial support of the Minnesota Agricultural Experiment Station, USDA-CSRS, Dow Elanco and Soil Teq Inc. is greatfully acknowledged.

[2] Graduate assistant, Professor and Assistant Professor, Department of Soil Science, and Soil Scientist, Southwest Experiment Station, respectively.

Table 2. Soil data for Nitrogen Specific Management by Soil Condition Becker 1992.

Soil Series	Symb.	Acres	Text.	Slope	T.C.	NO_3-N	Subgroup
				%	%	lbs/A	
Hubbard A	7A	8.5	ls	0-2	1.0	8.4	Udorthentic Haploboroll
Hubbard B	7B	6.1	ls	2-6	0.7	8.4	Udorthentic Haploboroll
Hubbard C	7C	1.1	ls	6-12	0.8	6.3	Udorthentic Haploboroll
Mosford A	768A	13.6	sl	0-2	1.0	8.9	Udic Haploboroll

T.C. Total Carbon (values for one foot depth)
NO_3-N Residual Nitrate (values for one foot depth)

Lamberton: Pioneer 3615, was planted on May 4, 1992 on 30 inch row spacing. Weed control was accomplished by using Lasso at 3.0 lbs/A and Bladex at 1.5 lbs/A on May 5 and cultivation on June 4. Twelve treatments consisting of eight constant N rates (60, 90, 120, 150 and 180 lbs N/A) and (60, 90 and 120 with N-Serve, N-Serve applied at 1 qt/A), two variable N rates (soil and residual nitrate) and two checks (zero N) were applied sidedress as anhydrous ammonia on May 15 (emergence) in 15 foot strips (6 rows) across the field in a split plot randomized complete block design with 4 blocks. Rates for the variable rate by soil (VSoil) treatment were determined by existing extension recommendations and the soil map units crop equivalency rating (CER). Rates for the variable by residual nitrate (VNO_3N) were determined by the grid soil samples and the nitrogen credit equation. The previous crop was soybeans in a corn-soybean rotation.

Becker: Pioneer 3751 was planted on May 1 at a desired plant population of 31,000 on 38 inch row spacing. Starter fertilizer was applied as a side banded application of 240 lbs/A of a 12-9-30 plus sulfur and zinc. Weed control was accomplished with a tank mix of Prowl at 2 pts/A and Attrex at 1.75 lbs/A, rotary hoe and cultivation. Eleven treatments consisting of eight constant N rates paired with N-serve (90, 120, 150 and 180 lbs N/A, N-Serve applied at 0.6 qt/A), one variable rate (VSoil), and two checks (zero N) were applied sidedress as anhydrous ammonia on June 12 in 25 foot strips (8 rows) across the field in a split plot randomized complete block design with 3 blocks. Rates for the variable by soil treatment were calculated using existing recommendations and the soils CER. The previous crop was corn on a corn-corn-soybean rotation.

Results and Discussion Lamberton: (Note: This is a presentation of preliminary results, the author reserves the right to change results and conclusions.) Grain yields on check plots ranged from 28 to 154 bu/A. Variability in grain yield from the check areas was high on all soils with standard deviations ranging from 14 to 24 bu/A. This suggests that soil map unit may not be the only parameter needed to describe soil variability. The yield averages for treatments by soil map unit are presented in Table 3. All soil map units responded to fertilizer N, but generally soil map units did not respond equally. This implies differential N response to fertilizer N between soil map units. Early indications show no statistically significant yield response to N-serve by map unit, however, pairwise comparisons of 40 ft harvest segments showed large positive and negative responses in various locations of the field.

Table 3. Grain yield averages and (Standard Deviations) by soil map units for Nitrogen Specific Management by Soil Condition, Lamberton 1991.

NRate	999B2	954C2	421B	446	423	86	884
lbs/A				bu/A			
60NI	86 (27)	71 (07)	125 (12)	114 (25)	116 (26)	119 (18)	121 (04)
90NI	105 (12)	74 (12)	117 (14)	122 (18)	128 (18)	122 (12)	112 (07)
120NI	104 (21)	65 (16)	130 (09)	113 (20)	113 (22)	127 (19)	113 (NA)
0	75 (24)	54 (21)	88 (14)	88 (20)	84 (19)	79 (10)	95 (19)
60	89 (23)	89 (NA)	112 (18)	112 (23)	117 (24)	117 (16)	125 (01)
90	108 (11)	50 (19)	126 (11)	123 (20)	136 (15)	124 (17)	125 (06)
120	109 (22)	92 (15)	133 (06)	120 (19)	114 (27)	129 (19)	127 (NA)
150	128 (08)	94 (10)	135 (09)	136 (09)	115 (28)	132 (14)	126 (09)
180	129 (07)	73 (32)	128 (12)	131 (11)	119 (29)	131 (13)	106 (14)
VSNI	128 (06)	93 (13)	127 (10)	132 (10)	124 (18)	122 (10)	123 (10)
VNO_3N	99 (18)	NA (NA)	127 (17)	117 (24)	131 (22)	129 (18)	NA (NA)

NI Nitrification inhibitor (N-Serve)
NA No data or not applicable
VSNI Variable by soil treatment (N-Serve applied to Canisteo soil only)

Table 4 presents the economics for variable rate application by soil map unit at Lamberton. Two commonly used statistical models (Linear Plateau and Quadratic) were used to quantify yield response to the constant rate strips. The economic optimum N rates (EOR) for each map unit were calculated using these models. The nitrogen fertilizer return (NFR) was calculated with model predicted yields, $2.00 per bu corn, $0.13 per lb N, and N rates based on the fertilizer strategy (Conv, 150 lbs N/A for all soils; VSoil, 150 lbs N/A on map units 999B2 and 421B and 120 lbs N/A on all other map units; EOR, N rates based on economic optimum N rates. Variable rate application, VSoil, performed as well or better than conventional application on all soils except 954C2 and 446. On these soils yields were slightly reduced by lower than economic optimum rates. The NFR EOR shows that significant improvement over conventional application can be obtained.

Table 4. Economic optimum N rate (EOR) and nitrogen fertilizer return (NFR) by soil map unit for Lamberton 1992.

Statistical Model		999B2	954C2	421B	446	423	86	884
Linear Plateau								
EOR	(lbs N/A)	173	144	106	145	66	97	48
NFR Conv	($/A)	78	33	64	62	54	78	26
NFR VSoil	($/A)	78	28	64	52	58	82	30
NFR EOR	($/A)	90	34	70	62	65	85	39
Quadratic								
EOR	(lbs N/A)	NA	NA	143	160	104	134	92
NFR Conv	($/A)	NA	NA	69	62	52	85	27
NFR VSoil	($/A)	NA	NA	69	59	63	86	40
NFR EOR	($/A)	NA	NA	71	62	64	86	44

NA Model doesn't fit data

Results and Discussion Becker: Grain yields varied from 73 to 146 bu/A on check strips with considerable variability in all soil map units and standard deviations ranging from 10 to 15 bu/A. Table 5 displays yield averages for each treatment by soil map unit. Early indications show no statistically (α=0.1) significant yield response to N-serve by map unit, however, a 4.7 bu/A response was observed on soil 7A. Also, pairwise comparisons of 50 ft harvest segments showed significant positive and negative responses in various locations of the field.

Table 5. Grain yield averages and (Standard Deviation) by soil map unit for Nitrogen Specific Management by Soil Condition, Becker 1992.

NRate	7A	7B	7C	768A
lbs/A	bu/A			
90NI	140 (11)	136 (20)	141 (08)	141 (09)
120NI	153 (11)	151 (11)	131 (05)	146 (13)
150NI	144 (08)	150 (11)	146 (02)	142 (13)
180NI	150 (12)	154 (12)	170 (NA)	151 (11)
0	105 (12)	106 (15)	99 (10)	105 (14)
90	129 (12)	141 (18)	144 (03)	144 (14)
120	142 (11)	143 (09)	140 (03)	135 (10)
150	148 (13)	143 (11)	145 (03)	140 (15)
180	140 (13)	156 (10)	138 (04)	144 (09)
VS	147 (08)	149 (13)	146 (02)	142 (13)

NI Nitrification inhibitor (N-Serve)
NA No data or not applicable
VS Variable by soil treatment

The economics for variable rate application at Becker (Table 6) were calculated with the same models and parameters as Lamberton except the conventional application rate was 180 lbs N/A and the variable rates by soil were 150 lbs N/A for 768A and 120 lbs N/A for 7A, 7B and 7C. The variable rate treatment was effective on two of the soils (768A and 7A), but did not supply adequate N on the others (7B and 7C). Conclusions for the NFR EOR at Lamberton apply to the Becker site as well.

Table 6. Economic optimum N rate (EOR) and nitrogen fertilizer return (NFR) by soil map unit for Becker 1992.

Statistical Model		7A	7B	7C	768A
Linear Plateau					
EOR	(lbs N/A)	120	162	141	93
NFR Conv	($/A)	59	70	63	53
NFR VSoil	($/A)	66	54	58	57
NFR EOR	($/A)	66	73	68	65
Quadratic					
EOR	(lbs N/A)	141	186	144	139
NFR Conv	($/A)	59	71	68	56
NFR VSoil	($/A)	62	62	70	60
NFR EOR	($/A)	64	71	72	61

PROFITABILITY OF VARIABLE NITROGEN APPLICATION, BUTTERFIELD, MN[1]

D.S. Long, P.C. Robert, and D. Fairchild[2]

An experiment was performed to study the profitability of variable applications of nitrogen (N) in a field. Mean net returns and production costs were compared with respect to a variable N application rate, a single conventional N application rate, and a zero N application rate. N rates were applied in strips across Clarion loams, Canisteo-Glencoe clay loams, and Clarion-Storden loams. Net return was computed for each treatment based on value of yield at $1.82 bu/ac minus production costs for grain drying, nitrogen fertilizer, soil sampling, fertilizer application, and soil mapping. Net return was maximum at 191 $/ac for variable application followed by 181 $/ac for conventional application and 163 $/ac for zero application. The analysis of variance was applied separately to the data of each soil mapping unit. Net returns for variable and conventional rates were significantly greater than that for the zero N rate. In Clarion soils, net return for the variable rate was significantly greater than that for the conventional application (192 $/ac vs. 174 $/ac). However, significant differences in net return were not detected between variable and conventional rates in Canisteo-Glencoe soils (182 $/ac vs. 171 $/ac) and Clarion-Storden soils (198 $/ac versus 197 $/ac).

Materials and Methods

A 360 X 1320 foot (10.9 acre) field near Butterfield, MN was divided into six 180 X 1320 foot blocks in 1992. Each block consisted of three 60 X 1320 foot strips that intercepted the following three soil map units: (1) Clarion loams, 1-4 % slopes, (2) Canisteo-Glencoe clay loams, and (3) Clarion-Storden loams, 3-6 % slopes, eroded. Each strip represented one of the following treatments: (1) a conventional application of 95 lbs N/ac stripped across all soils, (2) variable application of 135 lbs N/ac to Clarion soils, 50 lbs N/ac to Canisteo-Glencoe soils, and 95 lbs N/ac to Clarion-Storden soils, and (3) a check with zero-applied N. The field was planted to corn following application of the N treatments.

Net return was based on dollar value of corn yield ($1.82 per bushel) minus production costs for grain drying to 15.5 percent moisture, nitrogen fertilizer, soil sampling, fertilizer application, and mapping. Table 1 lists unit prices for each type of cost. Yield and net return were then tabulated for the conventional, variable, and zero N treatments. The analysis of variance was applied separately to the data of each soil map unit to test for significant differences in yield and net return at the 10 percent level of probability.

Results and Discussion

Table 2 presents the summary statistics for the gross return, production costs, and net return for the conventional, variable, and zero N treatments in the entire field. The ANOVA was not applied to the entire data set because the variable rate treatments were not balanced across all soils. Production costs included those for grain drying, soil sampling, nitrogen, custom fertilizer application, and soil mapping. Gross return was maximum at 284 $/ac for the variable N rate followed by 269 $/ac for the conventional N rate and 227 $/ac for the zero N rate. These differences in gross return were due to differences in mean yield which was 156 bu/ac for the variable N rate, 148 bu/ac for the conventional N rate, and 125 bu/ac for the zero N rate. Mean production costs were maximum at 93 $/ac for the variable N rate followed by 88 $/ac for the conventional N rate and 64 $/ac for the zero N rate. Evidently, the higher production costs for variable rate was offset by the higher gross return. Accordingly, mean net return was 191 $/ac for the variable rate followed by 181 $/ac for the conventional rate and 163 $/ac for the zero rate.

Table 3 shows the effect of zero, conventional, and variable N application on yield and net return for each soil map unit in the field. Mean yield and net return of the zero rate were significantly less than that of conventional and variable rates. Significant differences in mean yield and net return were not detected between conventional and variable rates in Canisteo-Glencoe soils and

---

[1] Support for this project was provided by a grant from USDA-CSRS and Soil Teq, Inc., Waconia, MN.

[2] D.S. Long and P.C. Robert are Scientist and Associate Professor in the Soil Science Department at the University of Minnesota, St. Paul, 55108. D. Fairchild is president of Agri-information Services, Inc., White Bear Lake, MN, 55110.

Clarion-Storden soils. However, mean yield and net return were 163 bu/ac and 192 $/ac for the variable rate versus 146 bu/ac and 174 $/ac for the conventional rate and these differences were significant.

Mean values for gross return, production costs, and net return for Clarion soils are reported in Table 4. Production costs were 104 $/ac for the variable rate, 92 $/ac for the conventional rate, and 65 $/ac for the zero rate. The higher production costs of the variable rate resulted from the higher amount of applied N. However, the higher N rate lead to increased yield and gross return which offset the associated production costs. This resulted in a net return of 192 $/ac versus 174 $/ac for the conventional rate and 158 $/ac for the zero rate.

Mean values for gross return, production costs, and net return for Clarion-Glencoe soils and Clarion-Storden soils are reported in Tables 5 and 6. In the Canisteo-Glencoe soils, production costs were 88 $/ac for the variable rate, 90 $/ac for the conventional rate, and 70 $/ac for the zero rate. The lower nitrogen costs associated with the variable treatment were balanced by higher costs for sampling, fertilizing, and mapping. This lead to the production costs for variable and conventional N rates being about equal. In the Clarion-Storden soils, the production costs were 85 $/ac for the variable rate, 83 $/ac for the conventional rate, and 57 $/ac for the zero rate. The slightly higher production costs for the variable versus conventional N rates were again due to additional costs for sampling, fertilizing, and mapping. In all soils, the lower net return and production costs for the zero N rate obviously resulted from avoiding inputs for sampling, nitrogen, fertilizing, and mapping.

Table 1. Unit costs of production for conventional, variable, and zero (check) nitrogen applications.

N Application	Grain Drying	Sampling	N	Application	Mapping
	-$/%-	-$/ac-	-$/lb-	-$/ac-	-$/ac-
Convent.	0.03	0.75	0.125	4.00	0
Variable	0.03	0.75	0.125	5.00	0.50
Zero	0.03	0	0	0	0

Table 2. Entire field: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	---$/ac---			
	Conventional N Rate; 95 lb/ac			
Gross Return	269.16	23.97	211.12	320.32
Drying	-71.59	8.15	59.12	86.42
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	180.94	n/a	n/a	n/a
	Variable N Rates; 135, 95, and 50 lb/ac			
Gross Return	283.62	21.72	256.62	351.26
Drying	-72.78	9.36	56.57	98.36
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-11.67	4.47	6.25	16.88
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	190.92	n/a	n/a	n/a
	Zero N Rate; 0 lb/ac			
Gross Return	227.10	21.81	182.00	254.80
Drying	-63.96	8.57	47.52	79.86
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	163.14	n/a	n/a	n/a

Table 3. Effect of zero, conventional, and variable N rates application on corn yield and net return for each soil.

N Application	Mean Yield †	Mean Net Return	N
	--bu/ac--	--$/ac--	
	Clarion Soils		
Zero	122.7 A	158.04 A	6
Conventional	146.3 B	174.43 B	6
Variable	163.2 C	192.27 C	6
	Canisteo-Glencoe Complex		
Zero	125.3 A	158.25 A	6
Conventional	143.3 B	171.22 B	6
Variable	148.5 B	182.26 B	6
	Clarion-Storden Complex		
Zero	126.3 A	173.12 A	6
Conventional	154.0 B	197.14 B	6
Variable	155.8 B	198.24 B	6

† Means with the same letter are not significantly different at the 10 percent level of probability based on method of least square means.

Table 4. Clarion Soil: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	----------------------$/ac----------------------			
	Conventional N Rate, 95 lb/ac			
Gross Return	266.33	35.83	211.12	320.32
Drying	-75.26	10.02	59.12	86.42
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	174.44	n/a	n/a	n/a
	Variable N Rate, 135 lb/ac			
Gross Return	296.96	31.93	256.62	351.26
Drying	-79.57	10.65	68.12	98.36
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-16.88	n/a	n/a	n/a
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	192.26	n/a	n/a	n/a
	Zero N Rate: 0 lb/ac			
Gross Return	223.25	29.00	183.82	252.98
Drying	-65.22	7.13	55.76	72.36
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	158.03	n/a	n/a	n/a

Table 5. Canisteo-Glencoe soils: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	-----------------------$/ac-----------------------			
	Conventional N Rate, 95 lb/ac			
Gross Return	260.87	18.97	242.06	283.92
Drying	-73.02	6.94	62.72	81.50
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	171.22	n/a	n/a	n/a
	Variable N Rate, 50 lb/ac			
Gross Return	270.27	9.05	262.08	283.92
Drying	-73.51	6.15	68.51	83.05
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-6.25	n/a	n/a	n/a
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	182.26	n/a	n/a	n/a
	Zero N Rate, 0 lb/ac			
Gross Return	228.11	26.86	182.00	254.80
Drying	-69.85	8.51	56.12	79.86
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	158.26	n/a	n/a	n/a

Table 6. Clarion-Storden soils: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	----------------------$/ac----------------------			
	Conventional N Rate, 95 lb/ac			
Gross Return	280.28	8.38	265.72	289.38
Drying	-66.51	5.29	62.46	76.90
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	197.14	n/a	n/a	n/a
	Variable N Rate, 95 lb/ac			
Gross Return	283.62	8.65	267.54	293.02
Drying	-65.25	4.73	56.57	70.54
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	198.24	n/a	n/a	n/a
	Zero N Rate, 0 lb/ac			
Gross Return	229.93	5.10	222.04	234.78
Drying	-56.81	4.61	47.52	60.04
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	173.12	n/a	n/a	n/a

MAPPING SENSOR MEASURED SOIL ORGANIC MATTER[1]

D.S. Long and P.C. Robert[2]

The soil monitoring and applicator regulator (SMART) system continuously measures soil red spectral reflectance to estimate organic matter directly. This system was investigated for potential in mapping soil organic matter in a field. For purpose of comparison, soil organic matter content also was measured by means of laboratory analysis of soil samples. Kriged maps made from SMART measured organic matter and from laboratory measured organic matter were similar in appearance. This suggested the potential usefulness of the SMART system for rapid survey of soil organic matter content.

Materials and Methods

A 730 X 2100 ft (35 acre) field near Clarkston, Minnesota was sampled for soil organic matter content. The soil monitoring and application regulator system (SMART) was used to estimate organic matter content along a series of six parallel transects that were oriented with the length of the field. Each transect was separated by 120 ft. The SMART system took approximately 50 samples along each transect thus yielding a sampling interval of about 42 ft.

Uncorrected readings (n=3) from the SMART sensor were calibrated to percent organic matter using an appropriate mathematical expression. This expression was found to be an exponential function of the form

$$y=ae^{bx} \tag{1}$$

where y is percent organic matter, a equals 0.00004, e is the exponential function, b is a constant equal to 2.54, and x is the SMART reading in volts. The conventional technique involved sampling soils in the 0-m to 0.15-m depth increment at points along each of the six transects. The separation distance between samples was 100 ft. The samples were analyzed for organic matter content in a laboratory using the Walkley-Black method.

Geostatistics were used to estimate values of organic matter to the nodes of a 7 X 12 estimation grid in a procedure known as kriging. Semivariograms using in kriging were based on a contiguous subset of the field where the data expressed no major trends and hence, was stationary. Estimated values of organic matter were generated to an 11 X 23 rectangular grid system having 22 separations in the x direction and 10 separations in the y direction. The x separation distance was 76.5 ft and the y separation distance was 99 ft.

Results and Discussion

SMART estimated organic matter ranged from a low of 1.3 % to a high of 4.5 %. Corresponding laboratory estimated organic matter ranged from a low of 2.2 % to a high of 8.0 %. Summary statistics reporting the mean, minimum, maximum, standard deviation, and coefficient of variation for each variable are given in Table 1.

Table 1. Summary statistics for SMART voltage, SMART calibrated percent organic matter content (OM_c), and laboratory measured percent organic matter content (OM_l).

Variable	Mean	Min.	Max.	S.D.	C.V.	N
Voltage	4.38	4.08	4.58	.108	2.47	271
OM_c	2.78	1.27	4.49	.728	2.62	271
OM_l	4.38	2.20	8.00	1.59	36.3	117

[1] Support for this project was provided by a grant from USDA-CSRS, and Tyler Inc., Benson, MN, 56215.

[2] D.S. Long and P.C. Robert are Scientist and Associate Professor in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108.

As indicated in Table 1, the minimum and maximum values of SMART and laboratory derived organic matter differed in magnitude. The lack of a sufficient number of observations to develop the calibration curve was a reason for this inconsistency. To properly develop this calibration, users of the SMART system should include a larger sample number from a diversity of soil conditions in a field.

Maps of kriged organic matter content are illustrated in Figures 1, 2, and 3. In general, the maps formed from SMART and laboratory measurements were similar in appearance. High and low areas of organic matter content were consistent from map to map. Areas of low and high organic matter were detected by both techniques and correspond with well drained soils in sloping terrain and poorly drained soils in depressions, respectively. This correlation suggests that the SMART system is a potentially useful technique for rapid survey of soil organic matter content in fields.

The correlation between SMART and laboratory measured organic matter content was 0.35. This weak correlation may be attributed to pairs of SMART and laboratory measurements that were not sampled from joint field locations. Instead only data were available that were located within approximately 10 ft of one another. Furthermore, the accuracy of the SMART sample locations is unknown and hence, sampling error may exist in measured observations of this variable. These problems suggest that this correlation should be interpreted with caution and that a future correlation should be based on jointly located pairs of samples.

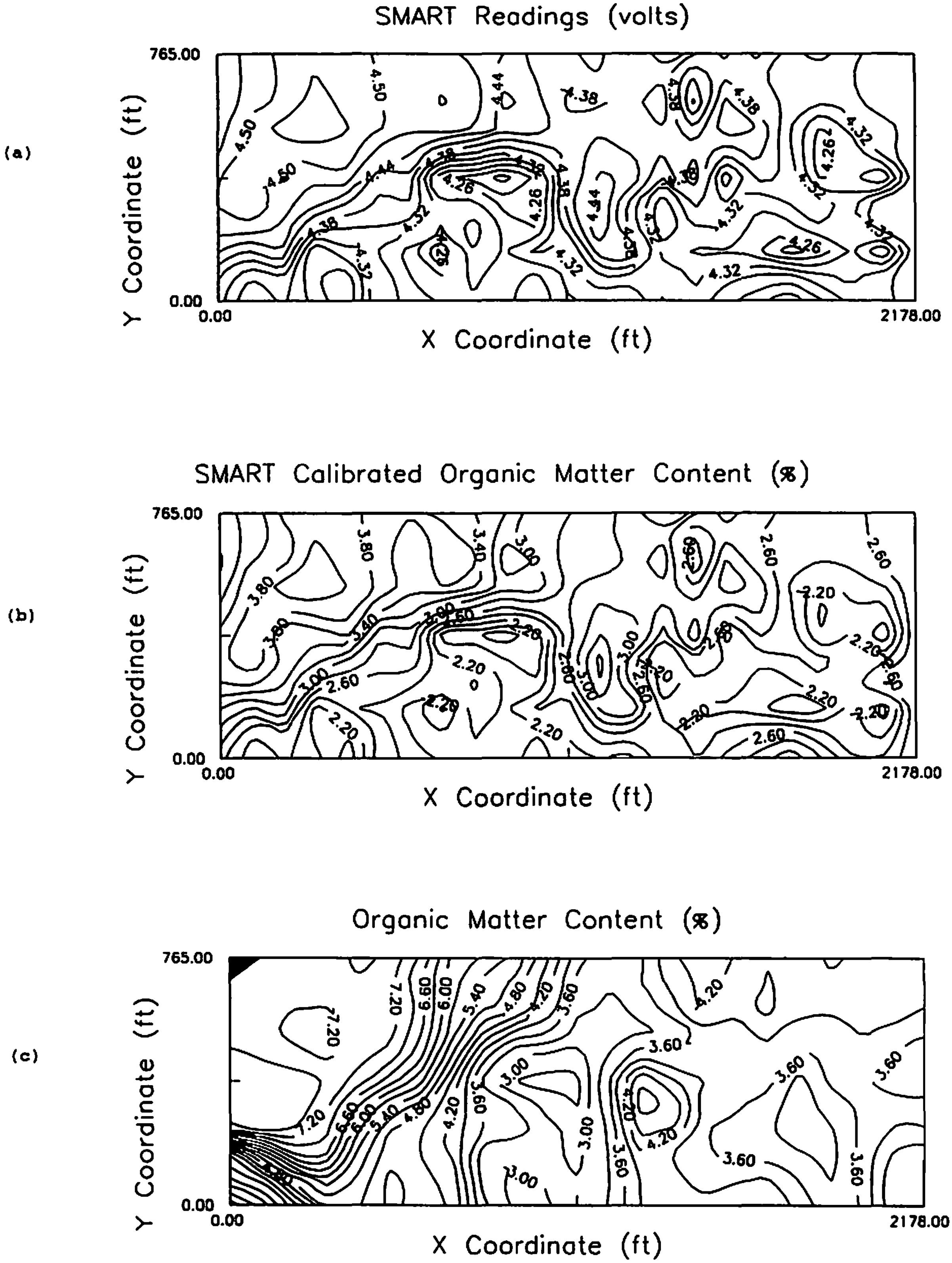


Figure 1. Maps of (a) kriged SMART voltage, (b) kriged SMART calibrated organic matter, and (c) kriged laboratory measured organic matter.

PERFORMANCE OF A VARIABLE TILLAGE IMPLEMENT[1]

D.S. Long, P.C. Robert, D.J. Fuchs, and D.R. Huggins[2]

A study to determine the performance of a variable tillage implement (VTI) was initiated in corn and soybean residues in 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 the following conventional tillage systems: no-till, field cultivation, and moldboard. Soybean residue cover left after tillage was about 6 percent despite different blade angle and depth settings of the variable rate implement. Field cultivation left 17 percent residue cover versus the variable rate implement at zero blade settings which left 9 percent. Corn residue cover left after tillage ranged from 46 percent at zero blade settings to 22 percent at maximum blade settings of 30 degree angle and 10 inch depth. These results suggest that better performance is obtained when the implement is used in corn residue versus soybean residue.

Materials and Methods

A variable 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. The residues were from crops that were harvested in fall 1991. Each residue type constituted a separate randomized complete block experiment. Testing will continue in 1993.

The experiment for soybean residue included the following tillage treatments: four different rates of the VTI unit, field cultivation, and no-till (Table 1). These treatments in turn subdivided three replicated mainplots of poorly drained Webster soils (Typic Haplaquolls) and well drained Ves soils (Udic Haplustolls). The tillage treatments were applied in early spring.

The experiment for corn residue included subunits of chopped and unchopped residue treatments that were stripped across three replicated mainplots of poorly drained Webster soils and well drained Ves soils. The residue was chopped in fall 1991. Each subunit was divided into the following tillage treatments: five different VTI rates, moldboard plow, and no-till (Table 1). Tillage treatments were applied in early spring.

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 square 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 difference between residue cover before and 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).

[1] Support for this project was provided by a grant from USDA-CSRS, Soil Teq Inc., and DMI Inc.

[2] D.S. Long and P.C. Robert are Scientist and Associate Professor in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. D.J. Fuchs and D.R. Huggins are Scientist and Assistant Professor at the Southwest Experiment Station, Lamberton, MN, 56152.

Results and Discussion

Soybean Residue Cover. The residue cover before tillage in early spring was about 44 ± 18 percent in all plots. Table 2 presents the summary statistics for percent soybean residue cover left after tillage. In general, the results show that soybean residue cover was maximum for no-till, followed by field cultivation and the VTI method. To satisfy the equal variances assumption in ANOVA, the no-till treatment was dropped from the analysis and the log-transform function was applied [$Y = \log(X)$]. This transform also produced normality for the data of each tillage treatment according to the Shapiro-Wilk test statistic at the 5 percent level of probability.

Table 3 presents the ANOVA for percent soybean residue left after tillage. The F statistic is significant for tillage treatments and hence, the null hypothesis of equal treatment means was rejected. Though the F value is significant for soil the effect of this treatment was difficult to interpret because the experiment was limited to only one field. Meanwhile, the soil-by-tillage interaction was insignificant.

Table 4 shows the effect of tillage treatments on percent soybean residue cover as measured across all soils. Residue cover was highest at 17 percent for field cultivation and this was significantly greater than that for all VTI treatments. Residue cover was second highest at 9 percent for the VTI treatment having zero blade settings and this was significantly greater than all other VTI treatments. There were no significant differences among the VTI treatments with respect to a blade angles greater than 15 degrees and blade depth greater than 2 inches. These results indicate that changing blade angle and depth beyond zero has little effect on incorporated levels of soybean residue.

Corn Residue Cover. The residue cover before tillage in early spring was about 67 ± 15 percent in all plots. Table 5 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. To satisfy the equal variances assumption in ANOVA, the no-till treatment was dropped from the analysis and the log-transform function was applied [$Y = \log(X)$]. This transform also produced normality for the data of each tillage treatment according to the Wilk-Shapiro test statistic at the 5 percent level of probability.

Table 6 presents the ANOVA for percent corn residue left after tillage. The F statistic was significant for tillage treatments and hence, the null hypothesis of equal treatment means was rejected. The soil-by-tillage interaction was significant, however, this interaction became insignificant when the moldboard treatment was excluded from the ANOVA.

Table 7 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. The results show that residue cover left after tillage with the VTI implement decreases with increasing blade angle and blade depth. Residue cover was highest at 46 percent for the VTI method with zero blade settings and decreased to 22 percent with blade angle of 30 degrees and blade depth of 4 inches. There may have been little practical difference between moldboard and maximum VTI blade settings (16.5 versus 21.8 percent). The results indicate that changing the blade angle and depth with the VTI implement does effect levels of incorporated corn residue.

Table 1. Tillage treatments in soybean and corn residues.

Soybean Residue	Corn Residue
1 No-till	1 No-till
2 Field Cultivation	2 Moldboard
3 VTI 0 deg. 0 in.	3 VTI 0 deg. 0 in.
4 VTI 15 deg. 5 in.	4 VTI 15 deg. 5 in.
5 VTI 15 deg. 10 in.	5 VTI 15 deg. 10 in.
6 VTI 30 deg. 5 in.	6 VTI 30 deg. 5 in.
	7 VTI 30 deg. 10 in.

Table 2. Descriptive statistics for percent soybean residue cover left after tillage relative to measurements from all soils.

Treatment	Mean	Variance	Max.	Min.	N
		---------%---------			
Fld. Cult.	17.4	88.4	40.1	6.7	40
No-till	72.0	4658.0	450.9	22.5	40
VTI 0 0	8.9	17.8	18.4	1.1	40
VTI 15 5	6.6	10.1	15.3	1.1	40
VTI 15 10	5.1	5.4	11.3	1.3	40
VTI 30 5	5.6	10.7	14.7	0.7	40

Table 3. Analysis of variance for percent soybean residue cover.

Source of Variation	Sum of Squares	F Statistic	P Value
Soil	3.005	12.94	.0004
Replications	1.661	.415	.1331
Tillage	21.18	22.8	.0001
Samples	7.619	10.93	.0001
Soil*Tillage	1.937	2.08	.0846

Table 4. Effect of tillage treatments on percent soybean residue cover.

Treatment	Residue Left After Tillage †	Standard Deviation	N
	------%------		
Fld. Cult.	17.4 A	9.4	40
VTI 0 0	8.9 B	4.2	40
VTI 15 5	6.6 C	3.2	40
VTI 15 10	5.1 C	2.3	40
VTI 30 5	5.6 C	3.3	40

† Means with the same letter are not significantly different at the 5 percent level of probability.

Table 5. Descriptive statistics for corn residue cover left after tillage expressed in percent relative to measurements from all soils and residue treatments.

Treatment	Mean	S.D.	Min.	Max.	N
	--------	-----	%	-----	
No Till	102.3	22.9	49.2	160.2	36
Moldboard	16.5	11.4	4.0	46.7	36
VTI 0 0	45.5	25.8	14.4	145.6	36
VTI 15 5	32.7	18.6	10.5	98.2	36
VTI 15 10	40.1	23.6	14.2	137.8	36
VTI 30 5	28.8	15.4	10.0	71.7	36
VTI 30 10	21.8	11.1	5.7	59.5	36

Table 6. Analysis of variance for percent corn residue cover left after tillage.

Source of Variation	df	Sum of Squares	F Statistic	P Value
Soil	1	0.649	2.72	0.10
Replications	2	2.93	1.46	0.0026
Residue	1	0.235	0.99	0.32
Tillage	5	30.42	25.5	0.0001
Soil*Residue	1	0.740	3.10	0.080
Soil*Tillage	5	5.52	4.63	0.0005
Samples	2	0.882	1.85	0.16

Table 7. Effect of tillage treatments on percent corn residue cover.

Treatment	Residue Left After Tillage †	Standard Deviation	N
	----------- %	----------	
VTI 0 0	45.5 A	25.8	36
VTI 15 10	40.1 AB	23.6	36
VTI 15 5	32.7 BC	18.6	36
VTI 30 5	28.8 CD	15.4	36
VTI 30 10	21.8 D	11.1	36
Moldboard	16.5 E	11.4	36

† Means with the same letter are not significantly different at the 5 percent level of probability.

LAND SPREADING OF YARD WASTE

Carl Rosen, Thomas Halbach, Jean Molina, Dave Birong, Jennifer Weiszel

ABSTRACT: A field experiment at the Sand Plain Research Farm in Becker, Minn. was conducted to determine the effects of applying yard waste applications (primarily tree leaves) on corn production and soil nitrate movement. The yard waste was applied in the fall of 1991. Treatments included four rates of yard waste (0, 20, 40, and 80 T/A) with either 0 fertilizer N applied, 200 lbs N/A during the 1992 growing season, or 66 lbs N/A applied with the yard waste plus 200 lbs N/A applied during the growing season. Yard waste application initially inhibited growth and depressed tissue nitrogen composition of developing corn plants. The inhibitory effect diminished when fertilizer N was applied. These results suggest that soil N was immobilized for 5-6 weeks after planting. By harvest, corn grain yield increased with increasing yard waste application when no fertilizer N was applied, presumably due to release of nitrogen and possibly other nutrients from the yard waste. When N was added during the growing season, with or without fall applied N, the effect of yard waste on grain yield was generally not significant. Maturity, as measured by % moisture in the grain, was delayed with yard waste application. Yard waste application tended to decrease nitrate leaching during the first year after application. Highest nitrate-N concentrations in soil water at the three foot depth were recorded when N was applied in the fall with or without yard waste. During the first year after yard waste application, acceptable yields were obtained at all rates of applied yard waste combined with 200 lb N/A without significant nitrate losses.

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 yard wastes from being put 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 generally low available nitrogen content. In addition, the effects on nitrogen use and crop production in general need to be ascertained. Therefore, the objectives of this study were to: 1) Determine the effects of direct application and incorporation of noncomposted yard waste (primarily tree leaves), with and without fertilizer nitrogen, on productivity of irrigated field corn, and 2) Characterize nitrogen release from the leaves during the growing 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. Initial soil chemical characteristics include (0-6"): organic matter, 1.7%; pH (1:1 soil:water), 6.8; Bray P, 26 ppm; K (NH_4OAc), 61 ppm. Extractable (KCl) nitrate-N and ammonium-N in the top 3 feet were 30 lbs/A and 4 lbs/A, respectively. The previous crop was rye. Yard waste was collected in October 1991 and applied to 15' x 35' plots with a front end loader on October 31, 1991. The yard waste primarily consisted of tree leaves, although some garden plants and grass clippings were also present. Subsamples of yard waste applied to each plot were collected for chemical analysis. The following 12 treatments were tested: 0, 20, 40, 80 dry tons/A yard waste (no added N); these same treatments with 200 lb N/A applied during 1992; these same treatments with 66 lb N/A applied in the fall of 1991 plus 200 lb N/A applied during 1992. The fertilizer N source used in all cases was urea. An average of 30% moisture was assumed for application of all yard waste treatments. The experimental design was a randomized complete block with 4 replications. The leaves were incorporated with a rototiller after application (fall 1991) and the whole field was moldboard plowed one week prior to planting in 1992. In addition, 235 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 28, 1992 at a population of 30,700 seeds/A (2.5 ft. between rows). At planting, 185 lbs/A 0-14-42 was banded 2 inches to

---

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

[2]Extension Soil Scientist, Extension Waste Management Specialist, Professor, Junior Scientist, and Senior Research Plot Technician, respectively, Department of Soil Science.

the side and two inches below the seed. On May 27, 100 lbs N/A was sidedressed with a hand pushed Gandy fertilizer applicator and cultivated in. Additional N at a rate of 50 lbs/A per application was applied with the Gandy applicator on June 17 and June 22 and irrigated in with 0.5 inch of water. Irrigation was used to supplement rainfall (Figure 1).

Soil samples at the 0-8 inch depth were collected from each plot before planting. After harvest, soil samples were collected from 0-6, 6-12, 12-24 and 24-36 inch depths. Soil nitrate and ammonium were determined on 2 N KCl extracts.

Suction tubes with ceramic cups were installed at a depth of 3 feet in two replications of each treatment. Suction tubes at the 6 foot depth were installed in two reps for the control and 40 T/A yard waste plus 266 lbs of N treatments. Water samples were collected every two weeks through the growing season and analyzed for nitrate. On one set of water samples (September 11), a more extensive elemental analysis was performed using an ICP spectrophotometer.

Whole plant samples (4 per plot) were collected at the three leaf stage (May 26) before fertilizer N was applied in 1992. Whole plant samples (4 per plot) at the 8-12 leaf stage were collected on June 26 after all fertilizer N was applied. Ear leaf samples at 50% silking were collected on July 28. Two, 20 foot rows were harvested for grain and stover yield from each plot on October 10. Subsamples of stover and grain plus cob were taken for moisture determinations, shelling percentages, and nitrogen analyses. Plant tissue samples were dried and then ground through a 30 mesh screen. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

RESULTS

Yard Waste Elemental Composition: The yard waste had an acid pH (Table 1). The average moisture content was 30% with a range of 18.6 - 48.1%. The outer part of the pile tended to be drier than the inner part. The C/N ratio averaged 37.8%, which is on the low side for leaves, but is in a range that should initially immobilize N. The yard waste contained 21.2 lbs N/dry ton, 3.2 lbs P/dry ton (7.4 lbs P_2O_5), and 14.4 lbs K/dry ton (17.3 lbs K_2O). The yard waste contained significant quantities of Ca, Mg and S. Trace elements were also present in the yard waste, but were not at levels considered to be detrimental to the environment.

Corn Growth and Yield: Initial growth of corn was significantly inhibited as leaf application rate increased (Table 2). Application of N tended to minimize the negative effect of yard waste application on initial corn growth. Greatest growth at the 8-12 leaf stage occurred when N was applied in the Fall and during the growing season. Yard waste application rate up to 40 T/A tended to increase final stand count. At the 80 T/A rate, stand count declined. Stand count also increased with increasing fertilizer N rate. At harvest, increasing yard waste rates increased grain yield when no N was applied, indicating a significant release of N from the yard waste. However, when N was added during the growing season with or without fall applied N, the effect of yard waste on grain yield was generally not significant. There was a slight decrease in grain yield at the highest yard waste rate and when fall N plus 200 lb N/A was applied. Stover yield increased with increasing yard waste application and fertilizer N rate. Yard waste and low fertilizer N tended to delay maturity as measured by higher kernel moisture percentage.

Tissue Nitrogen Concentrations: Nitrogen concentrations in whole plants sampled at the 3 leaf stage decreased as yard waste application increased (Table 3). These results indicate that early in the season N was immobilized by the yard waste. Fall applied N significantly increased N concentrations in the plant. By the 8-12 leaf stage, yard waste application was beginning to have a positive effect on N concentrations in the plant, while the effect of fall application of N began to diminish. Ear leaf N increased with increasing yard waste application when no fertilizer N was applied, but was not affected by yard waste when fertilizer N was applied. Application of fertilizer N increased N concentrations in the ear leaf. Cob N concentrations were not affected by yard waste application and were not consistently affected by fertilizer N application. Stover N concentrations tended to increase with increasing yard waste application, primarily when no fertilizer N was applied. Application of fertilizer N also increased N concentrations in the stover. Kernel N increased with increasing application of yard waste and increasing fertilizer N application. As with other tissues, the effect of yard waste was most pronounced when fertilizer N was not applied.

Soil Nitrogen Content: Soil nitrogen increased with increasing yard waste application in the top 6 inches, but was not significantly affected by yard waste at the lower depths (Table 4). Soil nitrogen increased with increasing fertilizer N application, with the fall applied N treatment having the highest residual N in the top 3 feet. It is interesting to note, however, that the initial soil nitrate-N content of 30 lbs/A was higher than the soil nitrate-N content following any of the fertilizer N and/or yard waste treatments.

Soil Water Elemental Concentrations: Elemental concentrations in soil water sampled on September 11 are presented in Table 5. Al, B, Cd, Cr, Cu, Fe, Mo, Ni, and Pb were generally below detection limits of the ICP. Ca, K, Na, and S tended to increase with increasing yard waste application. P concentrations tended to increase with increasing yard waste when no fertilizer N was applied, but was not consistently affected when fertilizer N was applied. Except for soil water nitrate (see below), other elements determined in soil water were not affected by yard waste application or fertilizer N.

Soil Water Nitrate Concentrations: Concentrations of nitrate-N in soil water as affected by treatments are presented in Figures 2-13. Yard waste applications tended to decrease nitrate concentrations in soil water at the three foot depth when fertilizer N was not applied. The control treatment had the highest water nitrate-N concentrations with levels slightly above 10 ppm. When yard waste was applied nitrate-N concentrations were less than 10 ppm. Nitrate-N concentrations at the three foot depth, when fertilizer N was applied during the season, tended to be highest when 80 T/A yard waste was applied at mid-season. However, by the end of the season, the 0 yard waste treatment with fertilizer N had the highest nitrate concentrations. Nitrate-N concentrations in soil water were greatest when fertilizer N was applied in the fall. Highest concentrations at mid-season were recorded when 0 T/A leaves were applied. Yard waste application tended to decrease nitrate-N concentrations; however, compared to the other N treatments, fall applied N resulted in the highest losses at the end of the growing season. From these measurements, yard waste amendments appear to reduce nitrate-N losses during the first growing season after application.

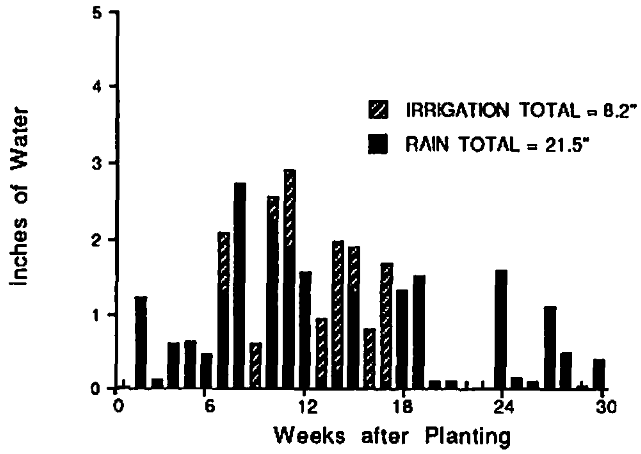


Figure 1. Rainfall and irrigation provided over the 1992 growing season.

Table 1. Elemental concentrations of original yard waste samples.

	Mean	Standard Deviation	Minimum	Maximum	lbs element/ dry ton
pH	4.9	0.2	4.4	5.5	
% moisture	29.7	7.7	18.6	48.6	
C to N ratio	37.9	3.2	29.6	42.6	
Macroelements (%)					
Carbon	39.76	3.49	33.56	45.95	795.2
Nitrogen	1.06	0.12	0.81	1.46	21.2
Phosphorus	0.16	0.02	0.12	0.20	3.2
Potassium	0.72	0.14	0.47	1.16	14.4
Calcium	2.33	0.25	1.75	2.75	46.6
Magnesium	0.37	0.04	0.27	0.49	7.4
Sulfur	0.19	0.02	0.15	0.22	3.8
Microelements (ppm)					
Aluminum	1052	464	254	1960	2.1
Boron	65	9	48	97	0.13
Cadmium	<0.52	0.35	<0.16	1.30	<0.10
Chromium	7.5	3.5	1.6	14.4	0.015
Copper	8.4	1.2	5.6	10.7	0.016
Iron	969	334	359	1755	1.9
Lead	<15.5	7.7	<2.2	39.6	<0.031
Manganese	249	40	177	399	0.50
Nickel	<6.5	3.3	<0.9	13.4	0.013
Sodium	105	23	60	163	0.21
Zinc	61	9	40	85	0.12

Table 2. Effect of leaf and nitrogen application on whole plant dry matter at the 8-12 leaf stage, final stand count, grain and stover yield, and kernel moisture.

Leaf rate	Nitrogen application	Whole plant dry matter (8-12 leaf)	Final stand count	Grain yield	Dry stover	Kernel moisture
-tons/A-	--lbs/A--	-grams/plant-	-plants/A-	-bu/A-	-tons/A-	- % -
0	0	16.0	26463	76	1.25	36
20	0	5.5	26789	99	1.37	39
40	0	8.8	28532	124	1.68	38
80	0	6.0	26681	130	1.86	36
0	200	21.8	27770	188	2.48	29
20	200	12.5	27334	185	3.06	34
40	200	9.3	27770	188	3.05	35
80	200	10.5	27770	182	3.17	35
0	66+200	29.3	27660	195	2.91	31
20	66+200	25.5	28859	203	3.01	30
40	66+200	15.0	28859	195	3.15	35
80	66+200	13.0	27661	176	2.95	34
Significance		**	NS	**	**	**
BLSD (5%)		9.3	—	20	0.50	3
Main effects						
Leaf Rate						
0		22.3	27298	153	2.22	32
20		14.5	27661	162	2.48	34
40		11.0	28387	169	2.63	36
80		9.8	27370	162	2.66	35
Significance		**	NS	NS	*	**
BLSD (5%)		5.3	—	—	0.34	2
Linear		**	NS	NS	**	**
Quadratic		*	*	*	NS	**
Nitrogen Application						
	0	9.0	27116	107	1.54	37
	200	13.5	27661	186	2.94	33
	66+200	20.8	28260	192	3.01	32
Significance		**	*	**	**	**
BLSD (5%)		4.3	892	10	0.24	2
Interaction						
Leaf x Nitrogen		NS	NS	**	NS	*

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

Table 3. Effect of leaf and nitrogen application on percent nitrogen present at various growth stages and in various plant tissues.

Leaf rate	Nitrogen application	Whole plant 3 leaf stage	Whole plant 8-12 leaf stage	Ear leaf silking stage	Cob	Stover	Kernel
-tons/A-	--lbs/A--	% Nitrogen					
0	0	4.19	1.74	1.34	0.31	0.38	0.92
20	0	3.19	2.49	1.97	0.29	0.42	1.01
40	0	3.03	2.57	2.05	0.28	0.47	1.12
80	0	2.80	3.00	2.31	0.27	0.52	1.24
0	200	4.21	3.14	2.89	0.25	0.53	1.26
20	200	3.20	3.80	2.94	0.26	0.58	1.29
40	200	3.16	3.96	2.68	0.24	0.61	1.35
80	200	3.19	3.71	3.04	0.26	0.60	1.37
0	66+200	4.32	3.08	3.00	0.26	0.57	1.35
20	66+200	4.39	3.30	2.51	0.26	0.65	1.38
40	66+200	4.10	3.57	2.95	0.26	0.63	1.41
80	66+200	3.60	3.66	2.94	0.27	0.55	1.41
Significance		**	**	**	**	**	**
BLSD (5%)		0.72	0.40	0.76	0.03	0.12	0.09
Main effects							
Leaf Rate							
0		4.24	2.66	2.35	0.27	0.49	1.18
20		3.59	3.20	2.47	0.27	0.55	1.23
40		3.43	3.36	2.56	0.26	0.57	1.29
80		3.20	3.46	2.76	0.26	0.56	1.34
Significance		**	**	NS	NS	NS	**
BLSD (5%)		0.39	0.23	--	--	--	0.05
Linear		**	**	NS	NS	NS	**
Quadratic		*	**	NS	NS	NS	NS
Nitrogen Application							
	0	3.30	2.45	1.92	0.29	0.45	1.07
	200	3.44	3.65	2.89	0.25	0.58	1.32
	66+200	4.10	3.40	2.84	0.26	0.60	1.39
Significance		**	**	**	**	**	**
BLSD (5%)		0.34	0.19	0.33	0.01	0.05	0.04
Interaction							
Leaf x Nitrogen		NS	NS	NS	NS	NS	*

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

Table 4. Effect of leaf and nitrogen application on soil nitrate-N (lbs/A) in the top three feet at the end of the growing season.

Leaf 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	0.78	0.74	0.75	0.72	2.98
20	0	1.24	0.99	0.94	0.64	3.81
40	0	1.90	1.54	1.47	0.67	5.58
80	0	2.96	2.53	1.36	1.12	7.97
0	200	2.35	2.34	1.67	0.74	7.09
20	200	4.22	3.78	2.24	1.22	11.46
40	200	5.30	4.10	2.63	1.25	13.28
80	200	6.34	3.76	2.10	0.79	12.99
0	66+200	2.73	3.29	1.54	1.18	8.74
20	66+200	7.98	9.50	6.82	3.14	27.44
40	66+200	7.96	6.69	2.93	1.42	18.99
80	66+200	9.20	5.10	3.31	2.19	19.80
Significance		**	**	**	**	**
BLSD (5%)		3.41	4.62	2.96	1.24	10.80
Main effects						
	Leaf Rate					
	0	1.95	2.12	1.32	0.88	6.27
	20	4.48	4.76	3.33	1.67	14.23
	40	5.05	4.11	2.34	1.11	12.61
	80	6.17	3.80	2.26	1.37	13.59
	Significance	**	NS	NS	NS	*
	BLSD (5%)	1.94	—	—	—	6.57
	Linear	**	NS	NS	NS	NS
	Quadratic	NS	NS	NS	NS	NS
	Nitrogen Application					
	0	1.72	1.45	1.13	0.79	5.08
	200	4.55	3.49	2.16	1.00	11.20
	66+200	6.97	6.14	3.65	1.98	18.74
	Significance	**	**	**	**	**
	BLSD (5%)	1.57	1.93	1.28	0.54	4.78
Interaction						
	Leaf x Nitrogen	NS	NS	NS	NS	NS

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

Table 5. Effect of leaf and nitrogen application on elemental composition of soil water collected at 3' from suction tubes - Sept. 11, 1992.

Leaf rate	Nitrogen application	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn
-tons/A-	--lbs/A--	ppm																
0	0	<0.18	<0.02	44	<0.006	<0.01	<0.03	<0.02	1.6	6	0.015	<0.01	6	<0.022	0.08	<0.09	33	0.11
20	0	<0.18	<0.03	55	<0.006	<0.01	0.06	<0.02	1.7	10	0.037	<0.01	38	0.028	0.08	<0.09	73	0.35
40	0	<0.18	0.17	111	<0.006	<0.01	<0.03	<0.02	1.6	13	0.052	<0.01	12	0.028	0.10	<0.09	97	0.15
80	0	<0.18	0.07	123	<0.006	<0.01	<0.03	0.03	3.8	14	0.017	<0.01	47	<0.024	0.21	<0.09	117	0.09
0	200	<0.18	<0.02	66	<0.006	<0.01	<0.03	<0.02	1.9	12	0.029	<0.01	12	<0.026	0.17	<0.09	58	0.17
20	200	<0.18	0.28	62	<0.006	<0.01	<0.03	<0.02	0.9	5	0.035	<0.01	17	<0.027	0.10	<0.09	45	0.20
40	200	<0.18	<0.02	81	<0.006	<0.01	<0.04	<0.02	1.6	8	0.027	<0.01	22	<0.023	0.08	<0.09	55	0.10
80	200	<0.18	<0.27	94	<0.006	<0.01	<0.05	<0.02	1.7	16	0.035	<0.01	27	<0.029	0.12	<0.09	83	0.13
0	66+200	<0.18	<0.15	89	<0.006	<0.01	<0.03	<0.02	2.7	10	0.036	<0.01	18	<0.029	0.07	<0.09	73	0.26
20	66+200	<0.18	<0.03	78	<0.006	<0.01	<0.03	<0.02	4.0	12	0.038	<0.01	24	<0.026	0.08	<0.09	67	0.19
40	66+200	<0.18	<0.04	67	<0.006	<0.01	<0.03	0.03	3.5	14	0.036	<0.01	22	<0.030	0.11	<0.09	65	0.19
80	66+200	<0.18	0.04	106	<0.006	<0.01	<0.03	0.04	8.3	20	0.096	<0.01	19	0.035	0.10	<0.09	86	0.25
Significance		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	0.08	--	--	--
Main effects																		
Leaf Rate																		
0		<0.18	<0.06	66	<0.006	<0.01	<0.03	<0.02	2.1	9	0.027	<0.01	12	<0.025	0.11	<0.09	55	0.18
20		<0.18	<0.13	67	<0.006	<0.01	<0.03	<0.02	2.3	9	0.036	<0.01	24	<0.027	0.09	<0.09	60	0.23
40		<0.18	<0.08	86	<0.006	<0.01	<0.03	<0.02	2.2	12	0.038	<0.01	19	<0.027	0.10	<0.09	72	0.15
80		<0.18	<0.13	108	<0.006	<0.01	<0.04	<0.03	4.6	16	0.049	<0.01	31	<0.029	0.14	<0.09	96	0.16
Significance		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	*	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	0.04	--	28	--
Linear		--	--	*	--	--	--	--	NS	*	NS	--	*	--	*	--	**	NS
Quadratic		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	NS	NS
Nitrogen Application																		
0		<0.18	<0.08	87	<0.006	<0.01	<0.03	<0.02	2.2	11	0.029	<0.01	24	<0.025	0.12	<0.09	81	0.15
200		<0.18	<0.15	76	<0.006	<0.01	<0.03	<0.02	1.5	10	0.031	<0.01	20	<0.026	0.12	<0.09	60	0.15
66+200		<0.18	<0.06	85	<0.006	<0.01	<0.03	<0.02	4.7	14	0.051	<0.01	21	<0.030	0.09	<0.09	73	0.22
Significance		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	NS	--	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Interaction																		
Leaf x Nitrogen		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	NS	NS

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

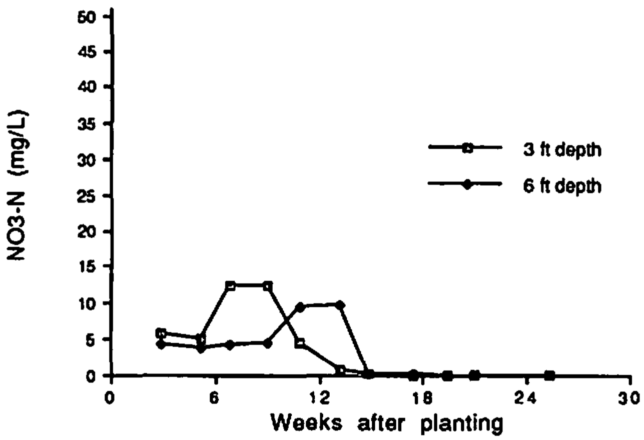


Figure 2. Nitrate-N concentration in soil water at 3 and 6 ft. depths over the 1992 growing season. Treatment 1: no leaves, no nitrogen applied.

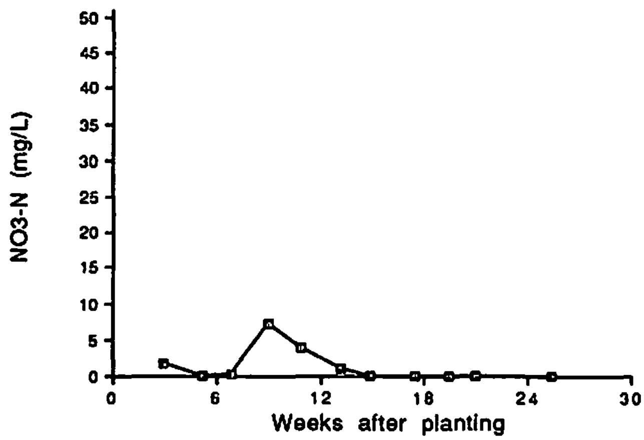


Figure 3. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 2: 20 tons/A leaves, no nitrogen applied.

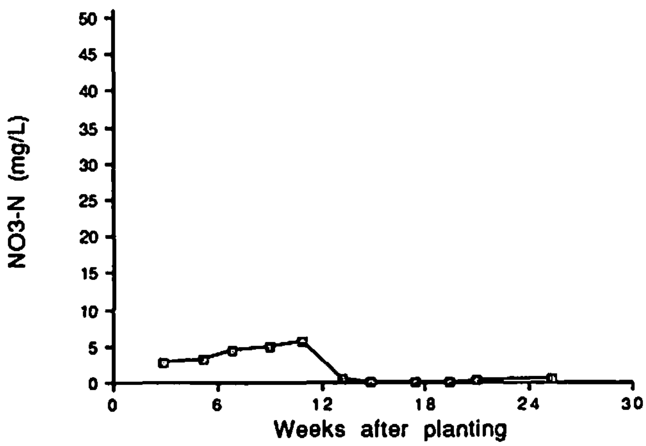


Figure 4. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 3: 40 tons/A leaves, no nitrogen applied.

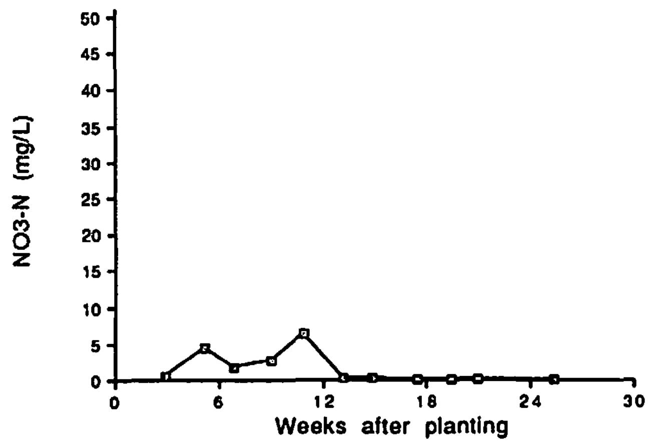


Figure 5. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 4: 80 tons/A leaves, no nitrogen applied.

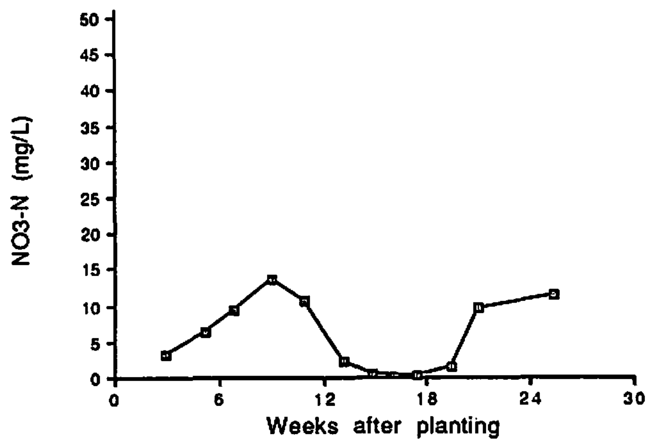


Figure 6. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 5: no leaves, 200 lbs/A nitrogen applied applied during the growing season.

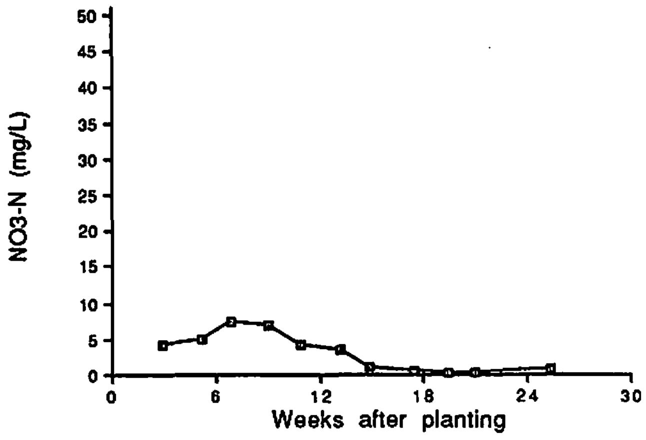


Figure 7. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 6: 20 tons/A leaves, 200 lbs/A nitrogen applied during the growing season.

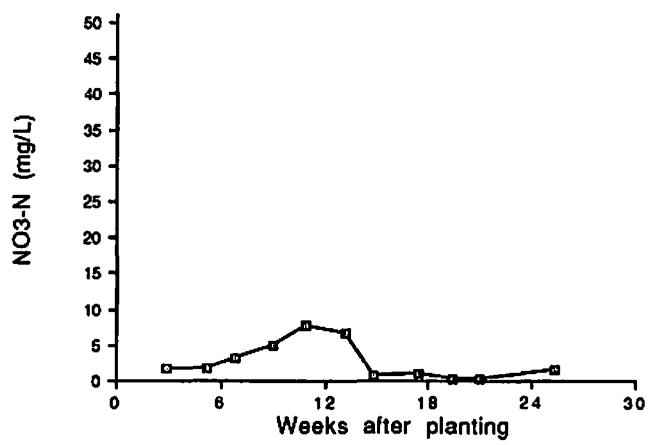


Figure 8. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 7: 40 tons/A leaves, 200 lbs/A nitrogen applied during the growing season.

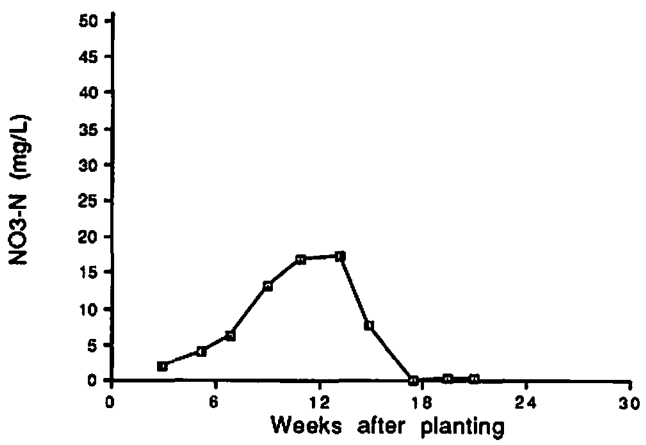


Figure 9. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 8: 80 tons/A leaves, 200 lbs/A nitrogen applied during the growing season.

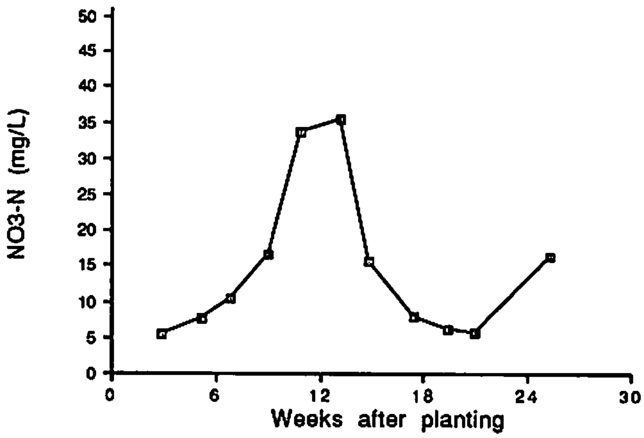


Figure 10. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 9: no leaves, 66 lbs/A nitrogen fall applied and 200 lbs/A applied during the growing season.

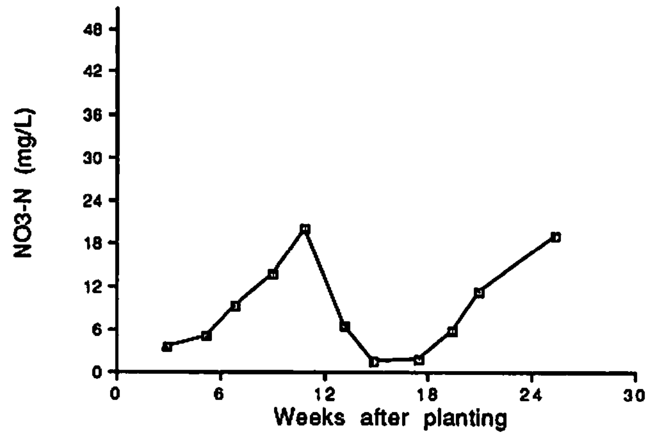


Figure 11. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 10: 20 tons/A leaves, 66 lbs/A nitrogen fall applied and 200 lbs/A applied during the growing season.

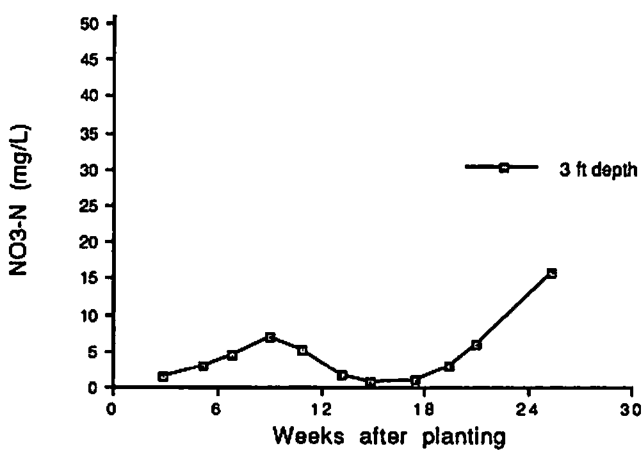


Figure 12: Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 11: 40 tons/A leaves, 66 lbs/A nitrogen fall applied and 200 lbs/A applied during the growing season.

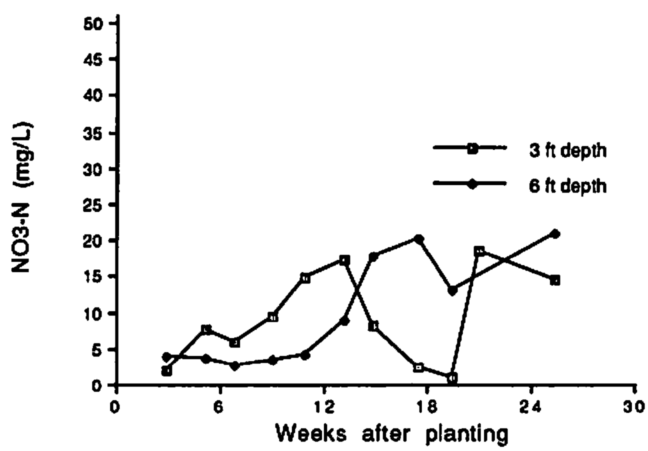


Figure 13: Nitrate-N concentration in soil water at 3 and 6 ft. depths over the 1992 growing season. Treatment 12: 80 tons/A leaves, 66 lbs/A nitrogen fall applied and 200 lbs/A applied during the growing season.

LAND TREATMENT OF SEWAGE SLUDGE INCINERATOR ASH - 1992[1]

Carl Rosen, Dave Birong, and Peter Bierman[2]

ABSTRACT: The sixth year of an ongoing experiment was conducted at the Rosholt Research Farm in Westport, MN to evaluate the use of sewage sludge incinerator ash as a phosphorus source for corn production. A major change in the experimental methods was initiated in 1991. Ash was applied at much higher rates than in past years to simulate a one time application, rather than smaller amounts spread yearly. In addition, 6 tons/A lime were incorporated in half of each plot. 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 were 4.3, 8.6 and 17.2 dry tons. Results reported here are from the second year after the final application of ash and phosphate fertilizer. Early plant (6-10 leaf) dry weight and grain yield significantly increased with both ash and fertilizer 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 1.5 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, P concentrations were greater with the fertilizer source compared to the ash source, even though more phosphate was applied with the ash than with the fertilizer. Tissue concentrations of Zn and Cu were higher with ash applications compared to fertilizer applications. Tissue levels of Mo increased slightly with ash applications. Heavy metals such as Cd, Pb, Ni, and Cr did not accumulate in the grain, stover, or cob 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 second year (residual effects) after this one time application of ash was applied.

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. Elemental characteristics of the ashes from each year are presented in Table 1.

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 were 4.3, 8.6 and 17.2 dry tons. Approximate loading rates of elements as a result of sewage sludge ash application are presented in Table 2. Treatments were applied to the same plots as in previous years, except that the rate of application was proportional to the original rate. Because of the increase in the amount of ash applied last year, the phosphate applied by ash was much greater than the amount of phosphate applied with the fertilizer. No additional phosphate fertilizer was applied in 1992. 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.

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

[2] Ext. Soil Scientist, Junior Scientist, Research Specialist, respectively, Soil Science Dept.

In 1992, each plot received 0-0-60 (200 lbs/A) and 45-0-0 (195 lbs/A). The fertilizers were broadcast by hand and then disked in. A split plot treatment arrangement with four replications was used. Phosphate treatment was the main plot and lime was the subplot. Field corn (Pioneer 3787 hybrid - 95 day) was planted May 6, 1992 at a population of 32,500 plants/A in 30" rows, along with a furrow application of Counter insecticide. Each plot consisted of four, 15' rows. Irrigation supplemented rainfall to provide approximately 1" of water per week. The entire plot was sidedressed with 100 lb N/A as ammonium nitrate on June 16. On July 3, 4 whole plants were sampled from each plot at the ends of the two middle rows. At this sampling, plant development corresponded to the 6-10 leaf stage. Ear leaf samples were collected from each plot at the mid-silking stage (August 12). Plots were harvested for grain and stover yields on October 14 (10' from the middle two rows). Subsamples of stover and grain plus cob were collected for moisture determinations, shelling percentages, and elemental analyses. All plant samples were ground in a Wiley mill to pass through a 30 mesh screen. Multiple element analysis using ICP procedures were performed on ashed samples dissolved in 1 N HCl. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

Soil samples were collected on October 5 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 3). At 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 extractable P was greater in fertilizer amended plots compared to ash amended plots. DTPA extractable Zn, Cu, Cd, and Pb increased with increasing ash application. Ammonium acetate extractable Ca, 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 affected by fertilizer or ash treatments. Lime application increased soil pH, soluble salts, extractable K, Ca, and Mg and decreased Olsen P, and DTPA extractable Mn, Fe, Cu, Ni, and Cd. All nitric acid extractable elements increased with increasing ash application (Table 4). Phosphate fertilizer increased nitric acid extractable Al, As, Fe, Mo, P, Ti, and V. Lime application increased nitric acid extractable B, Ca, Co, K, Mg, S, Si, Sr, and V. Lime application tended to decrease nitric acid extractable and Ni.

Yield Data. No differences in stand establishment due to treatment were detected. Both triple superphosphate fertilizer and ash significantly increased early plant dry weight compared to plants growing in the check plot (Table 5). This early plant response to P fertilizer is common in corn grown in low P soils, particularly under cool soil temperatures. Overall, grain yields were low due to cool temperatures preventing maturation. However, grain yield increased with phosphorus fertilizer and ash additions compared to the control plot. Addition of lime also increased grain yields. Stover yield was not affected by fertilizer or ash amendments. These results clearly show a an agronomic benefit to ash application and that the high rates of ash used had no detrimental effects on yield or stand establishment.

Tissue Analyses. Fertilizer and ash treatments increased tissue P concentrations in corn sampled at the 6 - 10 leaf stage (Table 6). Even though rates of ash were higher in total P application than the fertilizer, availability of P was still greater from the fertilizer source than the ash source. Tissue concentrations of Ca, Cu, Mo, and Zn tended to increase with ash applications; however, these nutrients are essential for plant growth and the levels of Mo, Cu, and Zn reported are well below those considered toxic to plants or animals. Although generally low, concentrations of Cd, a nonessential plant element increased with ash application. The other heavy metals, Pb, Ni, and Cr, were generally at background levels or not consistently affected by ash treatments. Increasing phosphate fertilizer rate increased tissue Ca and Mn and decreased tissue Al, Cu, Fe, Ni, and Zn. Liming decreased tissue Mn and Zn.

Ear leaves sampled at silking increased in P with fertilizer and ash applications (Table 7). As in whole plant samples, the increase was greater in the 0-46-0 plots than in the ash plots. Phosphate fertilizer increased tissue Ca, Mg, Al, Cr, and Mn, but decreased N, Cu, and Zn concentrations. Ash application increased Ca, Mg, Mo, and Zn concentrations, and decreased N, Cu, and Mn levels. Liming increased tissue P, Ca, Al, B, and Cu, but decreased tissue Mn.

Concentrations of P increased in stover to a greater extent in plants supplied with 0-46-0 than in plants supplied with ash (Table 8). Concentrations of Cd and Pb in stover were generally below detection limits for all treatments. Ash application increased stover concentrations of Ca, Mo, and Na and decreased concentrations of Mn. Increasing phosphate fertilizer increased stover K, Ca, and Mn and decreased stover B, Cu, and Zn. Lime application increased stover Ca and decreased stover Mn.

Concentrations of P in the cob increased with fertilizer and ash application (Table 9). Cob Zn significantly decreased when P fertilizer was applied and increased when ash was applied. Concentrations of Cd, Mo, and Pb were generally below detection limits. Cu concentrations in the cob decreased with fertilizer application, but were not affected by ash application. Cob Mg increased with both fertilizer and ash application. Cob N increased and K decreased with fertilizer application. Liming decreased cob N and Mn.

Phosphorus concentrations in grain tissue increased with increasing fertilizer and ash amendments (Table 10). Concentrations of Cd, Ni, Cr, and Pb in grain tissue were either at background levels or below detection limits. Molybdenum concentrations were generally below detection limits; however, some accumulation of Mo was detected with ash application. Nitrogen, K, Mg, and Fe concentrations in the grain tissue increased with fertilizer application, while Ca, B, and Zn concentrations decreased. Ash application increased K, Mg, and Zn concentrations in grain. Liming increased grain P, K, and Mg levels and decreased levels of Mn.

GENERAL DISCUSSION

As in previous years, phosphate is not as available from the ash source as it is from the fertilizer source. Over twice as much P_2O_5 was applied with the ash compared to the fertilizer, yet P availability was much 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 actually increased yield over the plots not receiving any P amendments. Ash application did not significantly affect accumulation of elements such as Cd, Cu, Pb, Cr, Mo, and Ni in grain, cob, or stover tissue, although whole plant samples at the 6-10 leaf stage and ear leaf samples did have higher levels of Cd and Mo when ash was applied. Residual effects of ash application in future years will be monitored with vegetable crops.

Table 1. Selected chemical characteristics of incinerator sludge ash collected in 1987 and 1991 (means of 3 samples).

	Ash Sampling Date	
Chemical Characteristic	1987	1991
Moisture (%)	37.6	36.0
Calcium Carbonate Equivalent (%)	13.7	16.5
Available P_2O_5 (%)	8.8	—
pH (1:1 water)	8.0	—
Acid Digestible Elements:	%	%
Phosphorus	7.40	5.06
Potassium	0.48	0.45
Calcium	9.14	8.78
Magnesium	1.86	1.19
Sodium	0.26	0.27
Aluminum	6.38	5.30
Iron	4.05	2.55
	ppm	ppm
Boron	42	49
Cadmium	128	41
Chloride	276	246
Chromium	1888	1055
Copper	3846	2950
Lead	710	515
Manganese	2353	2801
Molybdenum	45	50
Nickel	530	252
Sulfur	3293	3569
Zinc	7213	1946

Table 2. Approximate loading rates of selected elements as a result of 5 years of sewage sludge incinerator ash application.

Cumulative ash application	P_2O_5	P	K	Ca	Mg	S	Cu	B	Zn	Mo	Pb	Ni	Cr	Cd
(dry T/A)							lb/A							
4.3	750	606	40	778	133	30	30	0.4	40	0.4	5.3	3.4	13	0.8
8.6	1500	1212	80	1556	266	60	60	0.8	80	0.8	10.6	6.8	26	1.6
17.2	3000	2424	160	3112	532	120	120	1.2	160	1.6	21.2	13.6	52	3.2

Table 3. Effect of the cumulative six year 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	Source	Lime	pH	Salts	P	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
(lb/A)		(T/A)		(mmhos/cm)	ppm													
0	Ctrl	0	5.2	0.20	30	18	175	1758	228	<4.7	102	73	1.7	1.6	1.5	2.2	0.09	0.18
350	Fert	0	5.0	0.30	70	40	186	1733	220	<4.6	111	98	1.5	1.1	1.2	2.3	0.09	0.18
700	Fert	0	5.0	0.33	126	73	186	1771	216	<3.5	107	82	1.5	1.3	1.7	2.1	0.10	0.18
1400	Fert	0	5.1	0.28	243	126	194	1764	211	<3.8	103	69	1.8	1.6	1.2	2.2	0.10	0.20
750	Ash	0	5.3	0.23	151	82	172	1883	257	7.7	97	57	4.2	5.8	1.9	2.5	0.08	0.34
1500	Ash	0	5.5	0.33	247	96	175	2011	297	8.5	83	36	5.9	9.4	2.0	2.2	0.06	0.47
3000	Ash	0	5.9	0.23	458	125	173	2151	343	12.9	76	21	8.5	16.1	2.5	2.2	0.05	0.65
0	Ctrl	6	6.5	0.30	25	14	176	2879	259	5.2	60	21	1.2	1.0	<0.5	1.3	0.05	0.16
350	Fert	6	6.3	0.43	61	34	179	2900	272	<4.9	69	25	1.9	0.7	0.7	1.5	0.05	0.14
700	Fert	6	6.2	0.33	113	64	201	2660	240	<2.9	76	28	1.5	0.8	1.0	1.4	<0.04	0.15
1400	Fert	6	6.2	0.30	202	106	188	2790	251	3.0	71	23	1.4	0.9	0.6	1.5	0.05	0.15
750	Ash	6	6.3	0.45	144	57	198	2786	269	6.2	69	21	3.2	4.4	1.1	1.7	0.06	0.29
1500	Ash	6	6.6	0.30	257	81	212	2907	295	5.6	57	15	4.2	7.0	1.2	1.5	0.04	0.38
3000	Ash	6	6.5	0.38	438	115	191	2970	319	9.4	63	15	6.8	12.2	1.9	1.7	0.06	0.55
Significance			**	NS	**	**	NS	**	**	—	**	**	**	**	—	**	—	**
BLSD (0.05)			0.2	—	36	18	—	209	30	—	10	16	1.0	1.1	—	0.3	—	0.05
Main effects																		
Lime		−	5.3	0.27	189	80	180	1867	253	<6.5	97	62	3.6	5.3	1.7	2.3	0.08	0.31
		+	6.4	0.35	177	67	192	2842	272	<5.3	67	21	2.9	3.9	<1.0	1.5	<0.05	0.26
Significance			**	**	NS	**	*	**	**	—	**	**	**	**	—	**	—	**
P Treatment																		
P_2O_5 (lb/A)	Source																	
0	Ctrl		5.8	0.25	27	16	176	2319	243	<5.0	81	47	1.5	1.3	<1.0	1.7	0.07	0.17
350	Fert		5.6	0.36	65	37	182	2317	246	<4.8	90	61	1.7	0.9	1.0	1.9	0.07	0.16
700	Fert		5.6	0.33	120	68	194	2215	228	<3.2	91	55	1.5	1.1	1.3	1.8	<0.07	0.17
1400	Fert		5.6	0.29	222	116	191	2277	231	<3.4	87	46	1.6	1.3	0.9	1.8	0.07	0.17
750	Ash		5.8	0.34	147	69	185	2335	263	6.9	83	39	3.7	5.1	1.5	2.1	0.07	0.31
1500	Ash		6.1	0.31	252	89	193	2459	296	7.1	70	25	5.0	8.2	1.6	1.9	0.05	0.43
3000	Ash		6.2	0.30	448	120	182	2561	331	11.1	69	18	7.7	14.2	2.2	2.0	0.05	0.60
Significance			**	NS	**	**	NS	**	**	—	**	**	**	**	—	NS	—	**
BLSD (0.05)			0.2	—	26	13	—	172	21	—	7	12	0.7	0.8	—	—	—	0.04
Contrasts																		
Ctrl vs Rest			NS	NS	**	**	NS	NS	*	—	NS	NS	**	**	—	NS	—	**
Fert vs Ash			**	NS	**	**	NS	**	**	—	**	**	**	**	—	NS	—	**
Linear Fert			*	NS	**	**	NS	NS	NS	—	NS	NS	NS	NS	—	NS	—	NS
Quad Fert			*	NS	NS	NS	NS	NS	NS	—	*	*	NS	NS	—	NS	—	NS
Linear Ash			**	NS	**	**	NS	**	**	—	**	**	**	**	—	NS	—	**
Quad Ash			NS	NS	NS	**	NS	NS	NS	—	NS	NS	NS	NS	—	NS	—	**
Interactions																		
Lime by P			NS	NS	NS	NS	NS	NS	*	—	**	**	NS	**	—	NS	—	NS

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

Table 4. Effect of the cumulative six year application of sludge ash and phosphate fertilizer on 1N nitric acid extractable elements.

Treatment: Cum. P_2O_5 (lb/A)	Source	Lime (T/A)	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
			1 N Nitric Acid Extractable (ppm)																								
0	Ctrl	0	1799	1.5	1.6	102	3126	0.4	0.9	1.1	5.5	374	212	<0.2	457	184	0.5	7	4.5	111	7.5	42.7	375	9.1	3.2	1.9	6.7
350	Fert	0	1829	1.5	1.6	103	2890	0.3	1.0	1.0	4.3	403	217	<0.2	404	209	0.5	7	4.8	159	7.5	43.0	362	9.0	3.2	2.0	6.0
700	Fert	0	1882	1.6	1.6	102	3060	0.3	1.0	1.1	5.0	430	205	<0.2	420	197	0.5	8	4.6	265	7.8	44.1	366	9.4	3.5	2.1	6.5
1400	Fert	0	2008	1.7	1.6	107	3120	0.4	0.9	1.5	6.6	504	213	<0.2	417	206	0.6	9	4.8	460	8.5	44.0	379	10.0	4.2	2.4	7.4
750	Ash	0	2111	1.8	1.8	114	3686	0.8	1.0	2.6	20.4	492	223	0.2	496	206	0.6	15	5.4	530	11.4	49.0	441	11.1	4.9	2.3	14.8
1500	Ash	0	2392	2.0	2.2	125	4481	1.4	1.0	4.4	36.5	592	222	<0.3	613	215	0.7	24	5.7	970	14.8	55.6	533	13.1	6.8	2.7	22.2
3000	Ash	0	3055	2.6	2.7	148	6097	2.5	1.1	8.8	75.5	880	245	0.4	807	275	1.0	49	7.1	2068	23.5	70.9	774	17.7	12.1	3.5	40.9
0	Ctrl	6	1753	1.5	1.8	104	6226	0.3	1.0	1.1	5.4	325	239	<0.2	861	172	0.5	8	4.1	111	7.1	74.8	420	12.2	2.7	2.1	6.4
350	Fert	6	1853	1.6	1.9	111	5816	0.3	1.0	1.1	4.5	388	216	<0.2	795	190	0.5	8	4.6	154	7.6	76.5	440	12.6	3.2	2.3	7.5
700	Fert	6	1792	1.5	1.8	102	5448	0.3	1.0	1.1	4.4	389	229	<0.2	714	180	0.5	8	4.3	250	7.2	70.8	385	11.5	3.1	2.3	7.0
1400	Fert	6	1999	1.9	2.6	111	5198	0.4	1.2	1.5	5.6	464	228	<0.4	842	197	0.6	10	4.7	444	8.1	79.8	434	12.8	3.9	2.9	5.7
750	Ash	6	2069	1.8	2.0	116	6268	0.8	1.0	2.7	20.7	468	264	<0.2	856	204	0.6	16	4.9	556	11.0	85.7	489	13.6	4.7	2.5	13.7
1500	Ash	6	2381	2.0	2.3	125	7264	1.4	1.1	4.8	40.1	596	266	<0.2	945	233	0.7	26	5.3	1098	15.2	83.8	613	16.1	6.9	2.9	23.3
3000	Ash	6	2971	2.6	2.8	150	8404	2.4	1.2	8.4	70.4	847	283	<0.3	1091	293	1.0	43	6.8	1943	21.9	103.0	794	20.0	11.2	3.6	40.1
Significance			**	**	**	**	**	**	NS	**	**	**	**	—	**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (0.05)			183	0.2	0.5	12	763	0.2	—	0.7	6.4	59	37	—	121	25	0.1	4	0.6	174	1.6	12.1	60	1.4	0.9	0.3	4.2
Main effects																											
Lime	−		2154	1.8	1.9	115	3780	0.9	1.0	2.9	22.0	525	219	<0.2	516	213	0.6	17	5.3	652	11.6	49.9	461	11.4	5.4	2.4	14.9
	+		2117	1.9	2.2	117	6375	0.9	1.1	3.0	21.6	497	247	<0.2	872	210	0.6	17	5.0	651	11.2	82.0	511	14.1	5.1	2.7	14.8
Significance			NS	NS	**	NS	**	NS	*	NS	NS	*	**	—	**	NS	NS	NS	*	NS	NS	**	**	**	NS	**	NS
P Treatment: P_2O_5 (lb/A)	Source																										
0	Ctrl		1776	1.5	1.7	103	4676	0.3	1.0	1.1	5.4	350	225	<0.2	659	178	0.5	8	4.3	111	7.3	58.8	398	10.7	2.9	2.0	6.5
350	Fert		1841	1.6	1.7	107	4353	0.3	1.0	1.1	4.4	395	217	<0.2	600	199	0.5	8	4.7	156	7.5	60.0	401	10.8	3.2	2.2	6.8
700	Fert		1837	1.6	1.7	102	4254	0.3	1.0	1.1	4.7	410	217	<0.2	567	188	0.5	8	4.4	257	7.5	57.4	375	10.5	3.3	2.2	6.7
1400	Fert		2004	1.8	2.1	109	4159	0.4	1.1	1.5	6.1	484	220	<0.3	630	201	0.6	10	4.8	452	8.3	61.9	407	11.4	4.0	2.6	6.6
750	Ash		2090	1.8	1.9	115	4977	0.8	1.0	2.6	20.5	480	244	<0.2	676	205	0.6	16	5.1	543	11.2	67.3	465	12.4	4.8	2.4	14.3
1500	Ash		2386	2.0	2.3	125	5872	1.4	1.0	4.6	38.3	594	244	<0.2	779	224	0.7	25	5.5	1034	15.0	69.7	573	14.6	6.8	2.8	22.7
3000	Ash		3013	2.6	2.8	149	7251	2.5	1.1	8.6	72.9	863	264	<0.3	949	284	1.0	46	7.0	2005	22.7	86.9	784	18.9	11.7	3.6	40.5
Significance			**	**	**	**	**	**	NS	**	**	**	**	—	**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (0.05)			128	0.2	0.4	8	542	0.2	—	0.5	4.5	42	26	—	87	17	0.1	3	0.4	123	1.1	8.8	42	1.0	0.7	0.2	3.0
Contrasts																											
Ctrl vs Rest			**	**	*	**	*	**	NS	**	**	**	NS	—	NS	**	**	**	**	**	**	*	**	**	**	**	**
Fert vs Ash			**	**	**	**	**	**	NS	**	**	**	**	—	**	**	**	**	**	**	**	**	**	**	**	**	**
Linear Fert			**	**	NS	NS	NS	NS	NS	NS	NS	**	NS	—	NS	NS	**	NS	NS	**	NS	NS	NS	NS	**	**	NS
Quad Fert			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	—	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash			**	**	**	**	**	**	**	**	**	**	**	—	**	**	**	**	**	**	**	**	**	**	**	**	**
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 5. Effect of the cumulative six year application of sludge ash and phosphate fertilizer on final stand count, whole plant dry weight (6-10 leaf stage), and grain and stover yield (dry weight).

Treatment: Cumulative P_2O_5 (lb/A)	Source	Lime (T/A)	Final stand count	Whole plant 6-10 leaf dry wt. (g/plant)	Grain yield (bu/A)	Stover yield (T/A)
0	Ctrl	0	31363	8.4	94	2.54
350	Fert	0	31363	10.7	104	2.88
700	Fert	0	31363	13.0	110	2.73
1400	Fert	0	29403	15.3	108	2.66
750	Ash	0	30927	13.4	104	2.73
1500	Ash	0	32016	11.8	110	2.94
3000	Ash	0	31581	11.5	106	2.91
0	Ctrl	6	30927	7.7	99	2.82
350	Fert	6	31799	10.9	105	2.85
700	Fert	6	31145	13.7	110	3.01
1400	Fert	6	31145	15.6	111	2.76
750	Ash	6	31799	13.0	115	3.15
1500	Ash	6	29621	12.3	110	2.75
3000	Ash	6	31145	13.0	111	3.07
Significance			NS	**	++	NS
BLSD (0.05)			—	2.3	15	—
Main effects						
Lime −			31145	12.0	105	2.77
Lime +			31083	12.3	109	2.92
Significance			NS	NS	++	NS
P Treatment: P_2O_5 (lb/A)	Source					
0	Ctrl		31145	8.0	96	2.68
350	Fert		31581	10.8	104	2.87
700	Fert		31254	13.3	110	2.87
1400	Fert		30274	15.4	110	2.71
750	Ash		31363	13.2	109	2.94
1500	Ash		30819	12.1	110	2.85
3000	Ash		31363	12.2	108	2.99
Significance			NS	**	*	NS
BLSD (0.05)			—	1.6	8.8	—
Contrasts						
Ctrl vs Rest			NS	**	**	NS
Fert vs Ash			NS	NS	NS	NS
Linear Fert			NS	**	**	NS
Quad Fert			NS	*	*	NS
Linear Ash			NS	**	*	NS
Quad Ash			NS	**	**	NS
Interactions						
Lime by P			NS	NS	NS	NS

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

Table 6. Effect of the cumulative six year application of sludge ash and phosphate fertilizer on the elemental composition of whole plants at the 6-10 leaf stage.

Treatment: Cumulative P_2O_5	Source	Lime	N	P	K	Ca	Mg	Al	B	Cd	Cr	Cu	Fe	Mn	Mo	Na	Ni	Pb	Zn
(lb/A)		(T/A)	%					ppm											
0	Ctrl	0	4.09	0.36	4.54	0.56	0.38	362	6.7	0.5	1.2	10.5	335	97	0.6	20.9	1.5	<3.5	44
350	Fert	0	4.27	0.42	4.80	0.56	0.37	267	6.4	0.5	1.1	9.0	267	106	0.5	18.7	1.2	<2.5	47
700	Fert	0	4.26	0.44	4.26	0.60	0.41	215	6.6	0.5	1.1	7.7	228	104	0.6	23.2	1.3	3.5	41
1400	Fert	0	4.10	0.51	4.24	0.65	0.40	247	6.5	0.6	1.1	6.0	266	117	0.7	19.8	1.2	3.3	33
750	Ash	0	4.21	0.40	3.96	0.60	0.42	270	6.2	0.5	1.0	10.1	263	89	0.7	15.8	1.1	2.4	49
1500	Ash	0	4.23	0.44	4.00	0.62	0.46	301	6.6	0.6	1.1	11.0	298	85	1.1	22.6	1.2	<2.9	56
3000	Ash	0	4.17	0.46	4.12	0.64	0.44	316	6.7	0.7	1.3	11.5	293	80	2.6	21.4	1.3	3.4	54
0	Ctrl	6	4.06	0.34	4.47	0.55	0.35	361	6.6	0.5	1.3	10.7	351	82	0.7	24.3	1.5	3.7	41
350	Fert	6	4.20	0.41	4.09	0.62	0.42	330	6.4	0.4	1.1	8.6	309	91	0.5	18.8	1.2	<2.6	41
700	Fert	6	4.29	0.45	4.48	0.58	0.35	238	6.6	0.5	1.3	7.7	258	92	0.7	20.4	1.4	3.8	38
1400	Fert	6	4.14	0.48	4.14	0.65	0.39	244	6.2	0.4	1.0	5.8	275	99	0.5	15.7	1.0	<2.6	30
750	Ash	6	4.19	0.40	4.24	0.58	0.38	255	6.2	0.5	1.0	10.7	257	80	0.8	18.0	1.2	2.9	47
1500	Ash	6	4.29	0.44	4.22	0.63	0.41	307	6.5	0.6	1.2	11.5	297	83	1.3	20.4	1.3	3.3	50
3000	Ash	6	4.18	0.44	4.25	0.61	0.39	257	6.6	0.7	1.2	11.2	260	84	1.8	18.9	1.3	<3.4	53
Significance			NS	**	NS	**	NS	*	NS	*	*	**	*	**	**	NS	NS	—	**
BLSD (0.05)			—	0.03	—	0.06	—	97	—	0.2	0.5	0.9	88	13	0.5	—	—	—	7
Main effects																			
Lime		–	4.19	0.43	4.27	0.60	0.41	283	6.5	0.5	1.2	9.4	279	97	1.0	20.3	1.2	<3.1	46
		+	4.19	0.42	4.27	0.60	0.39	285	6.4	0.5	1.2	9.4	287	87	0.9	19.5	1.3	<3.2	43
Significance			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	—	*
P Treatment: P_2O_5 (lb/A)	Source																		
0	Ctrl		4.07	0.35	4.50	0.55	0.37	361	6.6	0.5	1.3	10.6	343	89	0.7	22.6	1.5	<3.6	43
350	Fert		4.23	0.41	4.45	0.59	0.39	298	6.4	0.5	1.1	8.8	288	99	0.5	18.7	1.2	<2.6	44
700	Fert		4.27	0.44	4.37	0.59	0.38	227	6.6	0.5	1.2	7.7	243	98	0.7	21.8	1.4	3.6	39
1400	Fert		4.12	0.49	4.19	0.65	0.39	245	6.3	0.5	1.1	5.9	270	108	0.6	17.8	1.1	<3.0	31
750	Ash		4.20	0.40	4.10	0.59	0.40	263	6.2	0.5	1.0	10.4	260	85	0.8	16.9	1.1	2.6	48
1500	Ash		4.26	0.44	4.11	0.63	0.43	304	6.6	0.6	1.2	11.2	297	84	1.2	21.5	1.2	<3.1	53
3000	Ash		4.17	0.45	4.19	0.63	0.41	286	6.7	0.7	1.2	11.3	277	82	2.2	20.2	1.3	<3.4	53
Significance			*	**	NS	**	NS	**	NS	**	NS	**	**	**	**	NS	NS	—	**
BLSD (0.05)			0.13	0.02	—	0.04	—	59	—	0.1	—	0.7	51	9	0.3	—	—	—	5
Contrasts																			
Ctrl vs Rest			*	**	NS	**	*	**	NS	NS	NS	**	**	NS	*	NS	*	—	NS
Fert vs Ash			NS	*	NS	NS	NS	NS	NS	**	NS	**	NS	**	**	NS	NS	—	**
Linear Fert			NS	**	NS	**	NS	**	NS	NS	NS	**	**	**	NS	NS	*	—	**
Quad Fert			**	*	NS	NS	NS	**	NS	NS	NS	*	**	NS	NS	NS	NS	—	NS
Linear Ash			NS	**	NS	**	NS	NS	NS	**	NS	*	NS	NS	**	NS	NS	—	**
Quad Ash			*	**	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	—	*
Interactions																			
Lime by P			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 7. Effect of the cumulative six year application of sludge ash and phosphate fertilizer on the elemental composition of ear leaves.

Treatment: Cumulative P_2O_5	Source	Lime	N	P	K	Ca	Mg	Al	B	Cd	Cr	Cu	Fe	Mn	Mo	Na	Ni	Pb	Zn
(lb/A)		(T/A)	%					ppm											
0	Ctrl	0	3.22	0.28	1.94	0.53	0.29	18.3	5.1	<0.2	0.8	11.3	250	72	<0.4	29.1	<0.7	<2.3	32
350	Fert	0	3.26	0.30	2.02	0.54	0.28	17.8	5.1	<0.2	0.8	9.6	219	93	<0.4	30.8	<0.7	<2.4	35
700	Fert	0	3.13	0.31	1.93	0.59	0.30	23.4	5.3	0.3	1.0	7.6	224	105	0.6	31.2	1.0	<2.9	31
1400	Fert	0	3.01	0.34	1.92	0.64	0.32	24.9	5.1	0.3	1.1	5.1	240	104	0.7	27.8	0.9	<2.8	19
750	Ash	0	3.16	0.30	1.87	0.58	0.29	19.8	5.3	<0.2	0.9	9.7	236	76	1.0	32.0	0.7	<2.3	40
1500	Ash	0	3.17	0.31	1.85	0.64	0.32	20.8	5.4	0.3	1.0	9.5	222	70	1.9	31.8	0.9	<2.7	49
3000	Ash	0	3.08	0.31	1.83	0.63	0.33	19.1	5.4	<0.2	0.8	8.9	241	55	4.0	30.7	<0.7	<2.3	44
0	Ctrl	6	3.22	0.28	1.92	0.60	0.29	19.5	5.3	<0.2	0.9	12.6	248	56	0.6	28.5	<0.8	<2.4	37
350	Fert	6	3.17	0.31	1.85	0.64	0.31	22.8	5.5	0.2	1.0	9.1	232	66	0.7	35.7	1.0	2.8	36
700	Fert	6	3.31	0.33	1.95	0.66	0.31	22.3	5.4	<0.3	0.9	7.8	232	78	0.6	30.7	<0.9	<2.8	33
1400	Fert	6	3.21	0.34	1.83	0.73	0.34	31.5	5.7	0.3	1.1	6.5	248	82	0.8	31.1	1.0	2.9	23
750	Ash	6	3.23	0.31	1.90	0.65	0.30	23.8	5.6	0.3	1.0	11.9	242	63	1.3	32.2	1.0	2.7	41
1500	Ash	6	3.15	0.32	1.94	0.66	0.29	23.0	5.6	<0.3	1.0	11.2	246	54	2.6	30.7	<1.0	<2.9	38
3000	Ash	6	3.14	0.32	1.89	0.66	0.31	20.3	5.6	0.2	0.9	10.4	228	55	3.2	28.6	0.8	<2.4	42
Significance			NS	**	NS	**	*	*	NS	—	NS	**	NS	**	—	NS	—	—	**
BLSD (0.05)			—	0.02	—	0.05	0.04	8.8	—	—	—	0.6	—	10	—	—	—	—	5
Main effects																			
Lime	−		3.15	0.31	1.91	0.59	0.30	20.6	5.2	<0.2	0.9	8.8	233	82	<1.3	30.5	<0.8	<2.5	36
	+		3.20	0.32	1.90	0.66	0.31	23.3	5.5	<0.2	1.0	9.9	239	65	1.4	31.1	<0.9	<2.7	36
Significance			NS	**	NS	**	NS	*	*	—	NS	**	NS	**	—	NS	—	—	NS
P Treatment																			
P_2O_5 (lb/A)	Source																		
0	Ctrl		3.22	0.28	1.93	0.56	0.29	18.9	5.2	<0.2	0.9	12.0	249	64	<0.5	28.8	<0.7	<2.3	35
350	Fert		3.21	0.31	1.93	0.59	0.29	20.3	5.3	<0.2	0.9	9.3	225	79	<0.5	33.2	<0.8	<2.6	35
700	Fert		3.22	0.32	1.94	0.62	0.30	22.8	5.4	<0.3	1.0	7.7	228	92	0.6	30.9	<0.9	<2.8	32
1400	Fert		3.11	0.34	1.87	0.68	0.33	28.2	5.4	0.3	1.1	5.8	244	93	0.8	29.5	1.0	<2.9	21
750	Ash		3.20	0.31	1.89	0.62	0.30	21.8	5.4	<0.2	1.0	10.8	239	70	1.1	32.1	0.9	<2.5	40
1500	Ash		3.16	0.32	1.89	0.65	0.31	21.9	5.5	<0.3	1.0	10.3	234	62	2.3	31.3	<0.9	<2.8	43
3000	Ash		3.11	0.32	1.86	0.65	0.32	19.7	5.5	<0.2	0.9	9.6	234	55	3.6	29.7	<0.7	<2.3	43
Significance			NS	**	NS	**	**	*	NS	—	NS	**	NS	**	—	NS	—	—	**
BLSD (0.05)			—	0.01	—	0.04	0.02	5.3	—	—	—	0.4	—	7	—	—	—	—	3
Contrasts																			
Ctrl vs Rest			NS	**	NS	**	*	NS	NS	—	NS	**	*	**	—	NS	—	—	NS
Fert vs Ash			NS	*	NS	NS	NS	NS	NS	—	NS	**	NS	**	—	NS	—	—	**
Linear Fert			*	**	NS	**	**	**	NS	—	*	**	NS	**	—	NS	—	—	**
Quad Fert			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	—	—	**
Interactions																			
Lime by P			NS	NS	NS	NS	NS	NS	NS	—	NS	**	NS	*	—	NS	—	—	**

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

Table 8. Effect of the cumulative six year application of sludge ash and phosphate fertilizer on the elemental composition of stover at harvest.

Treatment																			
Cumulative P_2O_5	Source	Lime	N	K	Ca	Mg	P	Al	B	Cd	Cr	Cu	Fe	Mn	Mo	Na	Ni	Pb	Zn
(lb/A)		(T/A)	%				ppm												
0	Ctrl	0	0.75	0.91	0.26	0.19	550	32.3	4.4	0.2	0.7	6.1	80	40	0.4	16.0	0.8	<2.6	11
350	Fert	0	0.81	1.18	0.28	0.18	584	43.1	4.2	<0.3	0.7	5.0	89	48	<0.4	21.0	<0.8	<2.8	10
700	Fert	0	0.77	1.26	0.30	0.19	572	45.5	4.1	0.3	0.7	3.7	84	50	<0.4	17.8	0.8	2.6	8
1400	Fert	0	0.68	1.19	0.31	0.17	737	40.0	4.0	0.2	0.6	2.7	83	49	<0.3	16.5	<0.6	<2.1	5
750	Ash	0	0.70	1.04	0.28	0.19	537	37.6	4.2	0.3	0.7	5.2	80	41	<0.4	12.6	<0.7	<2.2	12
1500	Ash	0	0.74	1.09	0.30	0.20	568	32.9	4.0	0.3	0.7	5.4	76	34	0.6	13.5	<0.7	<2.2	16
3000	Ash	0	0.66	1.01	0.29	0.19	653	39.9	4.3	0.4	0.8	5.5	79	28	1.2	22.3	<0.9	<3.2	14
0	Ctrl	6	0.76	1.00	0.28	0.19	565	47.5	4.5	0.3	0.8	6.2	93	31	0.5	16.3	0.9	2.8	13
350	Fert	6	0.74	1.03	0.30	0.20	602	41.2	4.3	0.3	0.8	4.5	80	32	<0.5	22.7	<0.9	<2.9	12
700	Fert	6	0.78	1.10	0.30	0.18	597	35.7	4.1	0.3	0.7	3.7	76	35	<0.4	15.7	<0.8	<2.5	8
1400	Fert	6	0.75	1.11	0.33	0.19	833	45.8	4.2	0.2	0.7	3.3	90	34	<0.4	18.5	<0.7	<2.3	6
750	Ash	6	0.74	1.15	0.30	0.18	606	37.4	4.4	0.3	0.7	5.9	87	34	0.5	14.3	0.7	<2.4	12
1500	Ash	6	0.61	1.11	0.29	0.18	549	40.4	4.0	0.3	0.7	5.3	79	26	0.7	13.2	<0.7	<2.4	10
3000	Ash	6	0.71	1.08	0.32	0.19	651	39.0	4.7	0.4	0.9	6.3	79	28	1.2	20.6	1.0	<3.4	13
Significance			NS	NS	**	NS	**	NS	NS	—	NS	**	NS	**	—	NS	—	—	**
BLSD (0.05)			—	—	0.03	—	98	—	—	—	—	0.7	—	5	—	—	—	—	3
Main effects																			
Lime −			0.73	1.10	0.29	0.19	600	38.8	4.2	<0.3	0.7	4.8	81	41	<0.5	17.1	<0.7	<2.5	11
+			0.72	1.08	0.30	0.19	629	41.0	4.3	0.3	0.8	5.0	83	31	<0.6	17.3	<0.8	<2.7	11
Significance			NS	NS	**	NS	NS	NS	NS	—	NS	NS	NS	**	—	NS	—	—	NS
P Treatment																			
P_2O_5 (lb/A)	Source																		
0	Ctrl		0.75	0.95	0.27	0.19	558	39.9	4.5	0.2	0.8	6.1	87	35	0.4	16.2	0.8	<2.7	12
350	Fert		0.77	1.11	0.29	0.19	593	42.1	4.3	<0.3	0.7	4.7	84	40	<0.5	21.9	<0.9	<2.9	11
700	Fert		0.78	1.18	0.30	0.18	584	40.6	4.1	0.3	0.7	3.7	80	43	<0.4	16.8	<0.8	<2.5	8
1400	Fert		0.71	1.15	0.32	0.18	785	42.9	4.1	0.2	0.7	3.0	87	42	<0.3	17.5	<0.6	<2.2	5
750	Ash		0.72	1.09	0.29	0.19	571	37.5	4.3	0.3	0.7	5.5	83	37	<0.4	13.5	<0.7	<2.3	12
1500	Ash		0.68	1.10	0.30	0.19	558	36.6	4.0	0.3	0.7	5.3	77	30	0.6	13.3	<0.7	<2.3	13
3000	Ash		0.69	1.05	0.30	0.19	652	39.4	4.5	0.4	0.8	5.9	79	28	1.2	21.4	<0.9	<3.3	14
Significance			NS	*	**	NS	**	NS	*	—	NS	**	NS	**	—	*	—	—	**
BLSD (0.05)			—	0.15	0.02	—	65	—	0.4	—	—	0.5	—	4	—	6.1	—	—	2
Contrasts																			
Ctrl vs Rest			NS	**	**	NS	*	NS	NS	—	NS	**	NS	NS	—	NS	—	—	NS
Fert vs Ash			**	NS	NS	NS	**	NS	NS	—	NS	**	NS	**	—	NS	—	—	**
Linear Fert			NS	**	**	NS	**	NS	*	—	NS	**	NS	**	—	NS	—	—	**
Quad Fert			NS	*	NS	NS	*	NS	NS	—	NS	**	NS	*	—	NS	—	—	NS
Linear Ash			NS	NS	**	NS	**	NS	NS	—	NS	NS	NS	**	—	*	—	—	NS
Quad Ash			NS	*	NS	NS	NS	NS	**	—	*	**	NS	NS	—	*	—	—	NS
Interactions																			
Lime by P			NS	NS	NS	NS	NS	NS	NS	—	NS	NS	NS	**	—	NS	—	—	**

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

Table 9. Effect of the cumulative six year application of sludge ash and phosphate fertilizer on the elemental composition of cobs at harvest.

Treatment: Cumulative P_2O_5	Source	Lime	N	K	P	Mg	Ca	Al	B	Cd	Cr	Cu	Fe	Mn	Mo	Na	Ni	Pb	Zn
(lb/A)		(T/A)	—— % ——		ppm														
0	Ctrl	0	0.31	0.49	266	167	104	<8.6	1.7	<0.2	<0.5	3.1	7.6	4.0	<0.5	<5.7	<0.9	<3.0	18
350	Fert	0	0.30	0.50	287	148	102	8.9	2.0	0.2	0.6	3.0	6.7	4.3	0.5	5.9	0.9	3.1	16
700	Fert	0	0.30	0.49	279	131	110	10.3	2.0	0.2	0.6	2.8	6.8	4.5	0.5	6.0	1.0	3.3	14
1400	Fert	0	0.28	0.45	293	110	100	10.1	1.8	0.2	0.6	2.4	7.2	3.9	0.6	7.2	1.1	3.5	7
750	Ash	0	0.30	0.46	271	135	104	9.5	1.9	0.2	0.6	3.3	6.2	3.8	0.5	6.5	1.0	3.5	19
1500	Ash	0	0.31	0.48	294	140	109	9.3	1.9	0.2	0.6	3.3	6.2	3.6	0.5	6.1	1.0	3.2	24
3000	Ash	0	0.30	0.46	318	126	109	<8.4	1.6	<0.2	<0.6	3.0	8.3	3.3	<0.5	<6.1	<0.9	<3.0	24
0	Ctrl	6	0.29	0.50	258	151	97	<8.4	1.8	<0.2	<0.5	3.1	6.3	3.3	<0.5	<5.6	<0.9	<3.0	19
350	Fert	6	0.29	0.47	286	137	109	10.5	2.1	0.2	0.6	3.1	6.6	3.4	0.5	9.2	1.0	3.5	16
700	Fert	6	0.29	0.46	288	131	114	9.3	1.8	0.2	0.6	2.7	6.4	3.7	0.5	8.3	1.0	3.2	14
1400	Fert	6	0.29	0.44	304	120	103	10.3	1.9	0.2	0.6	2.6	6.7	3.9	0.6	7.2	1.1	3.6	10
750	Ash	6	0.29	0.46	286	143	108	9.2	1.9	0.2	0.5	3.3	6.3	3.5	0.5	6.4	1.0	3.4	19
1500	Ash	6	0.29	0.45	294	132	106	9.5	2.0	0.2	0.6	3.4	6.7	3.2	0.6	6.4	1.0	3.4	19
3000	Ash	6	0.29	0.47	318	121	103	<8.0	1.7	<0.2	<0.5	3.0	6.8	3.2	<0.5	<5.6	<0.9	<2.8	21
Significance			NS	NS	**	**	NS	—	NS	—	NS	*	NS	**	—	—	—	—	**
BLSD (0.05)			—	—	31	19	—	—	—	—	—	0.7	—	0.5	—	—	—	—	2
Main effects																			
Lime	–		0.30	0.48	286	137	105	<9.3	1.9	<0.2	0.6	3.0	7.0	3.9	<0.5	<6.2	<1.0	<3.3	18
	+		0.29	0.46	290	134	106	<9.3	1.9	<0.2	0.6	3.0	6.5	3.4	<0.5	<7.0	<1.0	<3.3	17
Significance			*	NS	NS	NS	NS	—	NS	—	NS	NS	NS	**	—	—	—	—	NS
P Treatment: P_2O_5 (lb/A)	Source																		
0	Ctrl		0.26	0.49	262	159	101	<8.5	1.8	<0.2	<0.5	3.1	7.0	3.6	<0.5	<5.6	<0.9	<3.0	19
350	Fert		0.27	0.48	287	142	106	9.7	2.0	0.2	0.6	3.1	6.6	3.9	0.5	7.6	1.0	3.3	16
700	Fert		0.30	0.47	284	131	112	9.8	1.9	0.2	0.6	2.7	6.6	4.1	0.5	7.1	1.0	3.3	14
1400	Fert		0.29	0.44	299	115	102	10.2	1.9	0.2	0.6	2.5	7.0	3.7	0.6	7.2	1.1	3.6	8
750	Ash		0.26	0.46	278	139	106	9.4	1.9	0.2	0.6	3.3	6.3	3.6	0.5	6.5	1.0	3.4	19
1500	Ash		0.29	0.47	294	136	107	9.4	2.0	0.2	0.6	3.4	6.4	3.4	0.5	6.3	1.0	3.3	22
3000	Ash		0.29	0.47	318	124	106	<8.2	1.7	<0.2	<0.5	3.0	7.5	3.3	<0.5	<5.8	<0.9	<2.9	22
Significance			NS	NS	**	**	NS	—	NS	—	NS	**	NS	**	—	—	—	—	**
BLSD (0.05)			—	—	19	13	—	—	—	—	—	0.4	—	0.3	—	—	—	—	2
Contrasts																			
Ctrl vs Rest			NS	*	**	**	NS	—	NS	—	NS	NS	NS	NS	—	—	—	—	*
Fert vs Ash			NS	NS	NS	NS	NS	—	NS	—	NS	**	NS	**	—	—	—	—	**
Linear Fert			**	**	**	**	NS	—	NS	—	NS	**	NS	NS	—	—	—	—	**
Quad Fert			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	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 10. Effect of the cumulative six year 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	1.51	0.23	0.40	0.12	67	<7.0	2.3	<0.2	0.6	2.0	21	7.3	<0.4	<3.7	<0.8	<2.5	19
350	Fert	0	1.56	0.25	0.39	0.12	59	7.2	2.4	<0.2	0.6	1.8	21	7.3	<0.4	<4.5	0.9	<2.7	19
700	Fert	0	1.57	0.28	0.40	0.12	61	<5.2	2.1	<0.1	<0.5	<1.1	22	7.6	<0.3	<3.6	<0.6	<1.8	19
1400	Fert	0	1.57	0.32	0.42	0.13	53	<4.7	2.0	<0.1	0.7	<0.8	24	7.3	<0.3	<3.6	<0.6	<1.9	16
750	Ash	0	1.50	0.27	0.39	0.12	62	9.1	2.7	0.2	0.7	2.1	21	7.3	0.7	<4.5	1.1	3.3	20
1500	Ash	0	1.58	0.29	0.40	0.13	61	7.2	2.5	<0.2	0.6	1.8	21	6.8	0.6	<4.3	0.9	2.6	22
3000	Ash	0	1.54	0.32	0.42	0.13	59	<5.5	2.3	<0.1	0.5	1.4	20	6.4	0.6	<3.8	0.7	<2.1	21
0	Ctrl	6	1.51	0.24	0.39	0.12	64	6.9	2.4	<0.2	0.5	1.9	21	6.5	0.5	<3.8	0.8	<2.4	19
350	Fert	6	1.62	0.29	0.41	0.13	62	<7.1	2.5	<0.2	0.6	1.6	23	7.1	0.5	<3.9	0.9	<2.5	20
700	Fert	6	1.58	0.29	0.40	0.13	60	<4.6	2.0	<0.1	<0.4	<1.0	22	7.0	<0.3	<3.6	<0.6	<1.7	19
1400	Fert	6	1.62	0.34	0.42	0.13	57	<4.7	2.1	<0.1	<0.4	<0.9	25	7.0	<0.4	<3.6	<0.6	<1.9	18
750	Ash	6	1.54	0.29	0.40	0.13	57	8.6	2.7	0.2	0.7	2.0	22	6.6	0.6	<4.2	1.0	2.9	20
1500	Ash	6	1.59	0.31	0.42	0.13	60	<5.1	2.2	<0.1	<0.5	1.3	21	6.5	0.5	<3.6	<0.6	<1.9	20
3000	Ash	6	1.56	0.33	0.43	0.13	63	<6.0	2.3	<0.2	0.5	1.5	22	6.6	0.6	<4.4	0.7	<2.3	21
Significance			NS	**	*	**	**	—	NS	—	—	—	**	*	—	—	—	—	**
BLSD (0.05)			—	0.02	0.04	0.01	6	—	—	—	—	—	1.9	0.8	—	—	—	—	1
Main effects																			
Lime		−	1.54	0.28	0.40	0.12	60	<6.6	2.3	<0.2	<0.6	<1.6	21	7.1	<0.5	<4.0	<0.8	<2.4	19
		+	1.57	0.30	0.41	0.13	60	<6.1	2.3	<0.2	<0.5	<1.5	22	6.8	<0.5	<3.9	<0.7	<2.2	20
Significance			NS	**	*	**	NS	—	NS	—	—	—	NS	**	—	—	—	—	NS
P Treatment: P_2O_5 (lb/A)	Source																		
0	Ctrl		1.51	0.24	0.40	0.12	65	<6.9	2.3	<0.2	0.5	2.0	21	6.9	<0.5	<3.8	<0.8	<2.5	19
350	Fert		1.59	0.27	0.40	0.13	60	<7.2	2.4	<0.2	0.6	1.7	22	7.2	<0.4	<4.2	0.9	<2.6	19
700	Fert		1.57	0.29	0.40	0.12	60	<4.9	2.1	<0.1	<0.4	<1.0	22	7.3	<0.3	<3.6	<0.6	<1.8	19
1400	Fert		1.59	0.33	0.42	0.13	55	<4.7	2.0	<0.1	<0.6	<0.9	24	7.1	<0.3	<3.6	<0.6	<1.9	17
750	Ash		1.52	0.28	0.39	0.13	59	8.8	2.7	0.2	0.7	2.0	21	7.0	0.6	<4.3	1.0	3.1	20
1500	Ash		1.58	0.30	0.41	0.13	61	<6.1	2.3	<0.2	<0.5	1.6	21	6.6	0.6	<3.9	<0.8	<2.3	21
3000	Ash		1.55	0.32	0.43	0.13	61	<5.7	2.3	<0.1	0.5	1.5	21	6.5	0.6	<4.1	0.7	<2.2	21
Significance			*	**	*	**	**	—	**	—	—	—	**	*	—	—	—	—	*
BLSD (0.05)			0.07	0.01	0.02	0.01	4	—	0.4	—	—	—	1	0.6	—	—	—	—	1
Contrasts																			
Ctrl vs Rest			*	**	NS	**	**	—	NS	—	—	—	**	NS	—	—	—	—	NS
Fert vs Ash			NS	NS	NS	NS	NS	—	*	—	—	—	**	**	—	—	—	—	**
Linear Fert			*	**	*	**	**	—	*	—	—	—	**	NS	—	—	—	—	**
Quad Fert			NS	NS	NS	NS	NS	—	NS	—	—	—	NS	NS	—	—	—	—	NS
Linear Ash			NS	**	**	**	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 = nonsignificant; *, ** = significant at 5% and 1%, respectively.

AGRICULTURAL UTILIZATION OF NUTRALIME: ON FARM DEMONSTRATION PLOTS - 1992[1]

Carl Rosen, Dave Birong, Peter Bierman, and Jennifer Weiszel[2]

ABSTRACT: The second year of NutraLime demonstrations were conducted in Dakota, Isanti, and Washington counties. NutraLime was applied in 1991 at all three locations. Residual effects were monitored in 1992 on soybeans (Isanti and Washington counties) and potatoes (Dakota county). Application of NutraLime increased soil water sulfur concentrations at the 2.5 ft depth. Some trace metals were detected in soil water at the 2.5 ft depth, but levels in control plots were generally as high as those in NutraLime plots. In cases where NutraLime increased trace elements in soil water, 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 Cu and S, NutraLime did not affect nitric acid extractable elements in the 12-24 inch depth. Soybean yields increased with NutraLime application at the Isanti Co. site, but were not affected at the Washington Co. site. Potato yields were not affected by NutraLime application; however, scab problems increased with NutraLime, as a consequence of increasing soil pH. The scab problem limits the usefulness of NutraLime for potato production. In potato plants, Mo and to a lesser extent Ca and Cu tended to increase with increasing NutraLime application. Potato skins had the highest accumulation of trace elements. Even though the tubers were washed, some of this accumulation may have been due to contamination by soil particles adhering to the skin. In soybeans, tissue P generally increased with NutraLime application and was involved with the yield increases at the Isanti Co. site. As with potatoes, Mo also increased in soybean tissue with increasing NutraLime. The Mo levels accumulated in soybean grain tissue were above those considered safe for ruminants.

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.

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 are presented in Table 1. 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 on a wet and dry weight basis in Table 2. Elemental content of the NutraLime at each site was determined on concentrated nitric acid/perchloric acid digests (Table 3). In 1991, the crop at all three sites was corn. In 1992 the crop grown depended on the site.

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

[2]Extension Soil Scientist, Junior Scientist, Research Specialist, and Senior Research Plot Technician, respectively, Soil Science Department.

At the Dakota Co. site, the crop tested for response to Nutralime was potato, variety Norkotah Russet. Potatoes were planted April 26, 1992 at a spacing of three feet between rows and 10 inches within the row. At planting, 50 lbs N/A, 160 lbs P_2O_5/A, 55 lbs K_2O/A, 15 lbs S/A, 15 lbs Mg/A and 0.5 lbs B/A was applied as a band. Additional nitrogen was applied at emergence (100 lbs N/A) and hilling (125 lbs N/A). Irrigation was used to supplement rainfall when needed. At the Isanti Co. site, the crop tested for response to Nutralime was the soybean variety Pioneer 9061. The soybeans were planted May 12, 1992 at a rate of 200,000 seeds/A (15" between rows). No fertilizer was applied during the 1992 growing season. The site was nonirrigated. At the Washington Co. site, the crop tested for response to Nutralime was Jacques 231 soybeans. The soybeans were planted May 18 at a rate of 180,000 seeds/A (30" between rows). No fertilizer was applied during the 1992 growing season. 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. Five whole plant shoot and tuber potato samples, as well as 30 recently matured leaf (diagnostic leaf) samples were collected on July 14. All tuber samples were rinsed in deionized water before drying at 60 C. Whole plant soybean shoot samples (10 feet of row per replication) and 40 first trifoliate leaf (diagnostic leaf) samples were collected on July 9. Potato vines and tubers were hand harvested from two, 20 ft rows on August 20. Tubers were separated into marketable and nonmarketable categories and then weighed. Subsamples of vines were collected for elemental analyses. Twenty-five tubers were sampled for scab incidence, specific gravity, and elemental analyses. To prepare the tubers for elemental analysis, samples were washed in deionized water and then the skin was peeled off. Tuber skin and flesh samples were dried at 60 C and then ground to pass through a 30 mesh screen. Two, 20 ft rows of soybeans were harvested on October 6 at Isanti Co. and October 8 at Washington County. Samples were air dried and shelled, then the grain was weighed. A subsample of grain was dried in an oven at 60 C. Moisture content was determined and then the samples were ground to pass through a 30 mesh screen. Potato and soybean tissue samples were ashed, dissolved in 1 N HCl and then analyzed for elemental composition 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 no effect on growth of potatoes at mid-season (Table 4). Final potato yield and specific gravity were also not affected by NutraLime. Scab incidence was measured because liming is known to be associated with increased scab occurrence. Increasing NutraLime tended to increase incidence of moderate and heavy scab in Norkotah potatoes. This variety is considered susceptible to scab, so an increase in scab incidence with increasing pH was not surprising. The increase in scab incidence limits the usefulness of NutraLime for potato production.

Effects of NutraLime on soybean growth are presented in Tables 6 and 7. Early plant growth at the preflower stage tended to increased with NutraLime application at both sites compared to the control plots, presumably due to higher soil P with Nutralime application. Nutralime had no effect on final soybean stand counts at either location. Soybean yield tended to increase with Nutralime application at Isanti Co., although the 1X rate did not fall cleanly between the 0.5X and 2X rate. The overall trend for increasing soybean yield with NutraLime application, however, was significant. NutraLime had no effect on soybean yield at the Washington Co. location. As with corn results from 1991, these results indicate that when applied at realistic rates, NutraLime can have a beneficial effect on plant growth.

Elemental Concentrations in Soil Water. Elemental concentrations in water collected from suction tubes at the 2.5' depth are presented in Tables 8 - 10. At the Dakota Co. site Al, Cd, Fe, K, Mg, Mo, Ni, and P were all at background levels (Table 8). B, Cu, 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 Ca, Na, and S concentrations with increasing NutraLime were also detected. On one sampling date Cr concentrations decreased with NutraLime application.

At the Isanti Co. site Cd and K concentrations were generally below detection limits (Table 9). Concentrations of Cr were also below detection limits at two dates, but then slightly increased with NutraLime application at the last sampling date. All Cr levels detected were below drinking water standards. Concentrations of Mn and Ni increased with increasing NutraLime at the last sampling date, but as with Cr, levels were below drinking water standard limits. Concentrations of Pb were not consistently affected by NutraLime. At the first sampling date, all Pb levels were below detection limits. At the second sampling date, Pb increased with increasing NutraLime; however, at the third sampling date, Pb levels were not affected by treatment and the control Pb level at this date was actually at a higher concentration than the highest Pb level at the previous date, where a significant trend with NutraLime occurred. Concentrations of Mo were generally at background levels, although at the last sampling date Mo levels at the 1X NutraLime rate were significantly higher than control levels. Concentrations of Al, B, Cu, Fe, Na, P, and Zn did not show any trend with increasing NutraLime application. Significant increases in S concentrations with increasing NutraLime were detected at all sampling dates. Ca and Mg concentrations also tended to increase with increasing NutraLime at all sampling dates.

At the Washington county site, concentrations of all elements were at background levels. It is interesting to note that the suction tubes had to be reinstalled at this site. The low levels of all elements at both sampling dates may reflect a high adsorption capacity of the ceramic cup used to draw in the soil water. With time, as equilibrium approaches, elemental concentrations might conceivably increase.

Elemental Concentrations in Soil. Soluble salts, soil pH, Bray and Olsen P, ammonium acetate extractable cations and DTPA extractable metals are presented in Tables 11-13. Soil pH was still substantially higher (1.2-1.8 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 0.9-1.6 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. 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. 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. 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 12 inches. 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 Isanti Co. site only. 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. At the Washington Co. site, Cu significantly increased with NutraLime rate in the 12-24 inch depth. DTPA extractable Zn and Pb were not affected by NutraLime application at any of the sites. 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.

Nitric acid extractable soil elements are presented in Tables 14-16. All elements tested, except Be, Co, Li, K, and Ni, increased with NutraLime application in the top 6 inches at all sites. Li was frequently below detection limits, K and Ni increased with NutraLime application at one of the three sites, and Co increased at two of the three sites. Sulfur generally increased with NutraLime application in all depths at all 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, Al, As, B, Co, Fe, Mo, Na, and V increased with NutraLime application in the 6-12 inch depth. At the Isanti Co. site, all elements except Be, Co, Li, K, and Ni increased with increasing NutraLime treatment At Washington County, Cu, P, K, and Na 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 potatoes were grown. For this crop moldboard plowing to a depth of 10-12 inches is common. Except for S and Cu, NutraLime had no consistent effect on elemental concentrations in the 12-24 inch depth at any site. Background concentrations of most elements at this lower depth indicate that minimal leaching had occurred two years after NutraLime application.

Elemental Concentrations in Plant Tissue. Elemental concentrations in potato tubers, shoots, and diagnostic leaves sampled at mid-season, as well as elemental concentrations in tuber skin, tuber flesh, whole tubers (skin + flesh), and potato vines sampled at harvest are presented in Tables 17-23. Of all the elements determined, Mo and Cu consistently increased with NutraLime application in all potato tissues. Concentrations of Mo were below levels (15 ppm) that would cause Mo toxicity (molybdenosis) in ruminants. Mo seemed to accumulate in potato skin. Concentrations of Cu were also highest in the skin, but were below levels that would cause toxicity in plants or animals. Calcium concentrations also increased with NutraLime in potato tuber skin and flesh. Concentrations of Ca and Na increased with NutraLime rate in vines at harvest. Whole tuber and tuber flesh concentrations of trace elements such as B, Cd, Ni, Cr, and Pb were generally not significantly affected by NutraLime application; however, potato skin levels of Cd and B increased slightly with NutraLime rate. Some of the increases in the potato skin may be due to contamination by soil particles. Every effort was made to wash the skins before peeling; however, some soil may have still adhered to the skin. Levels of P in potato shoots or tubers were not affected by NutraLime, presumably due to the high rates of P applied in the starter fertilizer (160 lbs P_2O_5/A).

Elemental concentrations in soybean whole plants and diagnostic leaves sampled at mid-season and grain sampled at harvest are presented in Tables 24-29. As with potatoes, Mo concentrations increased significantly in all soybean tissue sampled and appeared to accumulate in the grain. Levels of Mo were above those considered safe for chronic ingestion by ruminants. Nonruminants are less susceptible to elevated Mo levels. High Mo in ruminant diets induces copper deficiency. A Cu/Mo ratio of < 2 has been shown to induce Cu deficiency. The Cu/Mo ratios in soybean grain tissue in the present study were less than 2 when NutraLime was applied at both sites. At the Isanti Co. site, Cu/Mo ratios were less than 2 in the controls as well. It may be possible to adjust the low Cu/Mo ratio by adding Cu to feed rations. Soybeans seem to accumulate Mo to a much higher degree (even without NutraLime additions) than corn. Concentrations of Mo in soybean grain can normally range from 1-10 ppm. Availability of Mo increases with increasing pH, so the Mo increases in grain tissue may partially be due to a pH response and not the higher Mo content in NutraLime per se. It is known that plants can accumulate high levels of Mo without causing phytotoxicity. Further research into Mo accumulation seems warranted, since sewage sludge applications can also increase Mo in soybeans.

In Isanti Co., P concentrations in soybean whole plant, diagnostic leaf and grain significantly increased with NutraLime application. Mg and Cu concentrations increased in whole plant and diagnostic leaf with increasing NutraLime. In contrast, Ni concentrations decreased in leaf and grain with increasing NutraLime. Concentrations of Zn in whole plants and Mn in diagnostic leaves decreased with increasing NutraLime rate. Concentrations of Cd and Pb in soybean tissue were not affected by treatment.

In Washington Co., P concentrations in whole plant and diagnostic leaves increased with increasing NutraLime rate. N concentrations in diagnostic leaf tissue increased with NutraLime application. Concentrations of Mg increased in whole plants with increasing NutraLime rate. NutraLime application decreased concentrations of Zn, Mn, and B in grain tissue.

GENERAL SUMMARY

NutraLime application increased soybean yield at one of two soybean sites and had no effect on potato yields at a third site. In potatoes, scab increased with NutraLime application, which would limit the usefulness of NutraLime for potato production. Any increases in trace elements with NutraLime were accentuated in tuber skin tissue, although some of this accumulation may have been due to contamination from soil particles adhering to the skin. In soybeans, improved P and Mo nutrition appeared to be involved with increases in yield, although other factors not measured may also have played a role. Accumulation of Mo in soybean grain exceeded 15 ppm when NutraLime was applied. These high Mo levels in soybean grain may limit the general use of this crop in sites where NutraLime is applied. Except for Cu, 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. Results from this second year suggest that NutraLime may be most suited for corn production, since this crop does not accumulate Mo to the same degree as soybean.

Table 1. Selected initial soil chemical characteristics of the demonstration sites. (1991)

Chemical Characteristic	Demonstration sites: Dakota Co.	Isanti Co.	Washington Co.
pH	6.3	5.5	5.7
Bray P1 (ppm)	120	40	81
Ammonium Acetate K (ppm)	256	170	214

Table 2. 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 3. Selected chemical characteristics of NutraLime used at each site (means of 4 or 5 samples).

Chemical Characteristic	Dakota Co.	Isanti Co.	Washington Co.
Moisture (%)	55.9	61.1	58.2
Calcium Carbonate Equivalent (%)[1]	33.3	41.7	45.7
Soluble Salt (mmhos/cm)	4.5	5.3	4.9
Chloride (ppm)	201	218	232
Mercury (ppm)	-	0.007	0.011
Total nitrogen (%)	-	0.05	-

Acid Digestible Elements[2]	Dakota Co. ppm	Dakota Co. lb/dry ton	Isanti Co. ppm	Isanti Co. lb/dry ton	Washington Co. ppm	Washington Co. lb/dry ton
Aluminum	42543	85	35722	71	33183	66
Arsenic	44	0.09	36	0.07	34	0.07
Barium	1260	2.5	815	1.6	960	1.9
Beryllium	0.7	0.001	0.8	0.002	0.7	0.001
Boron	39	0.08	36	0.07	34	0.07
Cadmium	32	0.06	37	0.07	35	0.07
Calcium	137573	275	159544	319	171478	343
Chromium	769	1.5	648	1.3	638	1.3
Cobalt	4.9	0.01	1.9	0.004	1.7	0.003
Copper	2270	4.5	2205	4.4	2011	4.0
Iron	19982	40	18500	37	17546	35
Lead	412	0.82	417	0.83	383	0.77
Lithium	11	0.02	10	0.02	10	0.02
Magnesium	13566	27	15579	31	15108	30
Manganese	3008	6.0	1809	3.6	1994	4.0
Molybdenum	38	0.08	27	0.05	26	0.05
Nickel	209	0.42	210	0.42	200	0.40
Phosphorus	39010	78	33171	66	29719	59
Potassium	3324	6.6	2766	5.5	2565	5.1
Rubidium	<105	-	<105	-	<105	-
Silicon	366	0.73	433	0.87	401	0.80
Sodium	2038	4.1	1994	4.0	1839	3.7
Strontium	273	0.55	273	0.55	272	0.5
Sulfur	2231	4.5	2543	5.1	2554	5.1
Titanium	318	0.64	312	0.62	266	0.5
Vanadium	38	0.08	33	0.07	32	0.06
Zinc	1591	3.2	1769	3.5	1673	3.3

[1] Calcium carbonate equivalent, chloride, mercury, total nitrogen, and acid digestible elements are expressed on a dry weight basis.

[2] Acid digestible - boiling concentrated nitric acid and concentrated perchloric acid. After 6 hours, 34-41% remained undigested.

Table 4. Effect of NutraLime on vine dry matter, tuber number and dry matter; sampled July 14, 1992 - Dakota County.

NutraLime Treatment	Tubers	Tuber dry matter	Vine dry matter
	--#/plant--	--g/plant--	--g/plant--
0	10.5	100.0	66.8
0.5X	11.7	115.5	73.2
1.0X	12.1	106.3	68.8
2.0X	9.9	95.2	63.1
Significance	NS	NS	NS
Linear	NS	NS	NS
Quadratic	NS	NS	NS

NS = not significant

Table 5. Effect of NutraLime on potato yield, fresh vine weight at harvest, specific gravity and scab severity; August 19, 1992 - Dakota County.

NutraLime	Tuber Size				Vines	Specific	Scab Severity			
Treatment	<3 oz	3-12 oz	>12 oz	total	fresh wt.	gravity	slight[1]	moderate[2]	heavy[3]	total
	cwt/A				--tons/A--		% infected			
0	55.3	338.4	87.9	481.7	8.05	1.0787	32.0	13.3	2.7	48.0
0.5X	45.8	346.4	122.0	514.2	7.54	1.0794	46.7	6.6	6.7	60.0
1.0X	41.1	289.7	126.4	457.2	6.63	1.0825	52.0	8.0	9.3	69.3
2.0X	38.8	356.1	102.5	497.4	7.81	1.0805	41.3	33.3	22.7	97.3
Significance	NS	NS	NS	NS	NS	NS	NS	*	NS	*
BLSD (5%)	--	--	--	--	--	--	--	17.8	--	30.8
Linear	NS	NS	NS	NS	NS	NS	NS	*	*	**
Quadratic	NS	*	NS	NS	NS	NS	NS	*	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%.
1 slight - surface scab, no pits.
2 moderate - pitted, less than 3 lesions per tuber.
3 heavy - pitted, 3 or more lesions per tuber.

Table 6. Effect of NutraLime on soybean whole plant dry weight at the pre-flower stage, final stand count and grain yield - Isanti County.

NutraLime Treatment	Plant dry wt. pre-flower	Final stand count	Grain Yield
	--g/10' row--	--plants/A--	--bu/A--
0	81	170,755	32.8
0.5X	133	182,952	41.9
1.0X	112	170,755	35.2
2.0X	97	177,724	46.2
Significance	*	NS	++
BLSD (5%)	30	--	10.0
Linear	NS	NS	*
Quadratic	*	NS	NS

NS = not significant, ++ = significance at 10%, * = significant at 5%.

Table 7. Effect of NutraLime on soybean whole plant dry weight at the pre-flower stage, final stand count and grain yield - Washington County.

NutraLime Treatment	dry wt. Plant yield pre-flower	Final stand count	Grain Yield
	--g/10 feet row--	--plants/A--	--bu/A--
0	224	136,488	27.4
0.5X	245	131,261	29.4
1.0X	311	144,619	28.3
2.0X	282	145,200	30.0
Significance	**	NS	NS
BLSD (5%)	35	--	--
Linear	**	NS	NS
Quadratic	**	NS	NS

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

Table 8. 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
		ppm																
June 1, 1992																		
	0	0.44	0.07	93	0.010	0.022	0.08	0.07	3.3	25	0.02	0.03	8	0.06	0.12	0.14	24	0.24
	0.5X	0.55	0.06	106	0.010	0.021	0.09	0.06	2.7	26	0.05	0.03	15	0.08	0.12	0.14	27	0.82
	1.0X	0.40	0.06	92	0.009	0.022	0.07	0.06	2.3	23	0.04	0.02	13	0.07	0.12	0.12	36	0.83
	2.0X	0.42	0.07	44	0.010	0.023	0.08	0.05	1.5	11	0.02	0.03	11	0.05	0.12	0.14	28	0.26
Significance		NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)		--	--	--	--	--	0.01	--	--	--	--	--	--	--	--	--	--	--
Contrasts																		
Linear		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	*
June 29, 1992																		
	0	0.43	0.07	69	0.011	0.023	0.09	0.05	3.0	19	0.01	0.03	8	0.06	0.11	0.15	19	0.12
	0.5X	0.56	0.06	91	0.010	0.024	0.09	0.06	2.9	21	0.05	0.03	13	0.06	0.09	0.13	24	0.26
	1.0X	0.40	0.06	70	0.009	0.020	0.08	0.06	1.8	16	0.03	0.02	12	0.06	0.09	0.14	29	0.23
	2.0X	0.47	0.08	47	0.010	0.025	0.09	0.05	1.6	12	0.02	0.03	11	0.06	0.11	0.15	28	0.12
Significance		NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)		--	0.01	--	--	0.003	--	--	--	--	--	--	--	--	--	--	--	--
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
October 6, 1992																		
	0	0.49	0.08	58	0.013	0.027	0.09	0.07	2.6	16	0.01	0.03	9	0.06	0.11	0.17	17	0.08
	0.5X	0.67	0.08	108	0.011	0.025	0.10	0.06	5.0	29	0.05	0.03	16	0.07	0.11	0.17	29	0.18
	1.0X	0.53	0.08	76	0.012	0.025	0.09	0.40	2.3	19	0.03	0.03	18	0.08	0.10	0.17	35	0.21
	2.0X	0.56	0.10	60	0.012	0.026	0.09	0.07	1.8	15	0.02	0.03	13	0.07	0.11	0.16	40	0.11
Significance		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
Quadratic		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 9. 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
		ppm																
June 29, 1992																		
	0	<0.24	0.04	26	<0.007	<0.02	0.05	0.05	<0.7	10	0.03	0.016	9	0.042	0.07	<0.084	15	0.07
	0.5X	0.33	0.05	40	<0.007	<0.02	0.06	0.03	<0.8	15	0.07	0.022	12	0.060	0.06	<0.084	25	0.08
	1.0X	0.37	0.05	39	<0.006	<0.01	0.08	0.10	<1.2	14	0.09	0.023	10	0.058	0.12	<0.087	34	0.24
	2.0X	0.40	0.05	45	<0.006	<0.02	0.08	0.14	<1.3	16	0.08	0.018	10	0.063	0.08	<0.084	37	0.19
Significance		—	NS	NS	—	—	NS	NS	—	NS	NS	NS	NS	NS	NS	—	*	NS
BLSD (5%)		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	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
August 13, 1992																		
	0	0.28	0.05	24	<0.007	<0.02	0.05	0.02	<0.7	9	0.02	0.020	10	0.046	0.07	0.097	12	0.05
	0.5X	0.36	0.06	42	<0.007	<0.02	0.07	0.03	<0.8	16	0.06	0.018	12	0.062	0.07	0.097	21	0.07
	1.0X	0.34	0.06	36	<0.007	0.02	0.07	0.04	<0.9	13	0.06	0.019	10	0.062	0.08	0.102	30	0.09
	2.0X	0.38	0.07	44	0.008	<0.02	0.07	0.04	<0.8	17	0.08	0.020	11	0.069	0.08	0.104	36	0.08
Significance		NS	NS	*	—	—	NS	NS	—	NS	NS	NS	NS	NS	NS	*	**	NS
BLSD (5%)		—	—	14	—	—	—	—	—	—	—	—	—	—	—	0.005	12	—
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
October 6, 1992																		
	0	0.38	0.06	27	0.009	0.018	0.07	0.05	<0.8	11	0.03	0.021	11	0.055	0.08	0.118	13	0.07
	0.5X	0.57	0.07	48	0.009	0.021	0.07	0.04	<0.9	18	0.07	0.020	14	0.072	0.09	0.115	23	0.12
	1.0X	0.45	0.08	39	0.009	0.023	0.07	0.04	1.0	14	0.06	0.024	10	0.078	0.08	0.121	30	0.06
	2.0X	0.56	0.07	84	0.009	0.022	0.07	0.04	<1.0	32	0.16	0.020	19	0.103	0.08	0.117	49	0.10
Significance		NS	NS	NS	NS	*	NS	NS	—	NS	NS	*	NS	*	NS	NS	NS	NS
BLSD (5%)		—	—	—	—	0.003	—	—	—	—	—	0.003	—	0.024	—	—	—	—
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 = not significant, * = significant at 5%, ** = significant at 1%.

Table 10. 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 29, 1992																		
	0	<0.18	0.05	40	<0.006	<0.01	<0.05	<0.03	2.5	11	0.04	0.02	11	0.04	0.19	<0.08	27	0.18
	0.5X	<0.18	0.06	50	<0.006	<0.01	0.04	0.03	1.8	14	0.02	0.02	18	0.04	0.13	<0.08	35	0.13
	1.0X	<0.18	0.06	48	<0.006	<0.01	0.04	0.02	1.5	13	0.01	0.02	23	0.03	0.17	<0.08	33	0.07
	2.0X	<0.18	0.05	55	<0.006	<0.01	0.04	0.02	2.0	18	<0.01	0.02	20	0.03	0.43	<0.08	29	0.08
Significance		—	NS	NS	—	—	—	—	NS	NS	—	NS	NS	NS	NS	—	NS	NS
August 13, 1992																		
	0	<0.19	0.05	37	<0.006	<0.01	<0.04	<0.02	2.7	11	0.03	0.01	11	0.03	0.11	<0.08	22	0.15
	0.5X	<0.18	0.07	29	<0.006	<0.01	<0.03	0.04	1.2	9	0.02	0.01	20	0.03	0.15	<0.08	24	0.09
	1.0X	<0.18	0.07	38	<0.006	<0.01	<0.03	<0.02	1.0	10	0.01	0.01	30	0.02	0.13	<0.08	34	0.08
	2.0X	<0.18	0.05	39	<0.006	<0.05	<0.03	<0.03	1.5	12	<0.01	0.01	18	0.02	0.36	<0.08	18	0.07
Significance		—	NS	NS	—	—	—	—	NS	NS	—	NS	NS	NS	NS	—	NS	NS
BLSD (5%)		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Contrasts																		
Linear		—	NS	NS	—	—	—	—	NS	NS	—	NS	NS	NS	NS	—	NS	NS
Quadratic		—	*	NS	—	—	—	—	NS	NS	—	NS	NS	NS	NS	—	NS	NS

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

Table 11. 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	6.3	0.23	97	46	191	1583	391	10.6	79	16.1	1.6	0.8	1.9	1.5	0.07	<0.03
	0.5x	7.2	0.37	181	73	189	2606	408	11.2	53	7.0	1.5	3.1	1.4	0.7	0.10	0.05
	1.0x	7.3	0.37	250	85	207	3706	441	11.5	51	7.2	1.7	4.6	1.9	0.7	0.12	<0.04
	2.0x	7.4	0.35	281	95	194	3747	444	13.1	50	6.0	1.6	4.9	1.4	0.7	0.09	0.05
Significance		**	NS	**	**	NS	**	*	NS	*	*	NS	**	NS	*	NS	—
BLSD	(5%)	0.5	—	61	14	—	514	30	—	19	6.8	—	1.0	—	0.6	—	—
Contrasts																	
Linear		**	NS	**	**	NS	**	*	NS	NS	NS	NS	**	NS	NS	NS	—
Quadratic		*	NS	*	**	NS	**	*	NS	*	*	NS	**	NS	*	*	—
6-12"	0	6.0	0.17	62	31	102	1544	353	11.9	84	13.9	1.1	0.8	1.6	1.4	0.06	0.04
	0.5x	6.7	0.33	122	46	122	2054	387	13.9	72	9.6	1.1	1.5	1.3	1.0	0.07	<0.03
	1.0x	6.9	0.33	120	46	98	2274	379	12.9	62	7.3	1.3	2.9	1.6	0.9	0.11	<0.03
	2.0x	6.9	0.30	107	37	119	2172	383	13.9	66	7.6	0.9	1.5	1.0	0.9	0.05	0.04
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	—
BLSD	(5%)	—	—	—	—	—	—	—	—	—	—	—	—	—	0.4	0.04	—
Contrasts																	
Linear		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	*	*	—
12-24"	0	6.1	0.10	9	6	53	1251	267	10.9	38	2.1	0.2	0.6	<0.7	0.6	<0.03	<0.02
	0.5x	6.2	0.23	14	10	59	1418	327	14.4	41	2.5	0.2	0.6	0.5	0.7	<0.02	<0.03
	1.0x	6.3	0.20	14	8	54	1426	308	12.9	43	2.1	0.3	0.7	<0.4	0.8	<0.03	<0.03
	2.0x	6.5	0.20	14	8	75	1419	330	12.3	34	1.4	0.2	0.6	0.6	0.4	<0.02	0.06
Significance		NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	—	NS	—	—
BLSD	(5%)	—	0.07	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	—	NS	—	—

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

Table 12. Effect of NutraLime on soil pH, soluble salts, Bray P1, Olsen P, ammonium acetate extractable cations, and DTPA extractable metals - Isanti County.

						NH4OAc 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	5.7	0.10	39	19	186	801	69	6.1	90	27.4	1.47	0.71	1.06	1.15	0.09	<0.04
	0.5x	7.3	0.20	102	33	177	1560	117	9.0	44	9.5	1.27	2.02	1.46	0.64	0.08	<0.03
	1.0x	7.4	0.27	133	34	148	1963	132	9.2	40	8.1	1.28	2.62	0.90	0.64	0.10	<0.02
	2.0x	7.5	0.20	157	43	132	2601	159	9.9	39	7.7	1.51	3.72	1.11	0.61	0.12	<0.03
Significance		**	**	*	NS	*	**	**	NS	**	**	NS	**	NS	**	NS	--
BLSD (5%)		0.3	0.06	71	--	42	792	38	3.1	13	9.0	--	1.00	--	0.11	--	--
Contrasts																	
Linear		**	**	**	*	**	**	**	*	**	**	NS	**	NS	**	NS	--
Quadratic		**	**	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	**	NS	--
6 - 12"	0	5.6	0.10	31	17	151	762	71	7.9	80	21.4	1.12	0.63	1.03	1.46	0.07	<0.04
	0.5x	7.0	0.20	70	22	139	1354	109	11.1	55	10.2	1.01	1.57	0.52	0.88	0.08	<0.03
	1.0x	7.1	0.27	91	25	141	1580	115	9.8	56	12.7	1.27	1.93	0.96	1.07	0.06	<0.04
	2.0x	7.2	0.27	93	25	127	1718	133	10.6	50	9.8	1.14	1.92	0.71	0.93	0.10	0.05
Significance		**	**	NS	NS	NS	*	NS	NS	**	*	NS	*	*	**	*	--
BLSD (5%)		0.3	0.07	--	--	--	555	--	--	14	6.2	--	0.85	0.34	0.28	0.03	--
Contrasts																	
Linear		**	**	*	NS	NS	**	**	NS	**	**	NS	*	NS	*	NS	--
Quadratic		**	**	NS	NS	NS	NS	NS	NS	*	*	NS	*	NS	*	*	--
12 - 24"	0	5.8	0.10	22	20	130	1135	205	11.8	86	5.4	0.21	0.61	<0.66	1.11	<0.02	<0.04
	0.5x	6.0	0.10	26	22	124	1175	207	13.6	82	3.9	0.19	0.62	0.44	0.82	<0.03	<0.04
	1.0x	6.4	0.10	22	14	89	1098	160	12.4	55	2.6	0.17	0.82	0.53	0.55	<0.02	<0.04
	2.0x	6.3	0.13	24	18	94	1233	197	12.8	64	4.7	0.20	0.75	<0.36	0.76	<0.05	<0.04
Significance		NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	--	NS	--	--
BLSD (5%)		--	--	--	--	17	--	--	--	--	--	--	--	--	--	--	--
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 = not significant, * = significant at 5%, ** = significant at 1%.

Table 13. 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	5.4	0.17	77	47	249	1733	252	3.9	140	48.2	2.3	1.33	2.59	2.67	0.15	0.07
	0.5x	7.1	0.30	145	85	269	3324	345	7.2	89	15.2	2.8	3.09	2.35	1.81	0.17	<0.03
	1.0x	7.5	0.33	166	93	233	4299	371	7.9	76	10.5	2.4	4.46	2.12	1.36	0.20	<0.03
	2.0x	7.7	0.30	228	130	315	4793	472	10.0	65	8.7	3.2	7.94	2.35	1.17	0.24	<0.04
Significance		**	**	**	**	NS	**	*	*	**	**	NS	*	NS	*	NS	--
BLSD (5%)		0.6	0.08	39	33	--	950	118	3.0	32	13.8	--	3.78	--	0.79	--	--
Contrasts																	
Linear		**	**	**	**	NS	**	**	**	**	**	NS	**	NS	**	*	--
Quadratic		**	**	NS	NS	NS	*	NS	NS	*	**	NS	NS	NS	NS	NS	--
6 - 12"	0	5.5	0.13	50	32	163	1862	285	5.1	117	27.1	1.4	1.10	1.88	2.70	0.11	<0.05
	0.5x	6.2	0.23	77	45	196	2507	334	8.3	106	19.4	2.4	2.32	1.89	2.61	0.16	<0.04
	1.0x	6.7	0.27	74	37	139	2626	331	9.8	98	15.7	1.6	2.22	1.63	2.33	0.11	<0.05
	2.0x	6.7	0.30	103	52	199	2640	372	11.7	99	14.6	2.1	2.19	1.39	2.02	0.11	<0.04
Significance		NS	NS	*	NS	*	NS	NS	**	NS	NS	NS	*	NS	NS	NS	--
BLSD (5%)		--	--	35	--	47	--	--	2.9	--	--	--	0.83	--	--	--	--
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	--
12 - 24"	0	5.9	0.10	10	9	121	1940	394	9.5	51	2.7	0.2	0.85	1.08	0.87	<0.02	<0.04
	0.5x	5.9	0.10	11	9	133	2144	406	9.3	60	3.8	0.3	0.89	1.35	1.34	0.04	<0.05
	1.0x	5.9	0.13	11	9	124	2127	381	10.2	56	3.7	0.3	0.92	0.84	1.14	<0.03	<0.03
	2.0x	6.0	0.20	17	11	129	2094	395	10.8	59	3.3	0.3	1.01	0.76	1.09	0.05	0.06
Significance		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	--	--
BLSD (5%)		--	0.06	--	--	--	--	--	--	--	--	--	0.11	--	--	--	--
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 = not significant, * = significant at 5%, ** = significant at 1%.

Table 14. 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	1708	1.6	121	0.4	1.5	0.3	2827	1.4	1.0	4	746	11	<0.20	710	137	0.53	3.8	199	283	469	10	12	34	10	3.3	6
	0.5x	2275	2.1	136	0.4	2.0	0.9	5606	3.8	1.3	32	1074	17	<0.22	888	225	0.76	3.7	969	303	747	30	16	59	16	4.5	14
	1.0x	2859	2.8	159	0.4	2.7	1.3	8257	6.0	1.5	58	1376	25	0.29	1089	309	1.01	4.9	1713	343	975	53	21	86	21	5.4	22
	2.0x	2782	2.7	148	0.4	2.5	1.4	8578	6.1	1.5	62	1331	24	0.29	1127	304	1.01	4.8	1814	332	946	52	20	82	20	5.2	22
Significance		**	**	**	NS	**	**	**	**	*	**	**	**	—	*	**	**	*	**	NS	**	**	**	**	**	**	**
BLSD (5%)		356	0.3	17	—	0.4	0.5	1923	1.2	0.3	16	250	4	—	226	65	0.19	1.0	438	—	169	9	3	12	3	0.7	4
Contrasts																											
Linear		**	**	**	NS	**	**	**	**	*	**	**	**	—	**	**	**	*	**	NS	**	**	**	**	**	**	**
Quadratic		**	**	**	*	**	*	**	**	*	**	**	**	—	*	**	**	NS	**	NS	**	**	**	**	**	**	**
6 - 12 inches	0	1738	1.6	115	0.4	1.3	0.3	2447	1.4	0.6	3	717	9	<0.21	638	87	0.54	3.3	106	135	481	11	12	31	10	2.9	5
	0.5x	2020	1.9	129	0.4	1.7	0.5	3774	2.4	0.8	14	891	12	<0.23	768	136	0.64	3.3	422	171	605	21	15	58	13	3.7	8
	1.0x	2213	2.0	134	0.4	1.7	0.6	4363	3.0	0.8	21	1011	14	0.27	790	153	0.74	3.5	590	166	697	27	16	60	15	4.0	11
	2.0x	2041	1.8	123	0.4	1.4	0.5	3800	2.5	0.8	16	885	12	<0.23	745	130	0.64	3.2	449	151	622	22	14	55	13	3.6	9
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%)		—	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	0.13	—	—	—	—	—	—	20	—	—	—
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	NS
Quadratic		*	**	NS	NS	*	NS	NS	NS	*	NS	*	NS	—	NS	NS	*	NS	NS	NS	NS	*	NS	*	NS	*	NS
12 - 24 inches	0	1429	1.4	79	0.3	0.8	0.2	1777	1.2	0.2	3	640	6	<0.23	499	30	0.45	1.7	55	64	442	12	12	21	14	2.5	4
	0.5x	1569	1.4	88	0.3	0.9	0.2	1958	1.3	0.3	3	708	7	<0.25	587	35	0.49	1.9	53	72	489	14	12	31	14	2.8	4
	1.0x	1679	1.6	94	0.3	0.9	0.2	2042	1.5	0.2	4	819	7	0.29	611	36	0.54	2.3	49	75	549	16	13	34	16	3.1	5
	2.0x	1629	1.4	90	0.3	0.8	0.2	1988	1.4	0.2	4	740	7	<0.25	605	33	0.49	1.7	56	76	526	15	13	32	15	2.9	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	NS
BLSD (5%)		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—
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

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

Table 15. Effect of NutraLime on nitric acid extractable elements - Isanti County

Depth	Trmt	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"	0	881	1.26	47	0.17	0.79	0.23	1268	0.92	0.42	2.8	960	6.9	<0.20	145	166	0.31	2.6	111	277	189	9	4.4	20	15	3.1	5.3
	0.5x	1025	1.56	55	0.17	1.09	0.54	2862	1.93	0.40	15.1	1080	10.4	<0.20	271	198	0.36	2.6	419	272	307	16	6.6	31	18	3.6	9.4
	1.0x	1203	1.80	62	0.18	1.27	0.76	3790	2.66	0.57	23.1	1215	11.5	<0.20	344	243	0.43	3.2	598	278	382	21	7.8	38	21	3.9	12.7
	2.0x	1404	2.08	67	0.18	1.52	1.07	5543	3.72	0.59	36.3	1294	14.1	<0.20	476	255	0.52	3.3	915	260	476	30	10.2	51	24	4.2	17.0
Significance		NS	NS	NS	NS	NS	*	*	*	NS	*	NS	*	--	*	NS	NS	NS	NS	NS	*	*	NS	*	*	NS	NS
BLSD (5%)		--	--	--	--	--	0.56	2837	1.83	--	22.5	--	4.7	--	212	--	--	--	--	--	173	14	--	21	6	--	--
Contrasts																											
Linear		*	*	*	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
6 - 12"	0	829	1.17	43	0.16	0.66	0.20	1158	0.93	0.31	2.2	923	6.0	<0.20	154	132	0.31	3.0	89	216	192	9	4.1	18	16	3.0	4.3
	0.5x	985	1.48	52	0.17	0.94	0.44	2451	1.73	0.28	11.7	1104	8.0	<0.20	257	162	0.36	3.2	315	218	294	17	6.3	32	19	3.6	7.8
	1.0x	1072	1.64	58	0.17	1.07	0.55	2792	1.95	0.45	14.9	1139	9.4	<0.20	275	209	0.39	3.6	383	245	315	18	6.8	39	19	3.6	9.5
	2.0x	1162	1.71	58	0.18	1.13	0.59	3233	2.32	0.43	17.2	1209	9.8	<0.20	340	199	0.42	3.4	445	214	363	22	7.5	43	22	3.9	10.5
Significance		NS	*	NS	NS	*	*	*	*	NS	NS	*	NS	--	*	NS	NS	NS	NS	NS	*	*	*	*	*	*	NS
BLSD (5%)		--	0.37	--	--	0.34	0.30	1417	0.98	--	--	177	--	--	101	--	--	--	--	--	87	8	2.3	15	4	0.5	4.8
Contrasts																											
Linear		*	*	*	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"	0	1064	1.26	35	0.18	0.61	0.15	1538	1.61	<0.13	1.9	1261	4.9	0.32	447	38	0.37	2.8	93	136	407	14	5.2	16	24	4.4	3.5
	0.5x	1144	1.84	37	0.21	1.36	0.18	1484	2.01	<0.12	2.9	1322	5.5	0.69	513	31	0.51	2.7	120	141	474	20	5.8	23	26	5.1	<2.8
	1.0x	1063	1.14	37	0.18	0.61	0.17	1624	1.72	<0.12	2.8	1227	5.0	0.36	439	34	0.37	2.1	77	117	455	16	5.4	20	28	4.6	3.9
	2.0x	1168	1.34	36	0.18	0.69	0.20	1717	1.87	<0.20	3.6	1399	5.4	0.41	555	42	0.40	3.0	100	120	506	17	5.5	23	27	4.6	4.5
Significance		NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--
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	--

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

Table 16. Effect of NutraLime on nitric acid extractable elements - Washington 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	1859	1.7	135	0.46	1.4	0.3	2912	1.3	1.0	5	808	12	<0.24	471	151	0.55	5.2	146	343	446	7	15	26	10	3.4	8
	0.5x	2041	2.1	151	0.46	2.0	0.8	6112	3.0	1.2	22	963	16	<0.21	670	210	0.64	5.8	598	358	680	18	19	43	13	4.5	15
	1.0x	2351	2.3	155	0.46	2.2	1.1	7905	4.4	1.2	34	1080	18	<0.23	816	225	0.72	5.8	832	331	838	26	21	54	16	4.9	19
	2.0x	3003	3.0	172	0.47	3.0	2.1	12607	7.2	1.6	75	1391	27	<0.22	1190	310	0.99	6.7	1818	475	1125	50	27	82	22	6.0	33
Significance		*	*	NS	NS	*	*	*	*	*	*	*	*	—	*	*	NS	NS	*	NS	*	*	*	*	*	**	*
BLSD (5%)		837	0.8	—	—	0.8	1.0	5980	3.6	0.4	46	341	10	—	417	94	—	—	1064	—	345	27	8	35	7	0.9	15
Contrasts																											
Linear		**	**	*	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
6 - 12 inches	0	1905	1.7	126	0.45	1.4	0.3	2859	1.4	0.6	4	793	10	0.31	544	96	0.56	5.0	84	215	529	8	15	24	13	3.4	7
	0.5x	1956	1.9	145	0.48	1.6	0.4	4191	1.9	0.7	10	840	11	0.30	647	117	0.59	6.7	220	244	599	13	18	34	13	3.8	10
	1.0x	2016	1.8	142	0.47	1.6	0.5	4475	2.1	0.7	12	874	11	<0.29	674	115	0.59	5.8	256	192	666	17	18	38	14	3.9	10
	2.0x	2035	1.7	139	0.45	1.7	0.5	4492	2.0	0.7	13	888	12	<0.22	690	128	0.58	5.4	298	274	633	19	17	41	14	4.0	11
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%)		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	47	—	7	—	5	—	—	—
Contrasts																											
Linear		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
12 - 24 inches	0	2146	1.8	109	0.40	1.1	0.2	2748	1.8	<0.2	4	1039	9	0.49	832	33	0.64	2.4	33	148	758	15	17	19	23	4.1	6
	0.5x	2038	1.8	120	0.43	1.1	0.2	2944	1.8	0.3	4	998	9	0.52	842	35	0.61	3.6	20	141	757	14	18	23	24	4.1	7
	1.0x	1942	1.5	116	0.40	1.0	0.2	2778	1.7	<0.2	4	1036	8	0.43	803	33	0.56	3.0	22	129	764	14	18	25	25	4.0	7
	2.0x	2101	1.7	112	0.39	1.1	0.2	3004	1.7	<0.2	5	1003	8	0.36	817	40	0.59	2.9	58	152	733	16	17	33	22	4.0	6
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%)		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.7	—	—	—	—	—	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	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 = not significant; * = significant at 5%, ** = significant at 1%.

Table 17. Effect of NutraLime on the elemental composition of potato tuber samples, July 14, 1992 - Dakota county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	1.57	0.27	2.12	623	1019	95	88	27	8.7	13.5	3.1	5.2	<1.68	1.11	0.54	<0.14	<0.24
0.5x	1.62	0.27	2.18	856	1122	68	66	30	7.5	12.2	4.6	5.1	<1.68	0.91	0.52	<0.14	0.90
1.0x	1.54	0.26	2.16	916	1080	84	76	37	7.6	12.4	6.2	5.4	<2.07	1.12	0.54	<0.16	1.48
2.0x	1.58	0.27	2.14	858	1087	73	69	32	7.4	12.2	5.7	5.3	<1.68	1.06	0.47	<0.16	1.63
Significance	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	—	NS	NS	—	**
BLSD (5%)	—	—	—	203	—	—	—	—	—	—	—	—	—	—	—	—	0.62
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 18. Effect of NutraLime on the elemental composition of potato shoot samples, July 14, 1992 - Dakota county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	4.86	0.36	5.19	1.73	1.18	563	411	58	176	30	6.7	27	<4.8	4.5	3.0	1.03	0.90
0.5x	4.54	0.32	4.99	1.92	1.32	905	617	82	151	27	11.4	27	7.6	5.4	4.4	1.19	3.91
1.0x	4.52	0.33	4.81	1.95	1.26	695	465	77	147	27	12.3	26	6.7	4.8	3.7	1.29	5.51
2.0x	4.61	0.34	4.87	1.90	1.27	677	441	73	148	23	11.9	26	<5.5	4.3	3.3	1.10	6.02
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	—	NS	NS	NS	**
BLSD (5%)	—	—	—	—	—	—	—	—	—	—	3.1	—	—	—	—	—	2.38
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 = nonsignificant, * = significant at 5%, ** = significant at 1%.

Table 19. Effect of NutraLime on the elemental composition of potato diagnostic leaf samples, July 14, 1992 - Dakota county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	5.86	0.44	3.56	0.88	0.69	26.2	81	33	62	22	8.3	22	<4.6	3.0	1.81	0.61	0.75
0.5x	6.00	0.48	3.52	0.99	0.81	22.5	80	33	59	24	11.0	22	<3.3	2.6	1.44	0.71	3.12
1.0x	5.95	0.47	3.42	0.97	0.74	23.5	80	36	43	23	12.2	22	<3.9	2.8	1.41	0.69	5.09
2.0x	5.96	0.48	3.69	0.92	0.72	18.0	83	26	53	23	11.6	22	<1.8	2.1	1.10	0.54	8.19
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	—	NS	NS	NS	**
BLSD (5%)	—	—	—	—	—	—	—	—	—	—	2.7	—	—	—	—	—	2.57
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	NS

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

Table 20. Effect of NutraLime on the elemental composition of potato skin samples, August 19, 1992 - Dakota county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	2.91	0.29	3.05	0.21	0.22	1140	694	92	33	23	9.5	15.7	5.3	3.6	2.1	0.55	1.2
0.5x	2.94	0.28	3.06	0.27	0.21	937	535	89	33	22	14.2	16.5	6.1	4.0	2.1	0.68	4.1
1.0x	3.00	0.29	3.20	0.29	0.24	898	507	98	34	21	15.2	16.7	7.0	3.8	2.4	0.74	6.5
2.0x	3.11	0.28	3.15	0.31	0.24	1296	798	125	47	26	19.6	18.1	7.5	5.2	3.1	0.83	6.7
Significance	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	**
BLSD (5%)	—	—	—	0.03	—	—	—	—	—	—	4.0	—	—	—	—	—	2.5
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	NS	NS	NS	*

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

Table 21. Effect of NutraLime on the elemental composition of potato flesh samples, August 19, 1992 - Dakota county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	1.37	0.25	1.80	383	1029	<11.8	26	25	7.2	13	3.3	4.4	<2.8	<1.17	<0.59	<0.24	<0.42
0.5x	1.69	0.27	1.79	521	1074	12.6	24	32	7.0	14	4.9	4.8	<3.4	1.56	0.75	0.33	1.64
1.0x	1.72	0.27	1.89	605	1148	<10.0	26	32	7.7	14	5.1	4.7	<2.7	1.27	0.61	0.26	2.75
2.0x	1.61	0.28	1.92	581	1130	11.6	30	31	7.4	13	4.7	4.5	<2.5	<1.03	<0.55	<0.24	2.31
Significance	*	NS	NS	**	NS	—	NS	NS	NS	NS	*	NS	—	—	—	—	**
BLSD (5%)	0.26	—	—	98	—	—	—	—	—	—	1.1	—	—	—	—	—	0.87
Contrasts																	
Linear	NS	NS	NS	**	NS	—	NS	NS	NS	NS	*	NS	—	—	—	—	**
Quadratic	*	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 potato tuber samples, August 19, 1992 - Dakota county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	1.71	0.25	1.81	445	1160	59	57	25	8.7	12.8	3.7	5.1	<4.4	<1.5	<0.79	<0.33	<0.74
0.5x	1.59	0.25	1.80	570	1043	48	48	31	7.5	12.2	4.5	5.2	<3.8	<1.4	<0.75	<0.33	1.24
1.0x	1.64	0.25	1.74	583	1078	42	42	32	7.5	12.5	5.1	6.3	<4.2	<1.5	<0.77	<0.36	2.69
2.0x	1.58	0.25	1.84	606	1103	54	52	34	8.1	12.0	5.0	5.4	<4.0	<1.5	<0.76	<0.35	2.66
Significance	NS	NS	NS	*	NS	NS	NS	*	*	NS	*	NS	—	—	—	—	**
BLSD (5%)	—	—	—	87	—	—	—	6	0.8	—	0.9	—	—	—	—	—	0.41
Contrasts																	
Linear	NS	NS	NS	**	NS	NS	NS	**	NS	NS	**	NS	—	—	—	—	**
Quadratic	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 potato vine samples, August 19, 1992 - Dakota county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	2.44	0.17	3.06	1.94	1.36	1060	620	105	237	21	7.2	25	5.2	4.2	3.0	0.72	0.9
0.5x	2.98	0.17	2.83	2.00	1.48	804	474	139	273	21	8.5	24	4.8	4.0	2.8	0.86	2.6
1.0x	2.74	0.17	2.40	2.16	1.58	1077	620	156	207	19	11.5	26	5.1	4.3	3.3	0.79	5.1
2.0x	3.09	0.18	2.98	2.12	1.41	1107	638	137	250	18	12.3	24	5.1	4.0	3.1	0.80	5.9
Significance	NS	NS	NS	*	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	**
BLSD (5%)	--	--	--	0.17	--	--	--	33	--	--	--	--	--	--	--	--	1.6
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 = nonsignificant, * = significant at 5%, ** = significant at 1%.

Table 24. Effect of NutraLime on the elemental composition of soybean whole plant (above ground) samples, July 9, 1992 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	3.35	0.25	0.28	12677	3367	456	385	60.1	85.1	35	9.2	29.5	5.5	3.2	1.9	0.35	1.0
0.5x	3.03	0.30	0.27	13570	3891	667	632	78.8	121.5	26	11.3	28.3	4.4	2.5	2.2	0.27	7.9
1.0x	3.51	0.31	0.28	13898	4258	516	460	68.9	84.0	24	11.3	27.4	4.2	2.5	2.0	0.28	9.4
2.0x	3.34	0.32	0.29	14323	4168	487	396	63.1	78.7	27	11.9	28.8	5.2	2.5	1.9	0.34	7.8
Significance	NS	**	NS	*	*	NS	NS	NS	NS	**	NS	*	NS	NS	NS	NS	*
BLSD (5%)	--	0.01	--	1062	578	--	--	--	--	5	--	1.3	--	--	--	--	5.3
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 25. Effect of NutraLime on the elemental composition of recently matured soybean trifoliate leaf samples, July 19, 1992 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	4.89	0.43	2.85	8735	3434	105.8	114	58.3	61.2	35	9.5	34.8	4.4	6.5	1.5	0.33	0.9
0.5x	4.79	0.52	2.98	9600	3739	85.9	113	37.2	49.0	32	10.1	34.3	2.9	4.7	1.2	0.24	10.8
1.0x	4.86	0.50	2.85	8958	3733	81.9	107	55.6	46.9	30	10.3	33.8	5.1	5.5	1.6	0.37	12.2
2.0x	4.90	0.50	2.92	9041	3689	86.7	106	68.1	45.4	31	10.5	33.8	5.7	5.5	1.7	0.38	12.1
Significance	NS	**	NS	NS	*	NS	NS	NS	*	NS	*	NS	NS	**	*	NS	*
BLSD (5%)	—	0.04	—	—	232	—	—	—	9.3	—	0.7	—	—	0.7	0.3	—	6.5
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 = nonsignificant, * = significant at 5%, ** = significant at 1%.

Table 26. Effect of NutraLime on the elemental composition of soybean grain samples, October 6, 1992 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	6.23	0.59	1.85	1663	2283	36	78	17	28	38	13	19	4.7	8.2	1.2	0.33	8.4
0.5x	6.46	0.64	1.86	1788	2518	38	91	15	28	38	15	16	5.0	5.0	1.3	0.36	22.3
1.0x	6.61	0.66	1.87	1680	2435	44	88	15	28	40	15	18	5.5	5.6	1.4	0.39	23.4
2.0x	6.48	0.66	1.87	1612	2520	31	82	14	27	39	15	19	5.2	5.6	1.3	0.38	35.4
Significance	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
BLSD (5%)	—	0.04	—	—	—	—	—	—	—	—	—	—	—	—	—	—	19.0
Contrasts																	
Linear	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 = nonsignificant, * = significant at 5%, ** = significant at 1%.

Table 27. Effect of NutraLime on the elemental composition of soybean whole plant (above ground) samples, July 9, 1992 - Washington county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	——— % ———			——— ppm ———													
0	3.81	0.34	3.00	15161	4916	352	297	31	82	37	9.2	39	4.0	4.3	1.6	0.47	0.5
0.5x	3.87	0.36	3.00	15590	5263	296	256	27	63	31	10.0	37	3.7	3.3	1.5	0.44	9.4
1.0x	3.88	0.38	3.08	15581	5291	316	269	28	69	30	10.7	38	4.1	4.0	1.6	0.49	12.2
2.0x	3.74	0.36	2.98	15012	5443	314	267	31	60	26	10.2	37	4.1	3.0	1.7	0.44	22.3
Significance	NS	**	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
BLSD (5%)	—	0.02	—	—	285	—	—	—	—	—	—	—	—	—	—	—	3.7
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	NS

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

Table 28. Effect of NutraLime on the elemental composition of recently matured soybean trifoliate leaf samples, July 9, 1992 - Washington county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	——— % ———			——— ppm ———													
0	5.46	0.63	2.98	9467	4264	71	109	20	74	45	9.0	37	<2.3	11.3	1.1	0.29	<0.3
0.5x	5.74	0.66	3.00	8980	4151	67	104	27	59	42	9.8	36	3.2	9.5	1.3	0.35	11.3
1.0x	5.78	0.68	3.09	8981	4203	64	100	33	62	43	10.4	36	3.9	10.7	1.4	0.45	15.0
2.0x	5.68	0.68	3.08	8975	4318	74	112	25	56	40	9.6	37	2.5	8.5	1.2	0.33	22.1
Significance	**	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	—	NS	NS	NS	**
BLSD (5%)	0.14	0.04	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4.1
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	*

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

Table 29. Effect of NutraLime on the elemental composition of soybean grain samples, October 9, 1992 - Washington county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%			ppm													
0	6.32	0.73	2.17	1373	2221	44	90	12.4	29	45	13.4	38	3.2	12.1	1.00	0.26	1.0
0.5x	6.64	0.73	2.11	1312	2176	51	96	10.9	27	42	12.4	35	<3.0	9.2	0.97	<0.22	19.9
1.0x	6.77	0.75	2.18	1273	2221	31	85	7.9	27	41	12.6	36	<1.9	10.5	0.72	<0.17	28.5
2.0x	6.65	0.76	2.20	1267	2249	40	90	11.0	26	38	12.8	35	<3.0	7.9	1.05	0.25	38.5
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	**	--	NS	NS	--	**
BLSD (5%)	--	--	--	--	--	--	--	--	--	2	--	2	--	--	--	--	3.4
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%.

RATE AND TIME OF NITROGEN APPLICATION FOR CORN PRODUCTION IN A RIDGE-TILL PLANTING SYSTEM

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

ABSTRACT: Growers who use ridge-till planting systems have questioned the nitrogen recommendations for corn production as well as the effect of frequency of application on corn yield. Therefore, this study was conducted at 3 locations to evaluate the impact of rate and frequency of application of fertilizer N on yield of corn grown with ridge-till planting systems. The rates of applied N were 0, 60, 120, and 180 lb./acre. Single and multiple applications were used. The optimum N rate was approximately 120 lb./acre at all sites. Although results were not completely consistent, split applications were beneficial in 1992. This is especially true for the low rates of applied N.

Some aspects of nitrogen (N) management for corn production in ridge-till planting systems have been studied extensively for several years. The question of frequency of application of fertilizer N has not received detailed attention. With ridge-till planting systems, there is the option of applying nitrogen fertilizers with the cultivator. The nitrogen can be applied once or as much as three times during the growing season.

Objective:

This study was conducted to evaluate the effect of frequency of nitrogen applications as well as rate applied on the yield of corn grown with ridge-till planting systems.

Experimental Procedure:

This study was conducted in fields of cooperating farmers who used ridge-till planting systems. The corn/soybean rotation was used at all sites and corn followed soybeans in 1992.

Soil samples were collected in late April prior to planting. Samples were collected from three locations (directly under the existing soybean row, the center of 2 rows, combination of row and center of 2 rows). Soil was collected from depths of 0-6, 6-12, and 12-24 inches. Samples were analyzed for NO_3-N and the amount of NO_3-N was reported in terms of lb./acre. The results are summarized in Table 1.

The treatments used are listed in Table 2. The preemergence application (PE) was applied immediately after planting. The N was applied as 46-0-0 over the row and was lightly incorporated. When applied at cultivation, the 46-0-0 was broadcast just prior to cultivation and this was adequate for incorporation.

Corn was planted in late April or early May by the cooperating farmers. Management practices that were conducive to high yields were used at all sites.

Ear leaf samples were collected at silking, dried, ground, and analyzed for N to monitor N uptake. Grain yields were measured in early October and corrected to a basis of 15.5% moisture.

Results and Discussion:

The measurement of residual NO_3-N was affected by the sampling scheme that was used (Table 1). Highest NO_3-N values were recorded when 100% of the sample was collected from the center of 2 rows. The lowest values were measured when 100% of the sample was collected from directly beneath the row from the previous soybean crop. Intermediate NO_3-N values resulted from the mixture of the 2 locations. The soybean crop is noted for extracting NO_3-N from the root zone. Considering the tap root configuration of the soybean root system, these results might be anticipated.

Grain yields are summarized in Table 2. When rate is considered, the application of 120 lb. N/acre appeared to be adequate for optimum yield at all locations. The response to applied N was curvilinear at all sites.

The split application increased yield at the two sites in Renville County. For the Kandiyohi County site, the split application was beneficial only when the rate of applied N was 60 lb./acre. In general, split applications of fertilizer N have not been beneficial when corn is grown with conventional tillage systems on fine textured soils. Perhaps, differences in root development in the two planting systems can be used to explain the differences in response to split applications.

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

Table 1. Effect of location of sample on the measurement of NO_3-N in 1992.

Site	Sample Location	Sample Depth (in.) 0-6	6-12	12-24	Total
		lb. NO_3-N/acre			
Kandiyohi	row	18.4	12.1	17.0	47.5
	center of 2 rows	22.0	20.1	24.8	66.9
	row + center	19.9	17.6	25.3	62.8
Renville (Gi)	row	17.1	12.4	18.2	47.7
	center of 2 rows	36.3	34.3	39.4	110.0
	row + center	28.0	26.3	30.1	84.4
Renville (Gu)	row	19.8	19.0	28.9	67.7
	center of 2 rows	22.0	20.5	33.0	75.5
	row + center	24.0	21.4	40.2	85.6

Table 2. The effect of rate and frequency of N application on corn yield in a ridge-till planting system.

PE	N Applied 1st cult	2nd cult	Site Kandiyohi	Renville (Gi)	Renville (Gu)
lb./acre			bu./acre		
-	-	-	117.7	121.5	139.9
-	60	-	139.2	137.8	145.9
-	120	-	157.7	151.2	153.6
-	180	-	163.6	153.6	164.2
30	30	-	154.0	146.6	156.7
30	90	-	160.4	148.2	163.6
30	150	-	163.1	167.3	176.7
30	75	75	158.4	154.8	159.6
30	45	45	156.1	163.6	151.1

The concentration of N in the ear leaf tissue at silking responded curvilinearly to rate of applied N (Table 3). The frequency of N application influenced concentration significantly at the Renville (Gi) site only. There was a reduction in N concentration when split applications are compared to the single application. This is not consistent with the observations with grain yield. Since this observation was not consistent for all sites, a large amount of importance cannot be attached to the results from one site.

Table 3. The effect of rate and frequency of N application on the N concentration of the ear leaf at silking.

N Applied			Site		
PE	1st cult	2nd cult	Kandiyohi	Renville (Gi)	Renville (Gu)
- - - - - lb./acre - - - - - -			- - - - - - - - - - % N - - - - - - - - - - -		
-	-	-	1.72	2.33	2.08
-	60	-	2.51	2.96	2.72
-	120	-	2.79	3.19	2.96
-	180	-	2.96	3.13	2.88
30	30	-	2.62	2.81	2.67
30	90	-	2.73	3.09	2.76
30	150	-	2.85	3.10	2.88
30	75	75	2.95	3.07	2.91
30	45	45	2.68	3.05	2.96

RESPONSE OF CORN PLANTED IN RIDGE-TILL PLANTING SYSTEMS TO THE BANDED APPLICATION OF POTASH

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

ABSTRACT: The importance of banded potash for optimum corn production in ridge-till planting systems was demonstrated in 1989. This study was conducted to define the rate of K_2O needed in the banded application. The rates of 0, 20, 40, 60 and 80 lb. K_2O were compared. The banded potash increased grain yield at 1 of 3 sites. Because of weather in the fall of 1991, K_2O was applied in the spring of 1992 at the sites where no response was measured. Application depth was not as deep as desired with the spring application and K_2O could have easily been thrown away from the ridge in the planting operation. This study will be continued in 1993.

The need for additions of potash to fertilizer programs for corn planted in ridge-till and no-till planting systems was established in 1989. There are, however, many questions that must be answered before this management practice can be used most effectively. The rate of potash needed to correct the problem is one major concern.

Objective:

This study was conducted to evaluate the effect of rate of K_2O application on the yield of corn planted in a ridge-till planting system.

Experimental Procedure:

This study was conducted at 3 sites in 1992. These sites were in fields of cooperating farmers. Because of the late fall snow storm in 1991, treatments were applied in the spring of 1992.

The soil at the Meeker (N) site was a sandy loam and 0-0-60 was used to supply 0, 20, 40, 60 and 80 lb. K_2O/acre in a band at 3.5 to 4.0 inches below the existing row. The previous crop was edible beans and the existing ridge was very small. The soil at the Meeker (J) and Kandiyohi sites was classified as a silty clay loam. To avoid major disturbance of the ridge, a spoke injector was used to supply the K_2O at these two sites. The potash was applied in late April and early May. The K_2O source was 0-0-30.

Corn was planted by the cooperating farmer. Recommended cultural practices such as plant population, herbicide selection, etc., were used at each site. Whole plant samples were collected from each plot at approximately 4 weeks after emergence. A second whole plant sample was taken at 6 weeks after emergence. These samples were dried, weighed, ground, and analyzed for K. Grain yields were measured and corrected to 14.5% moisture.

Results and Discussion:

The results from each site are summarized in Tables 1, 2, and 3. The response to applied potash was not consistent for all sites. The banded K increased early growth for both samplings and grain yield at the Meeker (N) site. The response was curvilinear in all cases. The rate of 20 lb. K_2O per acre was adequate to provide for optimum early growth and yield (Table 1).

The banded K_2O did not increase early growth and grain yield at the Meeker (J) and Kandiyohi sites (Tables 2, 3). These results are not consistent with the results of previous studies where fertilizer K_2O in a band increased corn yield even though the soil test for K was in the high or very high range. It is possible that the K_2O applied with the spoke injector at the non-responsive sites was moved away from the row by the planter sweep in the planting operation. The amount of K_2O remaining after planting may have been adequate to increase the K concentration in the young, whole plant tissue. The amount remaining in the band after planting may not have been adequate for increased yield.

The K concentration in the young plants at both sampling times increased with rate of applied K_2O. The increase was linear at all sites. These results indicate that some of the applied K was left in the band after planting. There was, however, no way to determine the amount of applied K_2)O remaining in the band.

Potassium uptake was computed from the dry weight and K concentration data. Therefore, the effect of banded rate of K_2O on K uptake would be expected to parallel the effects on K concentration in the young plants. This was true except for the Meeker (J) site.

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

Table 1. The effect of rate of banded K_2O on early growth and yield of corn at the Meeker (N) site.

K_2O Applied	1st Sample Plant Wt.	1st Sample K Conc.	1st Sample K Uptake	2nd Sample Plant Wt.	2nd Sample K Conc.	2nd Sample K Uptake	Grain Moisture	Yield
lb./acre	gm/6 plants	%	mg/plant	gm/4 plants	%	mg/plant	%	lb./acre
0	12.8	2.14	45.7	46.1	2.12	249.5	31.6	142.5
20	17.0	2.96	84.8	61.8	2.53	393.6	28.5	152.4
40	18.2	3.68	111.2	59.2	2.81	411.6	31.6	158.9
60	16.4	4.06	110.7	60.0	3.57	534.1	30.8	152.5
80	15.3	4.10	104.6	52.5	3.43	444.3	32.6	154.1

Soil Test K = 109 ppm

Table 2. The effect of rate of banded K_2O on early growth and yield of corn at the Meeker (J) site.

K_2O Applied	1st Sample Plant Wt.	1st Sample K Conc.	1st Sample K Uptake	2nd Sample Plant Wt.	2nd Sample K Conc.	2nd Sample K Uptake	Grain Moisture	Yield
lb./acre	gm/6 plants	%	mg/plant	gm/4 plants	%	mg/plant	%	lb./acre
0	9.7	2.41	38.9	35.0	2.58	225.4	22.0	170.4
20	9.5	2.43	39.0	34.0	2.64	223.8	21.7	162.7
40	9.0	2.72	40.8	34.7	2.95	259.1	22.2	167.4
80	8.2	2.66	36.4	30.5	2.96	223.3	21.1	168.8

Soil Test K = 167 ppm

Table 3. The effect of rate of banded K_2O on early growth and yield of corn at the Kandiyohi site.

K_2O Applied	1st Sample Plant Wt.	1st Sample K Conc.	1st Sample K Uptake	2nd Sample Plant Wt.	2nd Sample K Conc.	2nd Sample K Uptake	Grain Moisture	Yield
lb./acre	gm/6 plants	%	mg/plant	gm/4 plants	%	mg/plant	%	lb./acre
0	16.2	1.61	43.6	26.1	1.49	97.9	29.5	125.5
20	16.7	1.88	51.9	27.4	1.61	112.2	30.0	126.4
40	19.8	2.20	72.7	32.2	2.00	162.6	28.7	128.5
60	16.9	2.21	63.6	27.9	2.13	150.3	29.7	120.8
80	18.6	2.13	65.9	31.7	2.01	160.0	28.0	134.0

Soil Test K = 147 ppm

SOIL SAMPLING SCHEMES FOR RIDGE-TILL PLANTING SYSTEMS

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

ABSTRACT: This study was conducted to evaluate several schemes that might be used for collection of soil samples in a ridge-till planting system. Thirteen schemes were identified and used in three fields. Sampling scheme appeared to have no effect on measured pH. In general, higher values of P and K were measured when a high percentage of the sample was collected from directly under the existing row. Collecting various percentages of the sample from more than one location with respect to the existing row produced values that represented average values for P and K. This study will be continued in 1993.

The procedures needed for collecting soil samples in conventional planting systems have been identified and described for some time. Specific procedures for sample collection must also be described for ridge-till planting systems. This is especially true when phosphate and potash fertilizers are applied in a band instead of broadcast and incorporated prior to planting.

Objective:

The objective of this study was to evaluate the effect of various schemes for collection of soil samples on soil test values for pH, phsophorus (P), and potassium (K).

Experimental Procedure:

This study utilized fields of cooperating farmers. Thirteen soil sampling schemes were identified. These schemes are described in Table 1. Samples were taken to a depth of 0-6 inches for each scheme. The sampling schemes were followed in 3 fields. These fields varied substantially with respect to fertility level, soil texture, and number of years devoted to ridge-till planting systems.

Following collection samples were dried, ground and analyzed for pH, P, (Bray and Kurtz #1), and K. The results are summarized in Table 1.

The Meeker (N) site was planted to edible beans in 1991. The other sites were in soybeans in 1991.

Table 1. The influence of soil sampling scheme on soil test values in a ridge-till planting system.

Location of Sample			Location and Test								
			Meeker Co. (N)			Meeker Co. (J)			Kandiyohi Co.		
row	row centers	shoulder	pH	P	K	pH	P	K	pH	P	K
- - - - - - % from - - - - - -			- - ppm - - -			- - ppm - - -			- - ppm - - -		
100	-	-	5.7	63	131	6.2	35	165	6.0	15	173
-	-	100	5.5	59	107	6.0	19	154	5.9	10	137
-	100	-	5.6	68	129	6.4	23	175	6.3	8	145
33	33	33	5.3	64	113	6.3	23	169	6.3	8	148
50	50	-	5.5	75	115	6.2	34	168	6.2	10	153
50	-	50	5.8	59	105	6.0	31	165	6.2	10	154
-	50	50	5.6	53	102	6.1	22	164	6.0	10	147
33	67	-	5.5	53	112	6.2	25	191	6.1	8	141
-	67	33	5.5	59	122	6.2	23	179	6.0	9	129
33	-	67	5.2	48	92	6.0	23	153	6.1	12	163
67	33	-	5.5	53	98	6.1	37	176	6.0	11	136
67	-	33	5.3	58	96	6.2	26	159	5.8	17	153
-	67	33	5.3	43	97	6.1	27	148	6.1	11	137

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

Results and Discussion:

Soil sampling scheme had no apparent effect on the measured pH values at each site. The variability in pH measurements is consistent with the variability in pH measurements in most field conditions.

There was a wide range in soil test values for P and K among the fields sampled. The soil at the Meeker (N) site was an irrigated sandy loam. The soil textures at the other sites would be classified as a silty clay loam.

In general, highest soil test values for P and K were recorded when a major portion of the soil sample was collected from directly under the existing row. Lower soil test values were recorded when the major portion of the sample was taken from the center of two rows (row center position). Intermediate values were recorded when equal portions of the sample were taken from two or more positions.

It's obvious that broad and sweeping recommendations cannot be made from the results of sampling 3 fields in 1 year. These results must be related to crop response to P and/or K before definite recommendations can be made.

EFFECTS OF TILLAGE AND LIQUID DAIRY MANURE ON NITROGEN AVAILABILITY TO CORN[1]

T. W. Schumacher, J. F. Moncrief, and B. J. Johnson[2]

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 1992. Results from 1992 showed reduced yields and higher moisture contents than the long term average at this site. Annually applied manure produced the greatest yields (108 bu/A) and anhydrous ammonia applied at 180 lb N/A produced 99 bu/A. Biennially applied manure produced 107 bu/A of grain in the year of application and 66 bu/A of grain in the year following application. Triennially applied manure produced 96 bu/A the year of application, 72 bu/A the year after application, and 50 bu/A two years after application. The amount of surface residue left by the various tillage and N treatments and the corn population was lower than in previous years.

The total amount of N applied to the manure plots was higher than in past years. Total N applied as anhydrous ammonia was similar to past years. Unusual weather conditions this year, a dry spring and cool summer, may have been responsible for the low yields, depressed corn population, and high percent moisture.

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 (Typic hapludalf, fine-silty, mixed, mesic) 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 around the same time as 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 5, 1992. 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 41.7% residue cover (Table 2). Residue cover was reduced to 22.3% between the row in the no till system with the injection of liquid dairy manure. Chisel plowing reduced residue cover to around 10% for all plots. The initial corn population count was abnormally low for all plots. This may have been due to the dry spring and the timing of the population count. At harvest, the plant population was up to normal levels.

[1] Support for this project in part was provided by a USDA-CSRS grant and the Soil Conservation Service. Their support is greatly appreciated.

[2] Research Assistant, Associate Professor, and Assistant Scientist respectively, at Soil Sci. Dept., University of Minnesota, St. Paul, MN 55108.

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 reduced about 16% compared to 1991. The trend of yields were as follows: annual manure>biennial manure in year of application>commercial fertilizer>biennial manure in the year following application; this relative ranking was similar to previous years. Grain moisture was about 88% higher in 1992 compared to 1991, most likely due to the cool summer delaying corn maturation. Grain percent N was generally around 1.55%, except for biennial manure the year after 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 reduced grain yields by 11%, held grain moisture to about the same level, and reduced grain percent N by 10% compared to annually applied manure. Grain moisture was about 85% higher in 1992 compared to 1991. Grain percent N lowered each year after manure application.

Table 1. 1992 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	Corn	Pioneer 3751

Manure Application and Analysis: Liquid dairy manure injected on May 12, 1992.

	1992 rate	
	Mean	Std. Dev.
Manure (gal/A)	9700	-----
Total N (lbs/A)	387	35
NH_4 N (lbs/A)	192	8
P_2O_5 (lbs/A)	65	3
K_2O (lbs/A)	225	24
Solids (%)	9.1	.2

Fertilizer:

Material	Tillage	N (lbs/A)	Date Applied	Application
82-0-0	Both	180	June 5,1992	Injected
5-14-42	Both	6	May 18, 1992	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 May 18, 1992. Corn was harvested on October 24, 1992.

Insect control: 5.2 lbs/A Thimet 20G applied May 18, 1992.

Weed Control: .75 lbs/A Prowl and 1.2 lbs/A Bladex 90 DF applied on May 24, 1992.
All plots cultivated on June 10, 1992.

Table 2. Surface residue cover and population as affected by tillage, N source, and row position at the Flueger farm in Goodhue Co., MN.

N source AND FREQUENCY	Row POSITION	RESIDUE (%) NO TILL	CHISEL	6/5/92 Pop. (plants/A)[1] NO TILL	CHISEL	10/24/92 Pop. (plants/A) NO TILL	CHISEL
Annual Manure	In	18.7	9.7	17000	18100	24200	25900
	Between	22.2	7.7				
Anhydrous Ammonia	In	29.3	8.7	17600	18300	27600	24900
	Between	33.5	11.3				
Biennial Manure (yr. of application)	In	19.7	9.0	17700	19500	23700	28000
	Between	22.3	10.3				
Biennial Manure (yr after application)	In	36.7	9.7	16200	16300	22700	29400
	Between	41.7	11.0				

[1] Plant population count apparently taken prior to complete germination.

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	.000	.061	.276	.948	.880
Population	.231	.305	1.00	----	----	----	----
Harvest pop.	.021	.752	.011	----	----	----	----

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	94	86	**90**	36.1	36.6	**36.3**	1.45	1.47	**1.46**	64.9	59.9	**62.4**
Manure	200	125	125	**125**	37.1	37.0	**37.1**	1.58	1.52	**1.55**	92.2	91.0	**91.6**
	Mean	**110**	**106**	**108**	**36.6**	**36.8**	**36.7**	**1.49**	**1.50**	**1.50**	**78.6**	**75.5**	**77.0**
Biennial	0	120	99	**110**	37.5	38.5	**38.0**	1.54	1.53	**1.54**	86.0	71.7	**78.9**
Manure	200	91	114	**103**	35.6	39.0	**37.3**	1.62	1.38	**1.50**	68.0	72.0	**70.0**
(yr of)	**Mean**	**106**	**107**	**107**	**36.6**	**38.8**	**37.7**	**1.58**	**1.46**	**1.52**	**77.0**	**71.9**	**74.5**
Biennial	0	44	89	**67**	46.7	36.9	**41.8**	1.30	1.22	**1.26**	27.9	53.2	**40.6**
Manure	200	64	67	**66**	39.8	45.7	**42.8**	1.14	1.02	**1.08**	34.3	32.5	**33.2**
(yr after)	**Mean**	**54**	**78**	**66**	**43.3**	**41.3**	**42.3**	**1.22**	**1.12**	**1.17**	**31.1**	**42.9**	**36.9**
Anhydrous	0	83	115	**99**	40.6	37.1	**38.9**	1.54	1.57	**1.56**	60.7	85.4	**73.1**
Ammonia	200	90	108	**99**	40.4	37.6	**39.0**	1.61	1.63	**1.62**	68.7	83.2	**76.0**
	400	83	117	**100**	40.8	37.6	**39.2**	1.64	1.60	**1.62**	64.4	87.2	**75.8**
	Mean	**85**	**113**	**99**	**40.6**	**37.4**	**39.0**	**1.60**	**1.60**	**1.60**	**64.6**	**85.3**	**75.0**
Overall Mean		**91**	**104**	**98**	**39.3**	**38.2**	**38.8**	**1.53**	**1.47**	**1.50**	**63.0**	**70.7**	**66.8**
Check (0 N)[1]		26.2	41.3	**33.8**	42.9	38.7	**40.8**	1.21	1.21	**1.21**	4.2	7.3	**5.8**

	Till(T)	N source(N)	T*N	K rate(K)	K*T	K*N	K*N*T
Grain Yield	.084	.001	.259	.475	.913	.173	.206
Grain Moisture	.052	.000	.009	.433	.028	.351	.011
Grain N %	.011	.000	.081	.715	.096	.177	.518
N uptake	.238	.000	.109	.517	.866	.037	.337

[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** ---%---
First Year	0	93	36.3	1.44
	200	98	38.1	1.35
	Mean	**96**	**37.2**	**1.40**
Second Year	0	76	37.7	1.28
	200	68	38.0	1.15
	Mean	**72**	**37.9**	**1.22**
Third Year	0	50	36.0	1.08
	200	50	37.2	1.09
	Mean	**50**	**36.6**	**1.09**

THE EFFECTS OF TILLAGE AND TIME OF MANURE APPLICATION ON CORN RESPONSE AND LOSSES OF MANURE N AND P AT MEEKER COUNTY, MN[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, M.B. Kells, and B.J. Johnson[2]

Abstract

This is the third year of continuous corn treated with manure and tillage systems. Two manure sources (pig and dairy) applied in fall and spring were compared to spring applied anhydrous ammonia and control (non treated plots). Two tillage system studied were disc once and disc twice in spring. Residue cover were similar among tillages. Residue cover was higher by spring dairy application. Corn stands were similar among tillages. Corn stands at early growth were lower significantly with spring dairy compared to spring hog application. Corn growth stage were similar among tillage, time and manure source application. Grain yields were also similar by tillage. Fall application of manure resulted better yield compared to spring manure and anhydrous ammonia application. Grain moisture were similar among tillage. Fall dairy application resulted in the lowest grain moisture. Application of manure resulted in significantly higher Bray-P. Estimated soil loss were similar with discing once or twice. Estimated soil-P loss however slightly higher with discing once because of higher measured Bray-P on top 2-inch soil. Measured runoff indicates the importance of plant growth and residue cover on reducing runoff and the associated P loss. Distribution of soil-water nitrates over time was higher on plots treated with anhydrous ammonia.

Materials and Methods

In 1990 and 1991 tillage systems applied were fall chisel and fall moldboard followed with spring field cultivation. Different from the two previous years, in 1992 tillage systems applied were spring discing once or twice. The nutrient source treatments were dairy manure, pig manure, anhydrous ammonia and none as a control. The manure were applied in fall and spring and anhydrous ammonia was applied only in spring. The times of application were compared to evaluate corn response and loss of N and P.

Nitrogen (NH_4, NO_3) of soil water was monitored using suction samplers installed at selected treatments. The treatment selected were chisel and moldboard under spring dairy and anhydrous ammonia in 1991. In 1992, chisel was substituted with discing once and moldboard was substituted with discing twice under the same nutrient treatment as in 1991. This was done due to the excessive soil moisture.

Phosphorus loss from the land was measured and also estimated using USLE. Measured runoff and its associated P loss (total P, bioavailable P, and soluble P) was measured from erosion plots (76 feet by 10 feet) installed at selected treatments (fall dairy manure and none, as a control). The runoff was measured by collecting runoff in a 55 gallon barrel. The runoff samples was taken for sediment measurement and P determination. Total P was extracted by perchloric acid digestion. Bioavailable P was extracted by NaOH extraction and soluble P was obtained through filtration with 0.45 micron filter paper. P determination was conducted by spectrophotometer (at 882 nm) with blue Molybdate as a coloring agent.

Estimated soil loss was conducted from every treatment using data R (125), Area weighted K (0.23), LS factor 0.7 (l=200 ft, S=5%), and conservation practice factor (P=1). The K factor was weighted over the percentage of the area of the individual soil as described in Table 1. The C values for different treatment was evaluated based on residue cover and soil loss ratio during the year. The associated P loss with the sediments was estimated from the measured top 2 inch soil Bray-P concentration and an enrichment ratio of 3.4.

Residue cover was estimated by line transect method and characterized in and between the rows within each plots. Corn stands were estimated from the number of plants within the 10 feet row from each plot. Soil samples for Bray-P measurement was taken in the row and between the rows at three depths (0-2, 2-4, 4-6 inch). Grain yield and corn ears was harvest from rows 40 feet long.

The experiment was arranged in split plot with tillage as main plot and nutrient sources as subplot.

---

[1]Support for this project was provided by the Agricultural Utilization and Research Institute, the Minnesota Pollution Control Agency, the Soil Conservation Service, The Clear Water River Watershed District, and the Minnesota Extension Service. Their support is greatly appreciated.

[2]D. Ginting, J.F Moncrief, S.C. Gupta, B.J. Johnson are Graduate Student, Associate Professor, Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.B. Kells is the Tri-County Project Coordinator.

The design was extended to split-split-split plot to evaluate the row position and soil depth.

Results and Discussion

Residue Cover.Residue cover is similar among tillage treatments (Table 2a). Discing once or twice resulted in similar amount of residue cover. Residue cover was significantly different among manure treatments. Spring dairy application resulted in higher residue cover compared to other manure and time of application. Residue cover under pig manure and fall dairy plots was less than 30%. The least residue cover was on the control plot. In spite of the use of row cleaner attached to the planter, residue cover in row and between row were similar (Table 2b).

Corn Stand. Tillage did not significantly influence corn stands at early stages (Table 3). There was a tendency of difference of corn population under different nutrient source and time of application as presented in Fig.1. Spring dairy manure application resulted in lower corn stand compared to spring hog manure application which mainly due to the difference in residue cover. Corn stand was similar among fall manure and spring hog application.

Corn Growth Stage. Early corn growth was similar with nutrient source or tillage (Table 4). However, tillage and manure interaction showed that discing twice resulted in higher growth compared to discing once for all manure except spring dairy treatment (Fig. 2).

Corn Yield, Harvested ears and grain moisture. Discing once or twice resulted in similar yield. Grain yields are different by nutrient sources. Fall application of manure was better than spring application and the application of anhydrous ammonia. The lowest yield was from the control plots (not treated plots). There was an interaction between tillage and nutrient sources, especially with spring dairy manure application. All other nutrient sources application indicates an increase in yield if discing once compared to discing twice. With spring dairy application, discing twice showed a higher yield than discing once. The trend of grain yield as influenced by nutrient sources are according to the harvested corn ears (Table 7) and consequently also according to the corn population at harvest. Yield was not influenced by corn stand at early growth. Fall application of dairy and pig manure was better than the rest of time of application and nutrient source treatments. The ear number from control plots was the lowest. Grain moisture was similar among tillage treatments. Fall dairy application resulted in lower grain moisture compared to other time and manure application treatments (Table 6).

Soil Bray-P Means of soil Bray-P are different among treatments (Table 8). Manure application resulted in higher Bray-P compared to those from plots treated with anhydrous ammonia and control plots. Top 2 inches of soil treated with spring dairy manure contained the highest Bray-P. Bray P was higher in the row than between the row (Fig 3A). Bray-P was similar by tillage (Table 9). There was an interaction among tillage systems, manure source application and soil depth. Discing once with all manure application treatments except spring dairy treatment resulted in higher soil Bray-P at the top 2 inch soil (Fig. 3B).

Estimated soil and soil-P loss. Discing once or twice resulted in similar estimated soil loss (Table 10). This is mainly due to the amount of residue. The amount of the residue (which influenced C factor), were practically the same. The estimated P loss was a slightly higher with discing once because of a higher Bray-P on top 2-inch soil. Higher estimated sediment loss from control plots and spring hog plots are mainly due to less residue cover. Estimated annual sediment loss from all treatments were higher than 5 t/a. Estimated annual soil P-loss from all treatments were less than 2.5 lb/a.

Measured Runoff and associated P loss. Measured runoff volume from plot disced twice under fall dairy manure compared to control plots was significantly lower (Table 11). This was mainly due to the less residue cover and canopy cover of a poor growth of corn under the control plots. This resulted in a higher amount of sediment produced from control plot. This phenomenon is also followed by total P, bioavailable P and soluble P. Total P eroded from control plots were 103 gram per hectare during the month of July and August, 1992. The distribution of cumulative runoff, sediment and Phosphorus over time under daily precipitation are in Fig. 4 and Fig 5.

Soil-Water Nitrogen. Soil water samples collected were mainly in 1991. In 1992, There were no water samples in the sampler. Soil water nitrogen were mainly in NO_3 form. NH_4 form was mainly negligible (Fig. 7). Distribution of nitrogen with time under daily and cumulative daily precipitation was presented in Fig. 6 . From Fig. 6 it is shown that early at the growing season nitrate concentrations was clustered and with time the concentration diverged among the treatments, where the treatment with anhydrous ammonia indicated higher nitrate concentration. The concentrations were less than 20 ppm.

Table 1. Cultural practices at Meeker County, MN. 1992.

Tillage

1990-Fall chisel plowed, spring field cultivated
-Fall moldboard plowed, spring field cultivated

1991-Fall chisel plowed, spring field cultivated
-Fall moldboard plowed, spring field cultivated

1992-Spring discing twice.
-Spring discing once.

Crop

1990 Corn-Pioneer 375
1991 Corn-Northrop King N 3264
1992 Corn-Pioneer 3751

Planting and Harvest Dates

Plots were planted with a four row John Deere Maximerge planter equipped with spring tine row cleaners at a 38 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 8,1992	30,000 seeds/A	Oct. 14, 1992

1990 Fertilizer and Manure Analysis

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	----	lb/A	----	Date Applied
Corn	9-23-30[1]	150 lb/A	14	35	45	May 8, 1990
	82-0-0[2]	85 lb/A	70	0	0	April 24, 1990

1. Planter placement 2" beside and 2" below row.
2. Anhydrous ammonia was applied on selected plots.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Fall-1989.

Manure Type and Rate of Application		Nitrogen				Phosphorus	Potassium
		Mineral	Organic	Total	Available	P_2O_5	K_2O
Source	Rate	-------	lb/A	--------	- lb/A -	lb/A	lb/A
Dairy	13.2 t/A	62	97	159	86	107	134
Pig	4,100 g/A	120	75	195	146	212	100

1. All mineral N and 25% of organic N are available.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Spring-1990 (4/5/90 for liquid and 5/18/90 for dairy).

Manure Type and Rate of Application		Nitrogen				Phosphorus	Potassium
		Mineral	Organic	Total	Available	P_2O_5	K_2O
Source	Rate	-------	lb/A	--------	- lb/A --	lb/A	lb/A
Dairy	11.6 t/A	149	61	210	164	89	217
Pig	4,100 g/A	93	43	136	108	127	82

1. All mineral N and 25% of organic N are available.

1991 Fertilizer and Manure Analysis

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	----	lb/A	----	Date Applied
Corn	8-23-30[1]	150 lb/A	12	35	45	May 20, 1991
	82-0-0[2]	100 lb/A	82	0	0	May 13, 1991

1. Planter placement 2" beside and 2" below row.
2. Anhydrous ammonia was applied on selected plots.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Fall-1990 and Spring-1991.

Manure Type and Rate of Application		Nitrogen				Phosphorus	Potassium	Date
		mineral	Organic	Total	Available	P_2O_5	K_2O	Applied
Source	Rate	------- lb/A	--------		- lb/A --	lb/A	lb/A	
Fall Pig	3250 g/A	65	60	125	80	65	75	11/9/90
Fall Dairy	13.9 t/A	4	155	159	43	12	11	11/9/90
Spring Pig	3700 g/A	74	68	142	91	75	85	5/10/91
Spring Dairy	13.9 t/A	6	134	140	40	41	25	5/15/91

1. All mineral N and 25% of organic N are available.

1992 Fertilizer and Manure Analysis

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			----	lb/A	----	
Corn	9-23-30[1]	120 lb/A	11	28	36	May 8, 1992
	82-0-0[2]	100 lb/A	82	0	0	May 2, 1992

1. Planter placement 2" beside and 2" below row.
2. Anhydrous ammonia was applied on selected plots.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Fall-1991 and Spring-1992.

Manure Type	Nitrogen NH4	NO3	mineral	Organic	Total	P	K	Solid total solid	volatile	fixed
	-----------	-----------	-----------	-----------	-----------	----------- %	-----------	-----------	-----------	-----------
Dairy	.214	.008	.222	.361	.583	.293	.299	18.15	78	23
Pig	.195	.002	.197	.135	.332	.147	.184	3.24	61	39

Manure Type and Rate of Application		Nitrogen				Phosphorus	Potassium	Date
		mineral	Organic	Total	Available	P_2O_5	K_2O	Applied
Source	Rate	-------------	-------------	-------------	lb/A	-------------	-------------	
Fall Pig	2554 g/A	42	29	71	79	72	48	11/26/91
Fall Dairy	26.5 t/A	118	191	309	243	356	192	11/25/91
Spring Pig	3550 g/A	59	40	99	103	100	107	4/29/92
Spring Dairy	24.1 t/A	107	174	281	218	323	174	4/28/92

1. All mineral N and 25% of organic N of the year of application and 50% of the previous year is assumed available

Soil

The soils present at this site are as follows: 60% is Koronis fine sandy loam (Mollic Haplaudalfs, fine-loamy, mixed, mesic) with good internal drainage; 20% Cordova loam (Typic Argiaquolls, fine-loamy, mixed, mesic) with poor internal drainage; and the remaining 20% is Marcellon loam (Aquic Argiudolls, fine-loamy, mixed, mesic) with somewhat poor internal drainage.

Weed Control: - Lasso 2 lb a.i./a + Bladex 1 lb a.i./a (5/16/92)

Table 2a. Residue cover as influenced by corn residue and manure source and time of application at Ecker farm, Meeker Co,MN (5/20/92).

Manure Time/Source	Tillage Disc 2X	Disc 1X	Means
	------------- %	------------------	
Fall Hog	30.5(21.1)	24.4(14.3)	**27.4(18.2)b**
Spring Hog	21.1(10.7)	24.4(17.3)	**22.8(14.3)bc**
Fall dairy	22.5(12.1)	30.4(16.9)	**26.4(15.1)b**
Spring dairy	41.0(27.4)	28.5(20.5)	**34.8(24.8)a**
A. Ammonia	27.1(12.9)	28.6(19.7)	**27.9(16.5)b**
None	16.1(9.2)	19.3(10.5)	**17.7(9.9)c**
Means	**25.6(16.3)a**	**26.0(16.2)a**	

Means are arithmetic means.
The P>F: tillage=0.879(n=192);manure=0.065(n=64); tillage*manure=0.160(n=32).

Table 2b. Residue cover (%) as influenced by corn residue and manure source and time of application and row position at Ecker farm, Meeker Co,MN (5/20/92).

Manure Time/Source	In row	between row	Weighted Means
	--------------- %	-----------------	
Fall Hog	29.4(22.0)	25.5(13.5)	**26.4(15.3)b**
Spring Hog	23.6(15.7)	21.9(13.1)	**22.2(13.6)bc**
Fall dairy	26.9(16.2)	26.0(14.2)	**26.2(14.6)b**
Spring dairy	37.1(27.0)	32.4(22.5)	**33.4(23.5)a**
A. Ammonia	27.1(17.6)	28.6(15.6)	**28.3(16.0)b**
None	17.5(9.9)	17.9(10.0)	**17.8(10.0)c**
Means	**26.9(19.5)a**	**25.4(15.8)a**	

Means were weighted over in row and between row area.
The P>F: manure=0.065(n=64);Row position=0.288 (n=192);manure*row position=0.801(n=32).

Table 3. Corn population as influenced by tillage and manure source and time of application at Ecker farm, Meeker County, MN (6/9/1992)

Manure Time/Source	Tillage Disc 2X	Disc 1X	Means
	----------- X 1000 plants/a	--------	
Fall Hog	27.3(8.1)	28.5(5.1)	**27.9(6.6)ab**
Spring Hog	30.3(4.6)	30.2(10.4)	**30.2(7.9)a**
Fall dairy	29.4(3.7)	28.2(4.5)	**28.8(4.1)ab**
Spring dairy	23.9(6.0)	30.1(5.5)	**27.0(6.5)b**
A. Ammonia	28.4(3.4)	30.6(7.9)	**29.5(6.1)ab**
None	31.7(5.8)	28.8(4.5)	**30.3(5.3)a**
Means	**28.5(5.9)a**	**29.4(6.6)a**	

The P>F: tillage=0.248(n=96);manure=0.304(n=32); tillage*manure=0.100(n=16).

Table 4. Corn stage as influenced by tillage and manure source and time of application at Ecker farm, Meeker Co, MN (6/9/92).

Manure Time/Source	Tillage Disc 2X	Disc 1X	Means
	----------- leaves/plant	---------	
Fall Hog	4.1(0.6)	3.9(0.5)	**4.0(0.6)a**
Spring Hog	4.1(0.5)	4.0(0.6)	**4.0(0.5)a**
Fall dairy	4.0(0.5)	3.8(0.6)	**3.9(0.6)a**
Spring dairy	3.5(0.5)	3.8(0.6)	**3.7(0.6)a**
A. Ammonia	3.9(0.6)	3.8(0.6)	**3.9(0.6)a**
None	4.0(0.5)	3.7(0.6)	**3.9(0.6)a**
Means	**3.9(0.5)a**	**3.8(0.6)a**	

The P>F: tillage=0.472(n=96);manure=0.233(n=32); tillage*manure=0.023(n=16).

Table 5. Corn grain yield as influenced tillage and manure source and time of application at Ecker farm, MN (10/14/92).

Manure Time/Source	Tillage Disc 2X	Disc 1X	means
	------------ bu/a	---------------	
Fall Hog	99.5(22.5)	101.5(12.6)	**100.4(17.9)ab**
spring Hog	64.1(16.4)	86.2(25.8)	**74.4(23.3)de**
Fall dairy	107.6(19.5)	114.2(18.0)	**111.1(18.2)a**
Spr. dairy	101.8(18.6)	82.7(25.6)	**90.9(24.1)bc**
A. Ammonia	70.1(8.6)	94.5(13.3)	**82.3(16.6)cd**
None	66.1(15.3)	63.2(8.6)	**64.7(12.3)e**
Means	**84.6(24.8)a**	**90.5(24.1)a**	

The P>F: tillage=0.426(n=38);manure=0.001 (n=10-13);tillage*manure=0.115(n=5-8).

Table 6. Corn grain moisture as influenced by tillage and manure source and time of application at Ecker farm, Meeker Co, MN (10/14/92).

Manure Time/source	Disc 2X	Disc 1X	Means
	------------- %	---------------	
Fall Hog	27.5(0.8)	30.5(2.7)	**28.9(2.4)a**
Spring Hog	32.0(8.4)	29.0(1.1)	**30.6(6.2)a**
Fall dairy	26.7(1.4)	24.8(10.2)	**25.7(7.4)b**
Spr. dairy	29.3(2.7)	31.2(6.1)	**30.4(4.9)a**
A. Ammonia	29.6(1.0)	30.9(2.5)	**30.3(2.0)a**
None	27.4(0.8)	28.7(1.7)	**28.0(1.4)ab**
Means	**28.7(4.1)a**	**29.1(5.6)a**	

The P>F: tillage=0.604(n=38);manure=0.078 (n=10-14); tillage*manure=0.192(n=5-8).

Table 7. Number of corn ears at harvest as influenced by tillage and manure source and time of application at Ecker farm, Meeker Co., MN (10/14/92).

Manure Time/Source	Tillage Disc 2X	Disc 1X	Means
	--------x 1000 /a---------		
Fall Hog	26.6(2.9)	26.5(1.3)	**26.5(2.2)ab**
Spring Hog	24.1(2.7)	23.7(2.9)	**23.9(2.7)c**
Fall dairy	27.5(1.5)	28.1(2.6)	**27.8(2.1)a**
Spring dairy	25.7(3.0)	23.4(3.2)	**24.4(3.2)c**
A. Ammonia	24.4(2.8)	25.7(2.3)	**25.1(2.3)bc**
None	25.1(2.5)	23.6(1.0)	**24.4(2.0)c**
Means	**25.6(2.7)a**	**25.1(2.8)a**	

The P>F: tillage=0.232(n=37-38);manure=0.003 (n=10-13),Tillage*manure=0.409(n=5-8).

Table 8. Spatial distribution of soil Bray-P as influenced by manure treatment at Ecker Farm, MN (8/ 19/92).

Manure source/ time	Depth inch	Row Position In row	Between Row	Means
		--------------	ppm	---------------
Fall Hog	0-2	51.9(23.3)	47.6(18.8)	**49.7(20.9)**
	2-4	48.0(26.0)	32.5(13.1)	**40.7(22.0)**
	4-6	34.9(11.9)	27.2(15.0)	**30.4(13.9)**
	means	**46.3(22.9)**	**36.2(17.8)**	**41.1(20.9)**
Spr. Hog	0-2	55.3(22.4)	41.3(19.8)	**47.6(21.8)**
	2-4	32.0(17.2)	33.4(14.6)	**32.8(15.4)**
	4-6	31.2(19.8)	32.2(10.6)	**27.4(16.0)**
	means	**41.4(22.8)**	**34.2(17.6)**	**37.6(20.4)**
Fall dairy	0-2	56.3(21.7)	49.9(18.8)	**53.2(20.3)**
	2-4	56.0(28.1)	28.2(14.8)	**47.3(24.0)**
	4-6	37.5(29.1)	31.7(14.4)	**34.6(22.8)**
	means	**50.7(27.0)**	**40.6(17.7)**	**45.7(23.4)**
Spr. dairy	0-2	76.6(26.2)	53.6(13.5)	**65.1(23.6)**
	2-4	44.6(11.2)	36.0(17.4)	**40.5(18.5)**
	4-6	26.5(11.2)	25.7(10.1)	**26.1(10.6)**
	means	**50.4(28.7)**	**39.7(18.1)**	**45.3(25.0)**
An. ammonia	0-2	40.7(19.3)	29.5(17.0)	**35.1(19.0)**
	2-4	32.1(14.6)	24.6(14.0)	**28.3(14.4)**
	4-6	30.3(16.6)	28.6(17.1)	**29.4(16.4)**
	means	**34.6(17.1)**	**27.7(16.1)**	**31.2(16.8)**
None	0-2	38.2(17.2)	29.2(10.5)	**34.2(15.1)**
	2-4	30.6(8.3)	22.9(10.4)	**26.6(10.1)**
	4-6	38.3(37.2)	23.0(11.9)	**30.7(28.1)**
	means	**35.8(23.4)**	**24.9(11.1)**	**30.5(19.2)**

The P>F:Manure=0.047(n=74-100); Row Position=0.001 (n=246-247); Depth=0.001(n=149-182); Manure*Row position=0.995(n=28-57); Manure*Depth=0.001(n=20-40); Row*Depth=0.281(n=75-91); Manure*Row*Depth=0.055(n=9-17).

Table 9. Distribution of soil Bray-P as influenced by tillage and manure treatment at Ecker Farm, MN (8/19/92).

Manure	Depth (inch) 0-2	2-4	4-6	means
	------------------	ppm	------------	
		Disc Once		
F Hog	56.4(17.6)	43.8(17.5)	35.4(15.9)	**46.4(18.7)**
S Hog	61.9(16.3)	37.9(15.3)	34.3(17.9)	**47.4(20.7)**
F Dairy	55.5(18.9)	45.3(17.1)	26.8(9.5)	**44.2(19.7)**
S Dairy	60.4(18.8)	46.3(18.0)	27.8(10.8)	**45.8(20.9)**
A Amm.	39.9(21.5)	30.7(15.2)	35.9(16.7)	**35.8(17.9)**
None	35.0(10.2)	31.5(10.4)	31.8(16.4)	**32.8(12.5)**
Means	**53.4(20.0)**	**40.9(16.9)**	**31.6(14.5)**	**42.7(19.5)**
		Disc Twice		
F Hog	43.3(22.2)	37.6(26.0)	26.8(11.6)	**36.3(21.8)**
S Hog	28.0(9.6)	26.5(13.8)	18.2(5.4)	**24.7(10.7)**
F Dairy	50.1(22.2)	49.9(31.0)	42.5(29.2)	**47.6(27.2)**
S Dairy	69.4(27.0)	34.1(17.3)	24.4(10.4)	**44.7(28.1)**
A. Amm.	29.3(14.5)	25.2(13.8)	19.9(10.9)	**24.9(13.2)**
None	33.6(18.9)	22.8(8.4)	29.5(37.1)	**28.4(23.6)**
Means	**45.6(25.6)**	**33.9(22.2)**	**27.9(22.1)**	**36.3(24.5)**

The P>F:tillage=0.297 (n=238-255); manure=0.047 (n=56-110);depth=0.001(n=149-182); tillage*depth=0.729(n=73-95); manure*depth=0.001(n=16-40); tillage*manure=0.306(n=24-55) tillage*manure*depth=0.007(17-20).

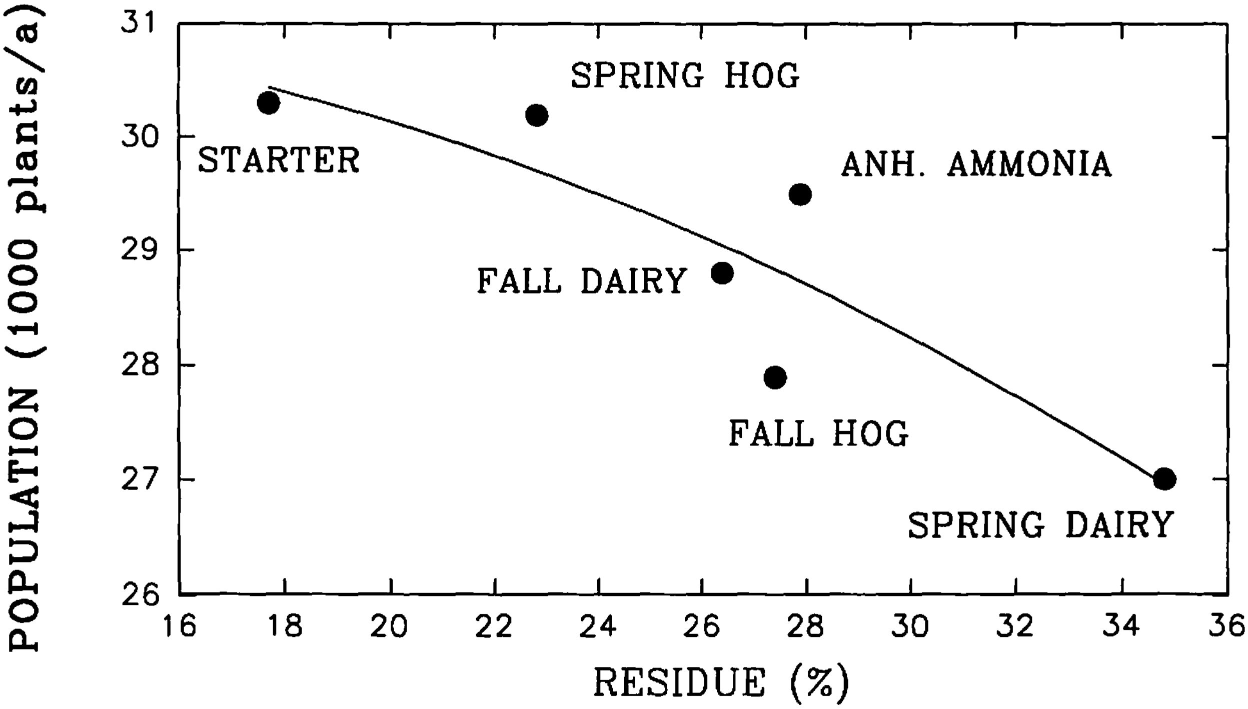
Table 10. Estimated soil and P loss (enrichment ratio 3.4) using USLE as influenced by residue from tillage and manure treatment at Ecker Farm, MN (8/19/92).

Manure	**Disc Once** sed t/a	Bray-P lb/a	**Disc Twice** Sed t/a	Bray-P lb/a	**Means** Sed t/a	Bray-P lb/a
F Hog	5.8	2.2	5.0	1.5	**5.4**	**1.9**
S Hog	5.8	2.4	6.1	1.2	**6.0**	**1.8**
F Dairy	5.1	1.9	5.9	2.0	**5.5**	**2.0**
S Dairy	5.3	2.2	4.3	2.0	**4.8**	**2.1**
A Amm.	5.3	1.4	5.5	1.1	**5.4**	**1.3**
None	6.3	1.5	6.8	1.5	**6.6**	**1.5**
Means	**5.6**	**1.9**	**5.6**	**1.6**		

Table 11. Measured total P, bioavailable P (Bio-P) ,soluble-P, runoff volume and sediment from a standard size plot disced twice under fall dairy manure and without treatment at Ecker Farm, MN (June/1992 - October/92).

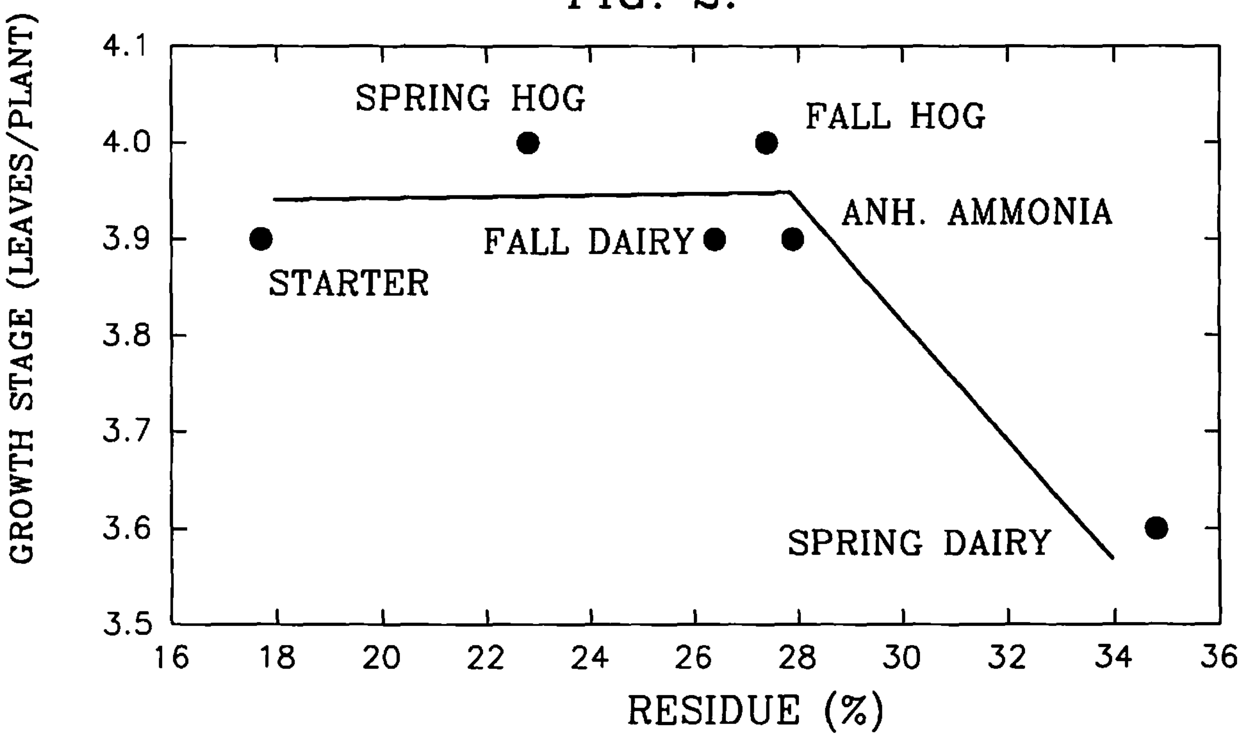
Manure	Total-P g/ha	Bio-P g/ha	Soluble.P g/ha	Runoff KL/ha	Sed kg/ha
F. dairy	**36.0**	**19.9**	**10.7**	**7.4**	**36.3**
None	**103.0**	**82.3**	**19.5**	**31.7**	**232.7**

FIG. 1



CORN POPULATION AS INFLUENCED BY RESIDUE COVER AT ECKER FARM, MEEKER COUNTY, MN (6/9/92)

FIG. 2.



CORN GROWTH AS INFLUENCED BY RESIDUE COVER AT ECKER FARM, MEEKER COUNTY, MN (6/9/92).

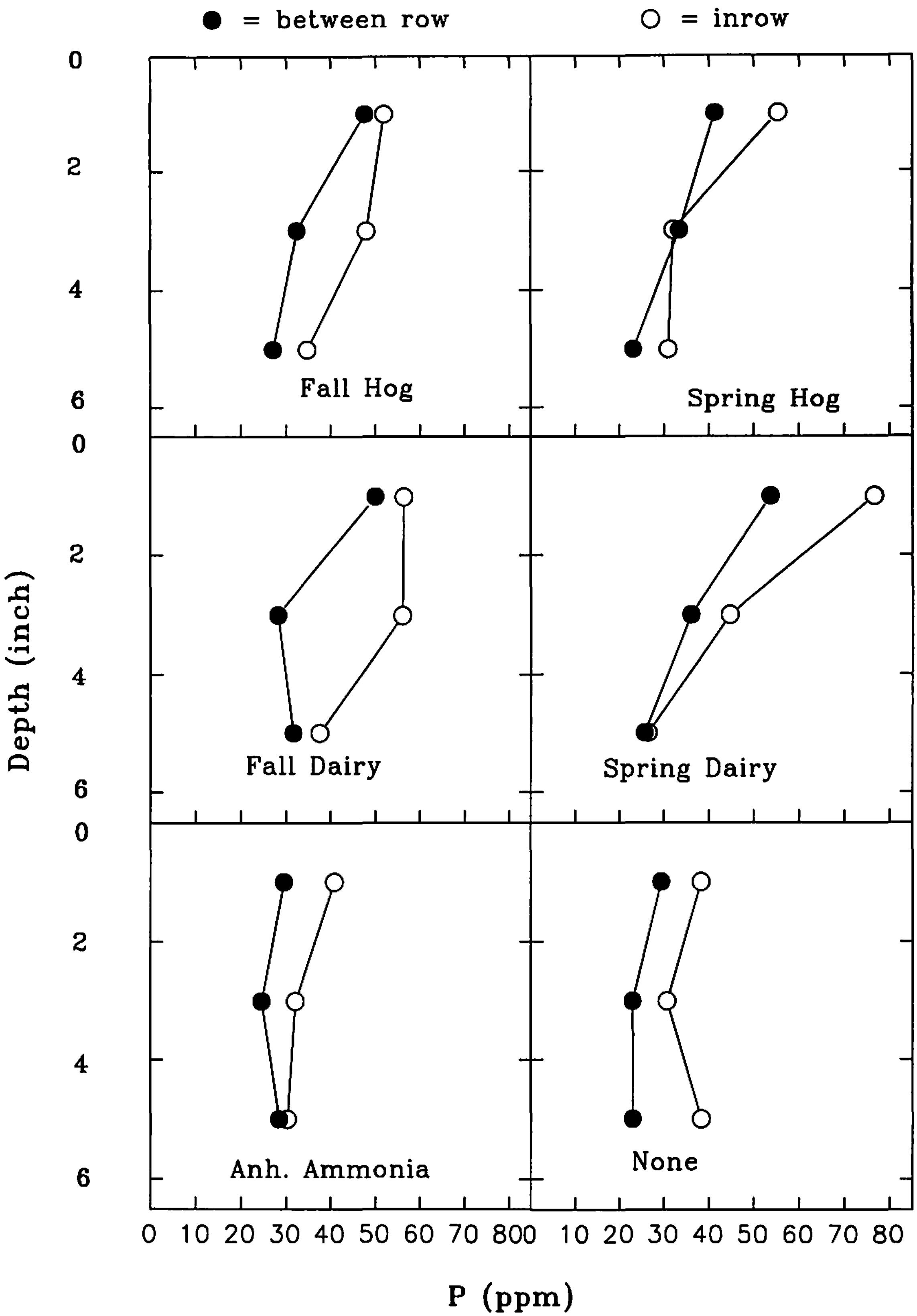


FIG. 3A. SOIL BRAY–P DISTRIBUTION WITH DEPTH UNDER VARIOUS MANURE SOURCE AND ROW POSITION AT ECKER FARM, MEEKER COUNTY, MN (8/19/92)

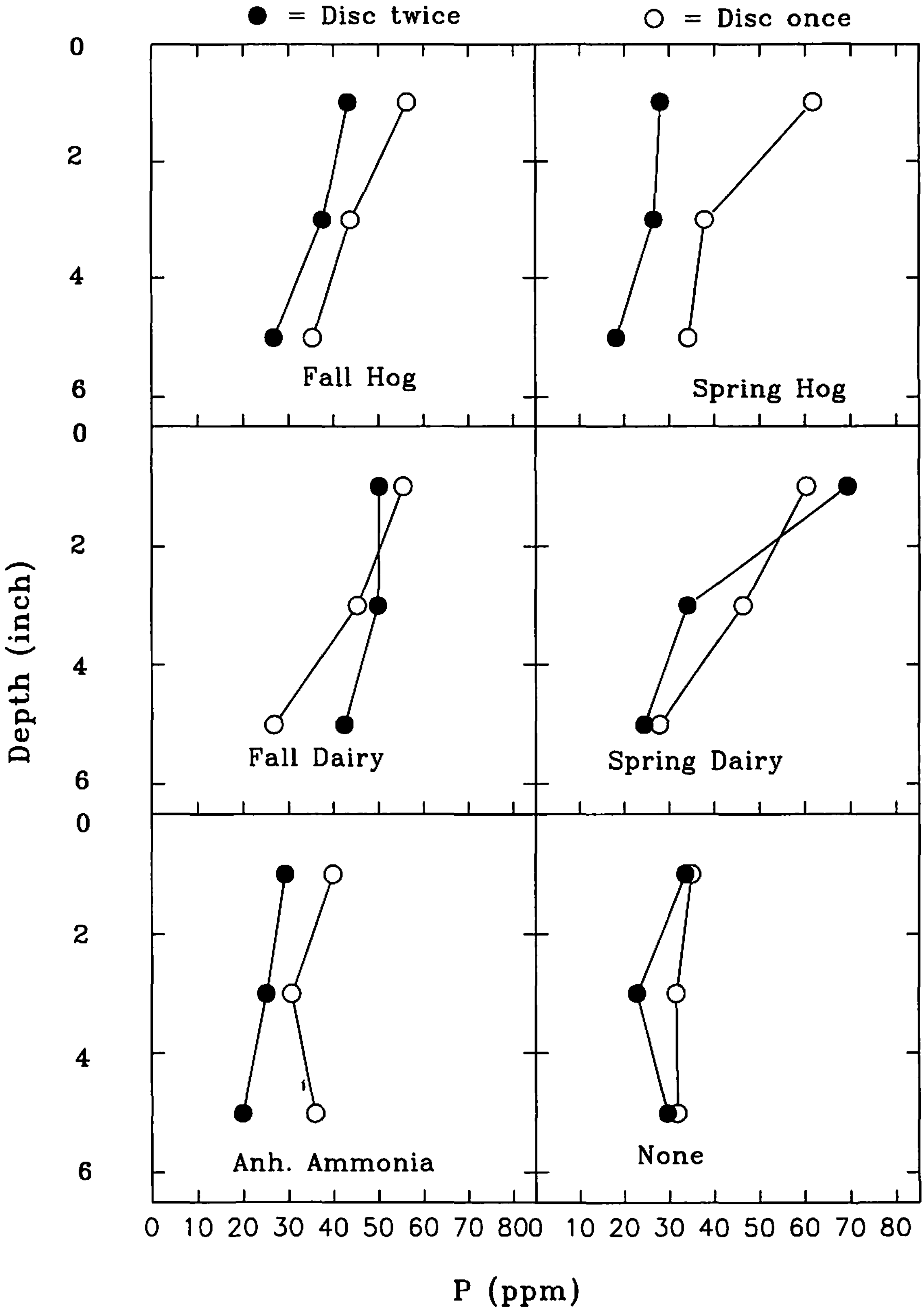


FIG. 3B. SOIL BRAY-P DISTRIBUTION WITH DEPTH UNDER VARIOUS MANURE SOURCE AND TILLAGE SYSTEMS AT ECKER FARM, MEEKER COUNTY, MN (8/19/92)

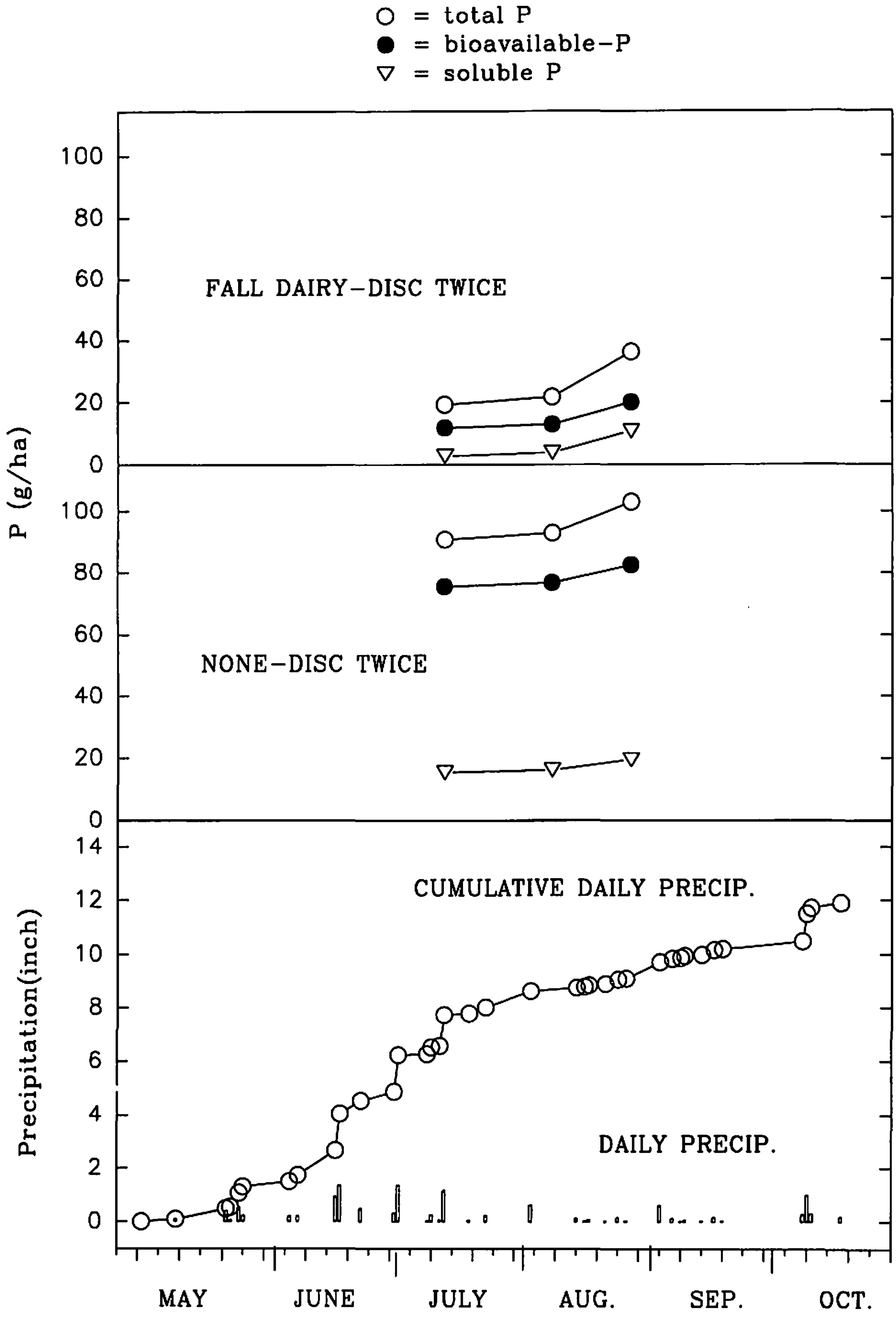


FIG. 4. CUMULATIVE PHOSPHORUS FROM RUNOFF PLOTS, AND PRECIPITATION AT ECKER FARM, MEEKER COUNTY, MN (1992).

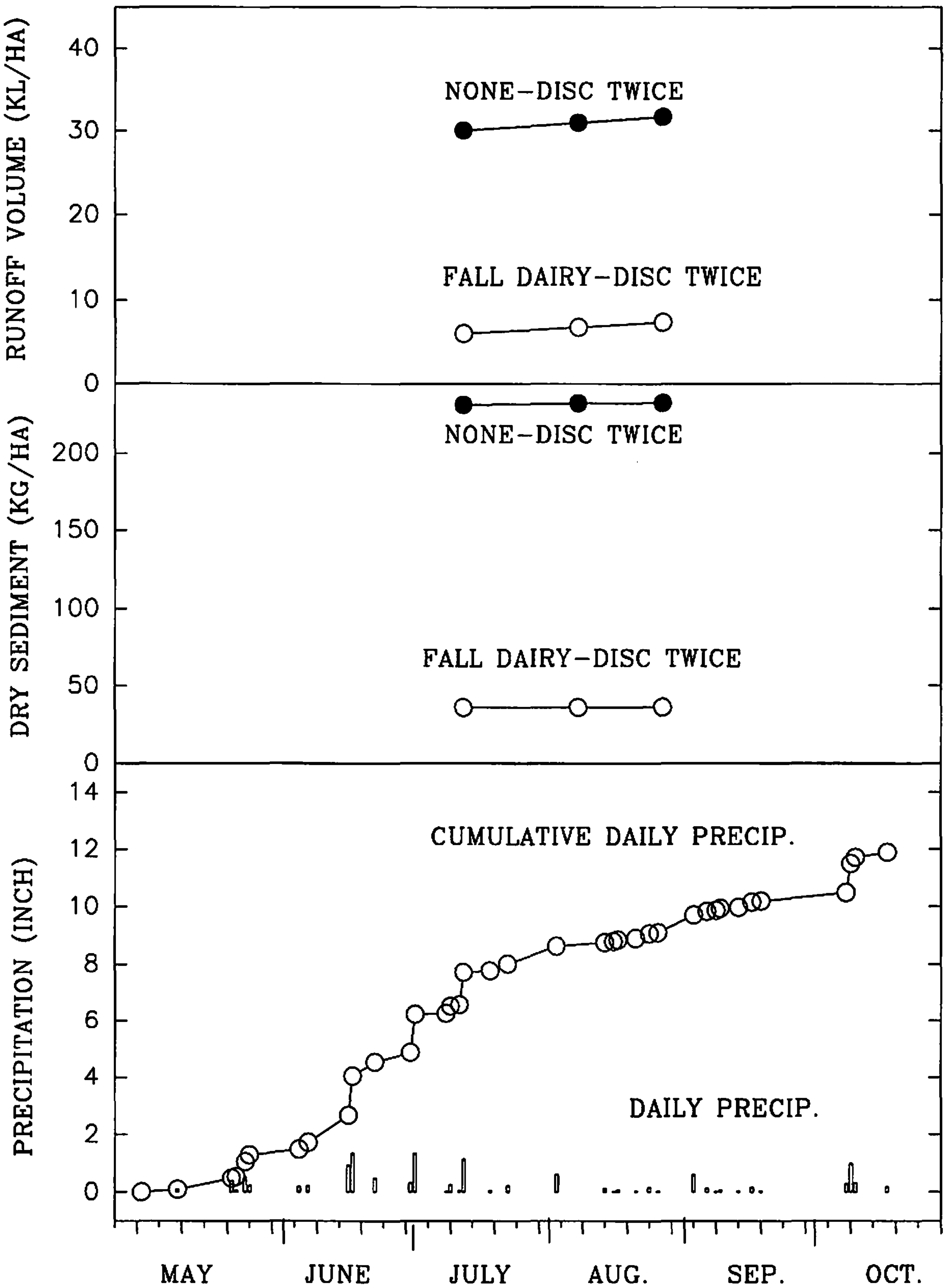


FIG. 5. MEASURED CUMULATIVE RUNOFF VOLUME AND SEDIMENT AND PRECIPITATION AT ECKER FARM, MEEKER COUNTY, MN (1992).

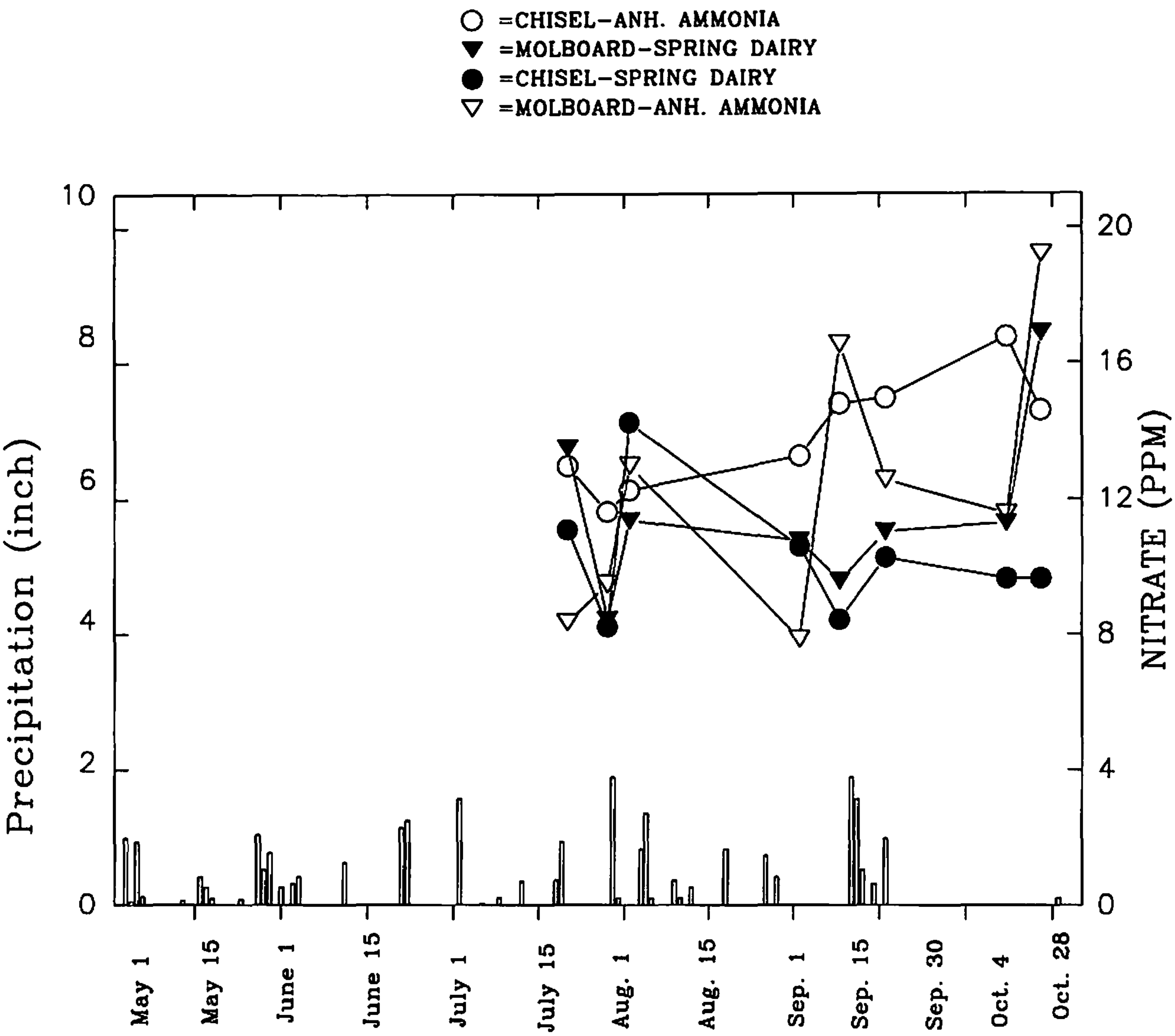


FIG. 6. PRECIPITATION AND SOIL WATER-NITRATE CONCENTRATION OVER TIME AT ECKER FARM, MEEKER COUNTY, MN (1991).

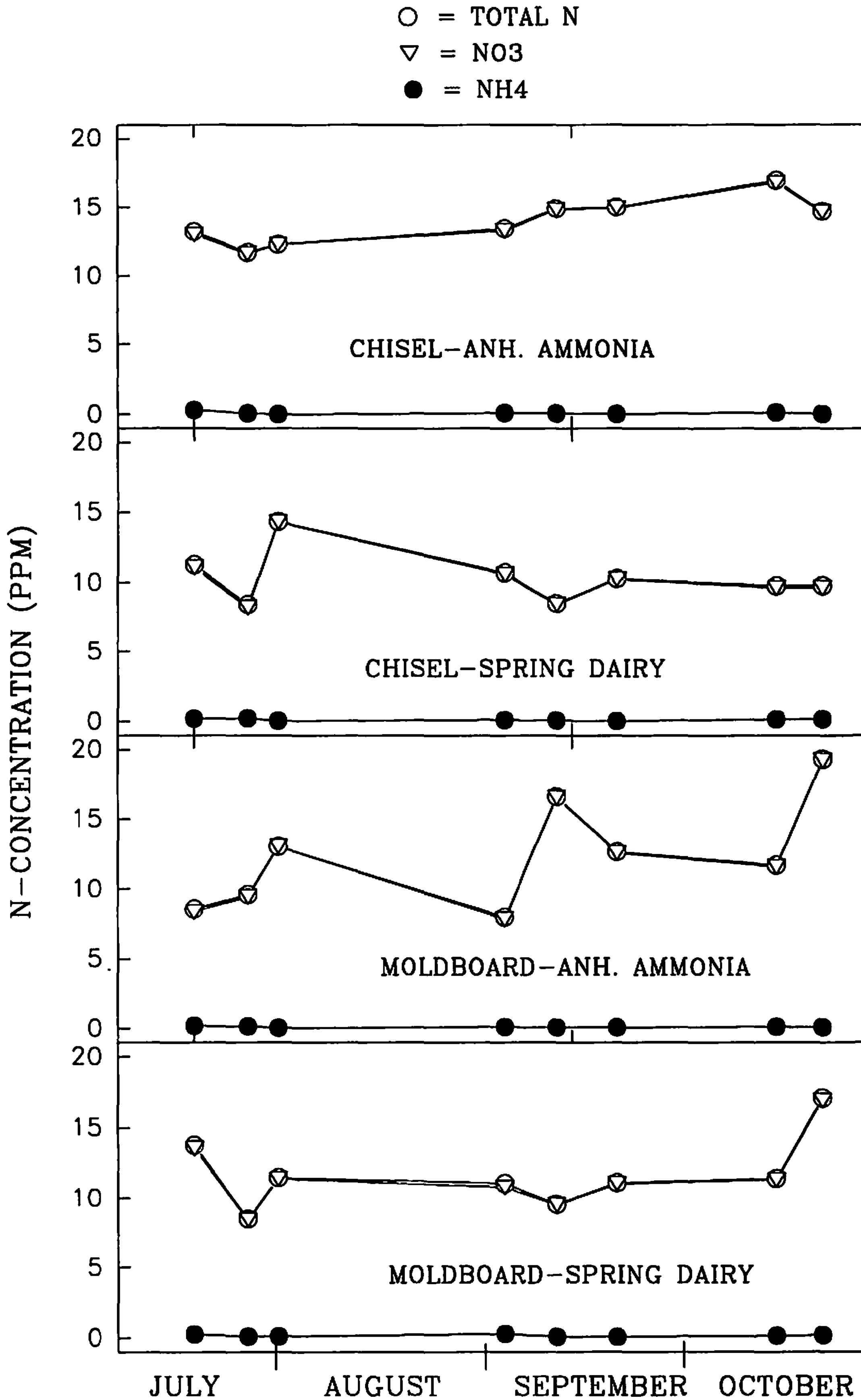


FIG. 7. SOIL WATER-N OVER TIME AS INFLUENCED BY TILLAGE AND MANURE APPLICATION AT ECKER FARM, MEEKER COUNTY, MN (1991).

TILLAGE EFFECTS ON SOYBEAN RESPONSE TO MANURE AT STEARNS COUNTY, MN[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, M.B. Kells, and B.J. Johnson[2]

Abstract

Tillage (no till, ridge till, chisel and moldboard plow) influence on the residual effects of two sources of plant nutrients (manure and anhydrous ammonia) on soybean performance was evaluated. Residue cover was less than 30 % for all tillage systems. Moldboard plowing resulted in less than 3% residue cover. Plant population in the ridge till system was lower compared to other tillage systems due to a different planter. Growth stage of beans were not significantly influenced by tillage. Residual effects of manure and anhydrous ammonia resulted in similar bean yield. Moldboard plowing resulted in a similar yield as chisel and both are higher than ridge till or no till. Low yield in the no till system was mainly due to competition by Russian Thistle and lower yield in ridge till mainly due to the lower population. Bean grain moisture were also similar among tillage systems. Soil water mineral nitrogen was mainly nitrate. Manure treated plots indicates a reduction of nitrate during the growing season but there was a slight increase at the end of the growing season. Moldboard plowed plots treated with anhydrous ammonia indicates a slight increase of nitrate over time.

Materials and Methods

The experiment on soybean-corn rotation with different tillage systems (notill, ridge till, chisel and moldboard) and manure application was the continuation of the experiments in 1989, 1990 and 1991. In 1989 (corn-year) dairy manure (barnyard and barngutter) were evaluated for the ability to provide nutrients for corn production. In 1990 (soybean-year) no plant nutrient was applied and residual effect of previous manure application was evaluated. In 1991 (corn-year), Manure and anhydrous ammonia were applied, to evaluate the crop performances and soil-water nitrate content. In 1992 (soybean-year), no plant nutrients was applied and the residual effect of 1991 (corn year) treatment was evaluated on bean performances and soil-water nitrate, however, no soil water nitrate samples was taken in this year.

Measurements. Measurements made were corn residue cover, population and growth stage, grain yield and grain moisture. Soil cover was characterized relative to row position (in row and between row), and measurements were made over 10 feet of row with 25 points each treatment. In row is defined as 10 inch strip centered over the row and between the row is the remainder. Soybean stands were estimated by tallying the number of plants in 10 foot row from each treatment. Grain yield estimates were made from area 10 feet by 4 feet and reported as dry yield.

Experimental design The experiment was arranged as split plot, with tillage as main plots and nutrient source as subplots.The design was extended to split-split-split plot to adapt the analysis of the influence of row position and soil depth on Bray-P.

Result and Discussion

Residue cover. Means of Residue cover were less than 30%. The residue cover were similar with no till, ridge till and chisel systems. Residue cover, however, under moldboard plowing was the least, less than 3%. There were higher residue cover in the row than between the row (Table 2).

Plant population and growth stage. Soybean population was significantly influenced by tillage system. Moldboard plowing resulted in similar population with no till, but higher than ridge till or chisel (Table 3). Ridge till indicated the lowest population, which mainly due to the different planter. However, growth stages were similar among tillages.

Grain Yield and moisture. Previous year application of manure and anhydrous ammonia resulted in similar bean yield (Table 4). Moldboard plowing resulted in similar yield as chisel and both are higher than ridge till or notill. Low yield in no till is likely due to competition from Russian Thistle and lower yield in ridge till is mainly due to the lower population. Grain moisture is similar between previous year manure and anhydrous ammonia application. Bean moisture were also similar among tillage systems (Table 5).

---

[1]Support for this project was provided by the Agricultural Utilization and Research Institute, the Minnesota Pollution Control Agency, the Soil Conservation service, the Clearwater River Watershed District, and the Minnesota Extension Service. Their support is greatly appreciated.

[2]D. Ginting, J.F. Moncrief, S.C Gupta, B.J. Johnson are Graduate Student, Associate Professor, Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M. B. Kells is the Tri-County Project coordinator.

Soil Water Nitrogen. Soil water mineral nitrogen was mainly in the nitrate form. Ammonium was negligible (Fig. 2). Nitrate content over time and precipitation was presented in Fig.1. During the growing season, nitrate content both in the manure and in the anhydrous ammonia treated plots were decreasing. However nitrate slightly increased at the end of October.

STEARNS COUNTY

Table 1. Cultural practices at Stearns County, MN. 1992.

Tillage

No Till
Ridge Till
Chisel plow + discing
Spring Moldboard Plowing + discing

Cropping History

1981-red clover and oats, 1982-corn, 1983-soybeans, 1984-corn, 1985-corn, 1986-soybeans, 1987-corn, 1988-Soybeans 1989-corn, 1990-soybean , 1991-Corn
1992-soybean, Sturdy

Planting and Harvest Dates

Ridge till plots were planted with a four row Buffalo Till planter equipped with 12" sweeps at a 36 inch row spacing. Notill, moldboard and chisel plowed plots were planted with a Tye notill drill

	Planting		
Crop	Date	Rate	Harvested
soybean	May 21, 1992	225,000 seeds/A	Oct. 21 1992

Fertilization History 1981-1987

The fertilization history at this site is as follows: 1981-none, 1982-low rate of dry starter, 1983-low rate of starter and 0-0-60, 1984-4 gal/A of 9-18-9 only, 1985-60 lb/A of N and 4 gal/a of 9-18-9, 1986-all soybean plots were split with and without a row fertilizer treatment at planting, and in 1987-all corn plots were split with three rates of starter.

				Actual			
	Material			N	P_2O_5	K_2O	
Crop	Analysis	Rate	Tillage	----	lb/A	----	Date Applied
Soybeans	9-18-9[1]	4 gal/A	Ridge Till	4	8	4	May 16, 1986
	0-0-60[2]	90 lb/A	All Others	0	0	54	May 16, 1986
Corn	Starter Fertilizer Treatments						
	9-18-9[1]	0 gal/A	All	0	0	0	April 29, 1987
	9-18-9[1]	4.9 gal/A	All	4.7	10	4.7	April 29, 1987
	9-18-9[1]	9.7 gal/A	All	9.3	18.5	9.3	April 29, 1987
	Nitrogen Management						
	28-0-0	11 gal/A	No Till[3]	33	0	0	June 1, 1987
	28-0-0	11 gal/A	All Others[4]	33	0	0	June 1, 1987
	28-0-0	11 gal/A	No Till[3]	33	0	0	June 25, 1987
	28-0-0	11 gal/A	All Others[4]	33	0	0	June 25, 1987

1. Planter placement 1" below the seed. 2. Potash was surface banded ahead of and incorporated by the fluted coulters. 3. Nitrogen was surface banded. 4. Nitrogen was surface banded and incorporated by cultivation.

1989 Fertilizer and Manure Analysis

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	----	lb/A	----	Date Applied
Corn	9-18-9[1]	5 gal/A	5	10	5	May 11, 1989
	28-0-0[2]	11 gal/A	33	0	0	June 15, 1989
	28-0-0[3]	11 gal/A	33	0	0	June 30, 1989

1. Planter placement 1" below the seed. 2. Urea-ammonium nitrate (UAN) solution was surface banded and incorporated by cultivation on all non-manure plots. Solution was surface banded with no incorporation on no till plots. 3. Urea-ammonium nitrate (UAN) solution was surface banded and incorporated by cultivation on all plots manured and non-manured. Solution was surface banded with no incorporation on no till plots.

Analysis and rate of application of manure in 1989.

						Total			Manure		Solids		
	Date	NH_4	NO_3	Mineral	Organic	N	P	K	Density	Rate	Total	Volatile	Fixed
Manure Source	Applied			%					lb/ft[3]	T/A		%	
Barn Gutter[1]	4/13/89	.260	.012	.272	.264	.536	.109	.424	64.8	16.4	27.66	45.96	54.04
Barnyard[2]	4/25/89	.050	.003	.053	.639	.692	.204	.377	33.8	15.0	16.50	64.62	35.38

1. Fresh daily manure collected every other day from barn gutters and applied the last two weeks of April.
2. A manure pack collected near a hay rack in the barnyard and applied April 25, 1989.

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

			Total		Nitrogen Available						
	Mineral	Organic	Nitrogen	$	1989	1990	1991	P_2O_5	$	K_2O	$
Source	-- Applied N lb/acre ---				-- lb/A -			lb/A		lb/A	
Barn Gutter	89	87	176	17.60	111	11	6	82	16.40	167	16.70
Barnyard	16	192	208	20.80	64	24	12	140	28.00	136	13.60

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively.
2. It is assumed that all of the mineral N and 25% of the organic N will be available during the year of application.

1990 Treatment

No manure or anhydrous ammonia was applied.

1991 Fertilizer and Manure Analysis

	Material		Actual			
			N	P_2O_5	K_2O	
Crop	Analysis	Rate	----	lb/A	----	Date Applied
Corn	9-18-9	5 gal/A	5	10	5	May 23, 1991
	82-0-0	75 lb/A	62	0	0	June 4, 1991

1. Planter placement 1" below the seed.

Analysis and rate of application of manure on May 1991.

						Total			Manure		Solids		
	Date	NH_4	NO_3	Mineral	Organic	N	P	K	Density	Rate	Total	Volatile	Fixed
Manure Source	Applied			%					lb/ft[3]	T/A		%	
Barnyard[2]	5/15/91	0.017	TR	0.017	0.559	0.576	0.02	0.08	33.8	22.7	21.03	71.54	28.46

2. A manure pack collected in and around a pole shed.
TR. Trace.

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

			Total		Nitrogen Available		P_2O_5		K_2O	
	Mineral	Organic	Nitrogen	$	1989	1991	1989	1991	1989	1991
Source	-- Applied N lb/A ---				--lb/A--		-- lb/A--		---lb/A---	
Barnyard	8	254	262	26.20	64	72	140	21	136	44

1. It is assumed that fertilizer cost .10 $ per lb of N
2. It is assumed that all of the mineral N and 25% of the organic N will be available during the year of application.

1992 Treatment

No manure or anhydrous ammonia was applied.

Soil

The soils at the Stearns County site are Fairhaven loam (Typic Hapludolls) which is well drained on 54 percent of the plot. Estherville sandy loam (Typic Hapludolls) which is somewhat excessively drained on 36 percent of the plot, Hawick loamy sand (Entic Hapludolls), this soil is excessively drained on the remaining 10 percent of the plot. The slope average for all three soils is 2.5 percent with the highest being 4 percent.

Weed Control

0.252 lb a.i./A Pursuit 2L + non ionic surfactant.

Table 2. The influence of tillage and row position on corn residue in soybean at Eckman farm, MN. (6/3/92).

Tillage	Row Position		
	In Row	Between Row	Means
	---------------- % ----------------		
Notill	24.8(17.4)	16.5(15.2)	**20.6(16.6)a**
Ridge Till	11.5 (7.8)	17.5(12.6)	**16.1(11.1)a**
Chisel	22.8(16.2)	10.0(10.7)	**16.4(15.0)a**
Moldboard	3.0(3.0)	2.5(4.1)	**2.8(3.5)b**
means	**15.5(15.1)a**	**11.6(12.7)b**	

The P>F: tillage=0.011(n=32); row=0.014(n=64) tillage*row=0.002(n=16).

Table 3. The influence of tillage on soybean population and growth stage at Eckman farm, MN. (6/19/92).

Tillage	population	growth stage
	x 1000	leaves
Notill	**236.9(59.3)ab**	**1.94(0.1)a**
Ridge Till	**118.2(29.2)c**	**1.88(0.1)a**
Chisel	**214.1(46.2)b**	**1.91(0.2)a**
Moldboard	**310.9(134.5)a**	**1.93(0.1)a**

The P>F for population tillage=0.007(n=16); for growth stage=0.778(n=16)

Table 4. The influence of tillage and manure on grain yield at Eckman farm, MN 10/21/92).

Tillage	Manure Treatment		
	manure	no manure	Means
	--------------bu/a ---------------		
Notill	14.6(5.8)	8.9(5.4)	**10.4(5.9)b**
Ridge Till	11.5(5.5)	8.8(5.6)	**10.0(5.5)b**
Chisel	15.8(7.6)	15.6(2.6)	**15.7(4.5)a**
Moldboard	17.2(7.3)	19.6(8.0)	**18.6(7.6)a**
means	**14.8(6.6)a**	**13.7(7.3)a**	

The P>F:tillage=0.004(n=11-19); manure=0.264 (n=23-38);tillage*manure=0.264(n=3-11)

Table 5. The influence of tillage and manure on grain moisture at Eckman farm, MN 10/21/92).

Tillage	Manure Treatment		
	manure	no manure	Means
	---------------- % ----------------		
Notill	11.6(1.5)	9.1(2.3)	**9.8(2.3)a**
Ridge Till	10.6(1.2)	10.1(1.0)	**10.3(1.1)a**
Chisel	11.0(0.7)	10.9(1.2)	**10.9(1.1)a**
Moldboard	11.0(1.7)	10.3(1.1)	**10.6(1.4)a**
Means	**10.9(1.3)a**	**10.1(1.5)a**	

The P>F:tillage=0.561(n=11-19); manure=0.139 (n=24-38);tillage*manure=0.689(n=3-11)

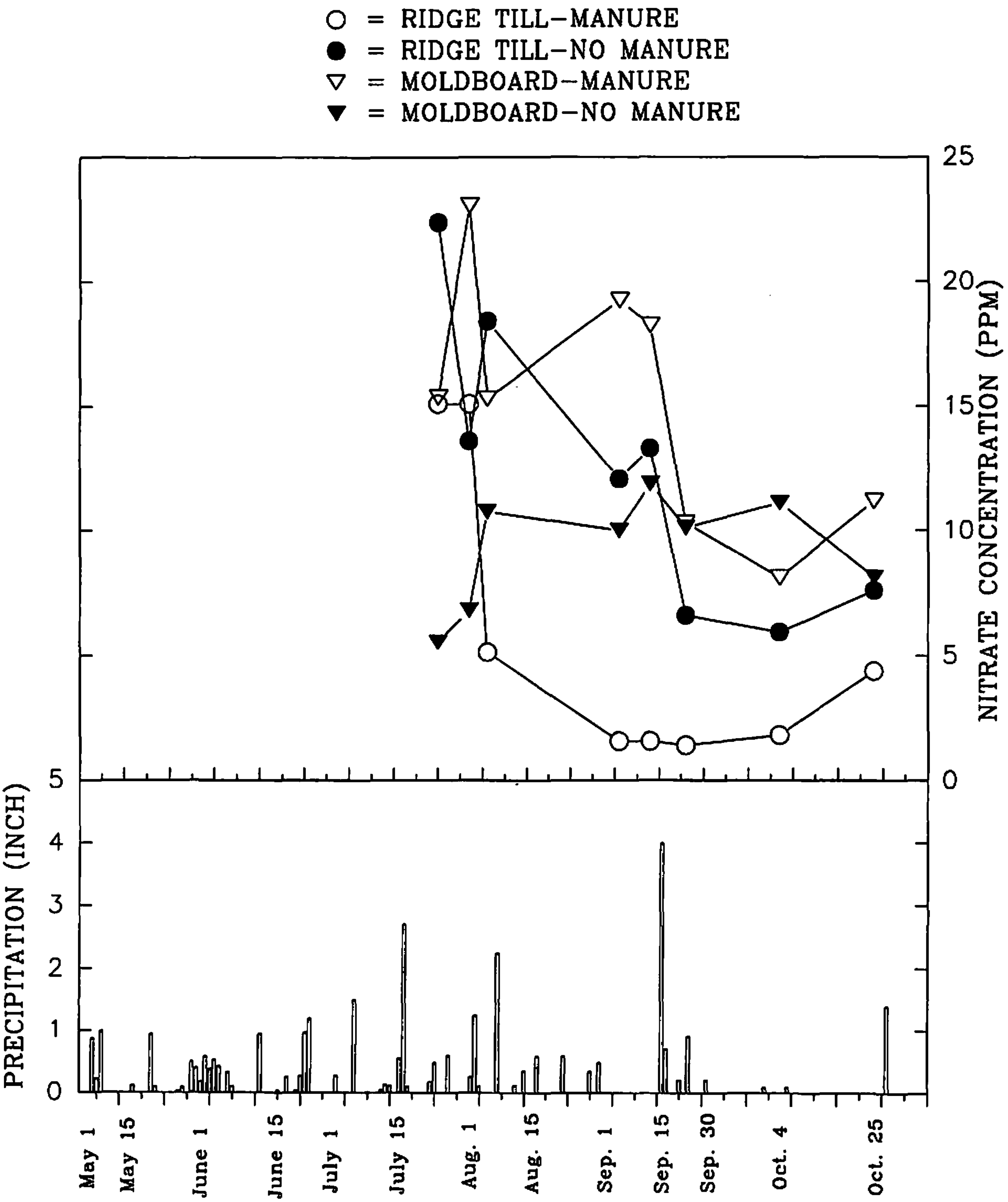


FIG. 1. PRECIPITATION AND SOL WATER NITRATE OVER TIME AT AS INFLUENCED BY TILLAGE AND MANURE AT ECKMAN FARM, STEARNS COUNTY, MN (1991).

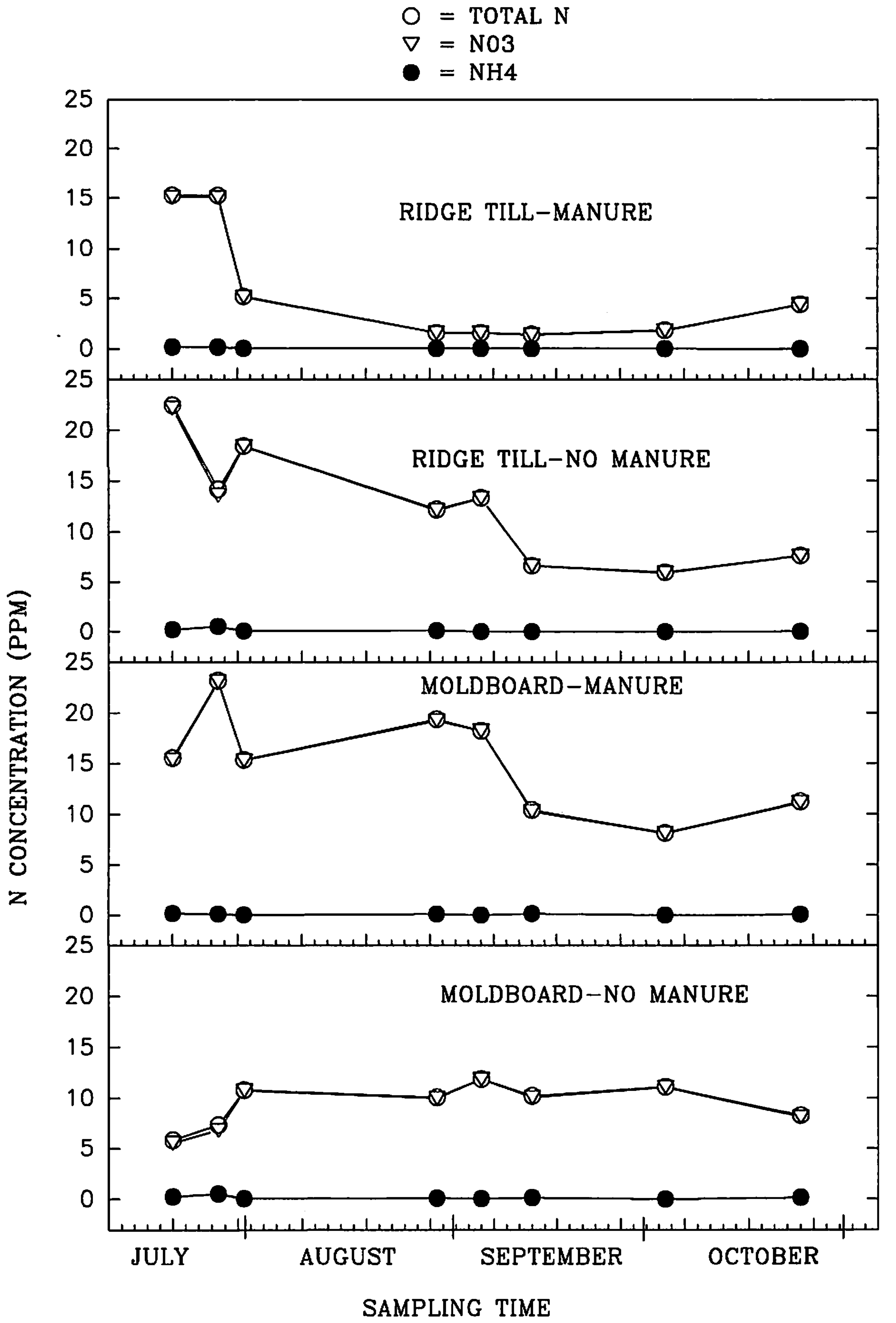


FIG. 2. SOIL WATER-N OVER TIME AS INFLUENCED BY TILLAGE AND MANURE APPLICATION AT ECKMAN FARM, STEARNS COUNTY, MN, (1991).

THE EFFECTS OF TILLAGE AND METHODS OF PHOSPHORUS APPLICATION ON CORN AND SOYBEAN RESPONSE AT KUECHLE FARM MEEKER COUNTY, MN[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, M.B. Kells, and B.J. Johnson[2]

Abstract

Corn and soybeans were grown in rotation for seven years, to demonstrate the influence of tillage and method of P placement on corn, soybean growth and distribution soil P and its potential for loss due to water erosion.

Results showed that no till systems left more than 30% soybean or corn residue cover for erosion control. Corn growth stage was lower with no till systems, although the population is similar among tillages. Corn yield was similar for both methods of P placements. Corn yield was higher in moldboard and ridge till than chisel and no till systems. Soybean population under no till systems was higher than other tillage systems, however growth stages were similar. Soybean yield and grain moisture are similar for both P placements and among tillage systems. Row placement of P fertilizer resulted in higher P in the row. Soil movement in the ridge and furrow system in the ridge till resulted in similar P content in the row and between the row. Soil Bray-P distribution with depth under moldboard plowing was similar from 0 to 6 inch depth.

Materials and Methods

This is the seventh and final year of this study with a corn-soybean rotation with different tillage systems (no till, ridge till, chisel and moldboard) and phosphorus application (row application and broadcast). The land was divided in to two halves for simultaneous rotation of corn-soybean every year.

The experiment is arranged in a randomized complete block split-plot design, with tillage as the main plots and method of P placement as subplots. Measurements were taken on residue cover, plant population, growth stage, yield, and soil Bray-P. Residue cover was characterized relative to row position (in row and between row), over 10 feet row with 25 points in each treatment. In row is defined as four inches centered over the row and between the row is the remainder. Corn stands were estimated from a 10 foot row from each treatment. Soil samples for Bray-P determination were taken from plots cropped with corn. Soil samples were taken in the row and between the row at two inch depth interval (0-2, 2-4, 4-6 inch)

Result and Discussions

Corn as Present Crop

Soybean residue in corn plots was significantly influenced by tillage systems (Table 2). Residue was significantly reduced in the order of no till, ridge till, chisel and moldboard. No till systems resulted residue of 37.9%, whereas moldboard plowing resulted less than 3% soybean residue. Soybean residue was significantly higher between the row.

Corn populations were similar among the tillages. Corn growth stages were significantly influenced by tillage. No till, which showed the highest soybean residue, resulted in a lower growth stage whereas ridge till, chisel and moldboard are similar (Table 3).

Broadcast and row application of P resulted in similar corn grain yield. There was significant interaction between tillage systems and method of P application. The interaction indicated that row application of P in ridge tillage system increased yield significantly compared to broadcast application. There are significant differences in yield as influenced by tillage. Moldboard and ridge till system yielded higher than chisel and no-till systems (Table 4). Grain moisture were similar among tillage and method of P applications.

---

[1]Support for this project was provided by the Agricultural Utilization and Research Institute, the Minnesota Pollution Control Agency, the Soil Conservation Service, The Clear Water River Watershed District, and the Minnesota Extension Service. Their support is greatly appreciated.

[2]D. Ginting, J.F Moncrief, S.C. Gupta, B.J. Johnson are Graduate Student, Associate Professor, Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108. M.B. Kells is the Tri-County Project Coordinator.

Soybean as Present Crop

Corn residue cover on soybean plots were similar in the row and between the row. Tillage systems, however, significantly influences the residue cover. Residue cover were significantly reduced in the order of no till, ridge till, chisel and moldboard. No till and ridge till showed residue cover more than 30 % where as chisel and moldboard plowing resulted in 9.5 and 4.9 percent respectively (Table 6). There was an interaction between tillage and row position. No till, chisel and moldboard systems resulted a lower residue cover between the row but ridge till system resulted in higher residue between the row. This was beneficial for erosion control on the furrow where the runoff concentrated.

Soybean population under no till system was higher than the population under the ridge till, chisel and moldboard systems (Table 7). There was no difference in growth stage among the tillage systems (Table 7). Soybean yield (Table 8) was also similar by method of P application and tillage systems. Grain moisture was significantly influenced by tillage. Chisel plowing resulted in significantly higher grain moisture compared to the other tillage systems. Tillage and method of P application indicated that row application of P increased grain moisture significantly compared to broadcast application (Table 9).

Soil Bray-P. Soil Bray-P from corn plots of 1991 and 1992 were merged to evaluate the distribution of soil P with depth as influenced by tillage, method of application and row position under the soybean and corn rotation (Table 10). The distribution with depth was presented in Fig. 1. Row application resulted in higher P in the row for all tillage systems as expected. However, in the ridge tillage system, soil P is almost similar in the row and between the row. This was due to the movement of soil from in row (ridge) to between row (furrow) in the ridge till system. P distribution decreases with depth, except moldboard plowing which resulted in a similar distribution of P from 0 to 6 inch depth.

Table 1. Cultural practices at Kuechle Farm, Meeker County, MN, in 1992.

Tillage
No Till
Ridge Till
Fall Chisel Plowed-disced prior to planting
Fall Moldboard Plowed-disced prior to planting

Cropping History
Corn-soybean rotation since 1978.

1991 Crop
Corn- Northup king N 3624
Soybeans- Northrup king B 095

1992 Crop
Corn-Pioneer 3751
Soybean-Sturdy

Planting and Harvest Dates

Corn - was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing.

Soybeans - ridge till was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing and all other tillage treatments were planted with a Tye no till drill with 7 inch row spacing equipped with 1 inch fluted coulter ahead of the double disc openers.

Crop	Planting Date	Planter	Rate	Harvested
Corn	May 7, 1992	Row	32,000 seeds/A	October 13,1992
Soybeans	May 7, 1992	Drill	225,000 seeds/A	October 21,1992

Fertilizer History 1985-1990

Crop	Material Analysis	Rate	Actual N (lb/A)	Actual P_2O_5 (lb/A)	Actual K_2O (lb/A)	Date Applied
Corn:	82-0-0	183 lb/A	150	0	0	Spring 1985
	4-15-40[1]	250 lb/A	10	38	100	Planting 1985
Corn:	4-15-40	300 lb/A	12	45	120	October 27, 1986
	7-21-7[1]	17 gal/A	13	40	13	April 28, 1987
	82-0-0	159 lb/A	130	0	0	May 15, 1987
Soybeans:	4-15-40	300 lb/A	12	45	120	October 27, 1986
	0-46-0[2]	45 lb/A	0	21	0	May 5, 1987
Corn:	10-34-0[3]	19 gal/A	22	76	0	April 28, 1988
	10-34-0[1]	9 gal/A	11	36	0	May 5, 1988
	82-0-0	183 lb/A	150	0	0	June 7, 1988
Soybeans:	10-34-0[3]	10 gal/A	12	40	0	April 28, 1988
	10-34-0[1]	5 gal/A	6	20	0	May 5, 1988
	0-46-0[2]	358 lb/A	0	165	0	May 5, 1988
Corn:	7-21-7[4]	15 gal/A	12	35	12	May 10, 1989
	82-0-0	183 lb/A	150	0	0	May 31, 1989
Soybeans	7-21-7[5]	15 gal/A	12	35	12	May 22, 1989
Corn :	7-21-7[4]	18 gal/A	14	42	14	May 10, 1990
	82-0-0	220 lb/ A	180	0	0	July 5, 1990
Soybean :	7-21-7[5]	18 gal/A	14	42	14	May 10, 1990

1. Planter placement 2" beside and 2" below row.
2. Drill soybeans were split with row fertilizer which was surface banded ahead of and incorporated by the fluted coulters.
3. Broadcast applied.
4. Planter placement 2" x 2" on 1/2 the plots.
5. Planter placement 2" x 2" on 1/2 the plots, Ridge Till only.

1991 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5 lb/A	Actual K_2O	Date Applied	Method of Application
Corn:	10-34-0	5 gal/ac	6 -	20	- 0	5/16/91	Row placement 2"x2" below row.
	0-46-0	87lb/ac	0 -	40	- 0	5/13/91 5/15/91	Broadcasted.
	83-0-0	260lb/ac	217-	0	- 0	6/25/91	Injected.
soybean:	10-34-0	5 gal/ac	6 -	20	- 0	5/16/91	Row placement 2"x2" below row.
	0-46-0	87lb/ac	0 -	40	- 0	5/13/91 5/15/91	Broadcasted.

1992 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5 lb/A	Actual K_2O	Date Applied	Method of Application
Corn:	7-21-7	10 gal/ac	8 -	25	- 8	5/7/92	Row placement 2"x2" below row.
	83-0-0	180lb/ac	149-	0	- 0	6/4/92	Injected.
Soybean	7-21-7	10 gal/ac	8 -	25	- 8	5/7/92	Row placement 2"x2" below row.

Soil

The soils present at this site are as follows: 29% of plot area is Delft clay loam (Cumulic Haplaquolls, fine-loamy, mixed, mesic), 43% is Koronis fine sandy loam (Mollic Hapludalfs, fine-loamy, mixed, mesic), and the remaining 28% is Marcellon loam (Aquic Argiudolls, fine-loamy, mixed, mesic).

Weed Control

Corn
Roundup 1.5 lb a.i./a + Lasso 2 lb a.i./a + Bladex 2 lb a.i./a + Basagran 1 lb a.i./a on May 14, 1992.

Soybeans
Roundup 1.5 lb a.i./a (May 14, 1992); Pursuit 0.252 lb a.i./a + Basagran 1 lb a.i./a on June 11,1992.

Table 2. Soybean residue cover as influenced by tillage and row position in corn at Kuechle farm, Meeker Co (5/29/92)

Tillage	Row Position In Row	Row Position Between Row	Weighted Means
	%		
No till	21.2(14.2)	42.5(11.9)	**37.8(16.8)a**
Ridge Till	10.0(9.6)	24.7(10.4)	**21.4(12.4)b**
Chisel	6.0(6.6)	7.5(6.8)	**7.2(6.7)c**
Moldboard	2.2(3.1)	2.3(3.5)	**2.3(3.3)d**
Means	**9.8(11.6)b**	**19.3(18.1)a**	

The P>F: tillage=0.001(n=48);
row position=0.020 (n=96);
tillage*row position=0.413(n=24).

Table 3. Corn population and growth stage as influenced by tillage at Kuechle farm, Meeker county (6/11/92).

Tillage	Population	Growth Stage
	x 1000 plants/a	---leaves----
Notill	**30.2(4.0)a**	**4.05(0.5)b**
Ridge Till	**29.8(4.2)a**	**4.49(0.4)a**
Chisel	**29.3(2.5)a**	**4.43(0.5)a**
Moldboard	**29.9(2.6)a**	**4.61(0.4)a**

The P>F for population=0.804(n=24)
for growth stage=0.019(117-121).

Table 4. Corn yield as influenced by tillage and P-fertilizer methods of application at Kuechle farm, MN (10/13/92)

Tillage	Broadcast	Row application	Means
		bu/a	
Notill	79.0(24.7)	83.7(24.5)	**81.2(23.8)c**
Ridge Till	105.9(12.6)	114.5(11.3)	**110.1(12.4)a**
Chisel	96.5(11.9)	93.0(25.6)	**94.8(19.3)b**
Moldboard	113.0(20.9)	110.0(19.0)	**112.2(19.1)a**
Means	**97.7(21.7)a**	**100.7(23.5)a**	

The P>F: tillage=0.036(n=12-15); method of
fertilizer application=0.905(n=28-29)
tillage*application=0.072(n=6-8).

Table 5. Corn grain moisture as influenced by tillage and P-fertilizer method of application at Kuechle farm, MN (10/13/92)

Tillage	Broadcast	Row Application	Means
		%	
Notill	38.9(5.2)	35.8(5.1)	**37.4(5.2)a**
Ridge Till	35.9(3.9)	34.6(3.1)	**35.2(3.5)a**
Chisel	33.1(5.9)	35.1(3.0)	**34.1(4.6)a**
Moldboard	36.7(2.5)	34.0(3.7)	**35.3(3.3)a**
Means	**36.2(4.9)a**	**34.9(3.7)a**	

The P>F: tillage=0.661(n=12-15); method of
fertilizer application=0.195(n=28-29).
tillage*application=0.379(n=6-8)

Table 6. Corn residue cover as influenced by tillage and row position in soybean at Kuechle farm, Meeker Co.(5/29/92)

Tillage	Row Position In Row	Row Position Between Row	Weighted Means
	%		
Notill	43.7(17.8)	37.0(20.1)	**38.5(19.2)a**
Ridge Till	21.3(26.7)	35.0(21.5)	**32.0(24.7)a**
Chisel	16.0(8.4)	7.7(4.3)	**9.5(7.8)b**
Moldboard	7.0(12.4)	4.3(3.5)	**4.9(10.0)b**
Means	**22.0(21.9)a**	**21.0(21.4)a**	

The P>F: tillage=0.002(n=24);
row position=0.581(n=48);
tillage*row position=0.003(n=12).

Table 7. Soybean population and growth stage as influenced by tillage at Kuechle farm, Meeker county (6/19/92).

Tillage	Population	Growth Stage
	1000 plants/a	---nodes----
Notill	**152.8(120.8)a**	**3.94(0.6)a**
Ridge Till	**103.2(93.8)b**	**4.26(0.5)a**
Chisel	**111.3(114.3)b**	**4.34(0.7)a**
Moldboard	**117.8(123.7)b**	**4.03(0.7)a**

The P>F for population,tillage=0.060(n=24)
for growth stage=0.358(n=53-62).

Table 8. Soybean yield as influenced by tillage and P-fertilizer methods of application at Kuechle farm, MN (10/21/92)

Tillage	Broadcast	Row application	Means
		bu/a	
Notill	39.6(5.8)	35.0(9.4)	**37.2(7.9)a**
Ridge Till	29.8(5.3)	30.9(5.3)	**30.4(5.1)a**
Chisel	42.1(5.0)	28.7(12.1)	**35.4(11.3)a**
Moldboard	42.9(13.7)	41.9(11.1)	**42.4(12.1)a**
Means	**38.9(9.5)a**	**34.2(10.7)a**	

The P>F: tillage=0.417(n=14-16); method of
fertilizer application=0.103(n=31);
tillage*application=0.140(n=7-8).

Table 9. Soybean grain moisture as influenced by tillage and P-fertilizer method of application at Kuechle farm,MN (10/21/92)

Tillage	Broadcast	Row Application	Means
		%	
Notill	10.1(0.5)	10.1(0.3)	**10.1(0.4)b**
Ridge Till	10.3(0.3)	10.5(0.8)	**10.4(0.6)b**
Chisel	10.2(0.4)	12.5(2.6)	**11.3(2.2)a**
Moldboard	10.1(0.3)	10.1(0.4)	**10.1(0.4)b**
Means	**10.2(0.4)a**	**10.8(1.7)a**	

The P>F: tillage=0.037(n=14-16); method of
fertilizer application=0.167(n=31).
tillage*application=0.008(n=7-8)

Table 10. Distribution of soil Bray-P with depth as influenced by tillage, method of P application, row position and soil depth at Kuechle Farm, Meeker Co., MN (August 19/92).

Tillage	Method of P Application	Depth	In row	Between Row	Means
		inch	ppm		
Notill	Broadcast	0-2	10.8(5.6)	16.0(8.6)	**13.4(7.4)**
		2-4	6.6(2.6)	7.6(2.0)	**7.1(2.4)**
		4-6	5.5(2.0)	5.5(1.6)	**5.5(1.7)**
		means	**7.6(4.2)**	**9.7(6.7)**	**8.6(5.6)**
	Row applied	0-2	26.0(8.3)	12.8(10.7)	**19.4(11.4)**
		2-4	9.7(6.7)	10.1(6.5)	**9.9(6.3)**
		4-6	9.7(5.3)	8.1(4.7)	**8.9(4.8)**
		means	**15.1(10.2)**	**10.3(7.5)**	**12.7(9.2)**
Ridge Till	Broadcast	0-2	14.3(5.6)	20.3(9.5)	**17.3(8.4)**
		2-4	10.2(6.3)	11.1(7.2)	**10.7(6.5)**
		4-6	8.9(5.6)	7.8(4.2)	**8.3(1.7)**
		means	**11.1(6.3)**	**13.1(8.7)**	**12.1(7.6)**
	Row applied	0-2	30.1(16.1)	25.3(19.2)	**27.5(17.2)**
		2-4	19.6(12.9)	14.5(10.8)	**17.1(11.6)**
		4-6	7.7(4.0)	8.8(4.5)	**8.2(4.1)**
		means	**18.5(14.4)**	**16.2(14.1)**	**17.3(14.1)**
Chisel	Broadcast	0-2	15.0(6.9)	13.7(6.0)	**14.4(6.2)**
		2-4	10.1(4.6)	10.4(4.7)	**10.2(4.4)**
		4-6	8.4(4.4)	7.4(3.9)	**7.9(4.0)**
		means	**11.2(5.8)**	**10.5(5.3)**	**10.8(5.5)**
	Row applied	0-2	16.5(10.4)	14.1(9.7)	**15.3(9.7)**
		2-4	13.3(8.0)	8.3(3.1)	**11.0(6.6)**
		4-6	7.4(3.4)	7.3(4.1)	**7.3(3.6)**
		means	**12.4(8.3)**	**10.0(6.8)**	**11.2(7.6)**
Moldboard	Broadcast	0-2	7.7(5.4)	8.7(5.1)	**8.2(5.0)**
		2-4	9.5(6.1)	7.5(2.9)	**8.5(4.6)**
		4-6	7.2(4.9)	7.1(3.4)	**7.1(4.0)**
		means	**8.2(5.2)**	**7.7(3.7)**	**7.9(4.4)**
	Row applied	0-2	8.9(5.7)	9.7(5.2)	**9.3(5.2)**
		2-4	9.1(5.9)	6.6(3.9)	**7.8(4.9)**
		4-6	8.4(3.5)	7.4(3.7)	**7.8(3.4)**
		means	**8.8(4.8)**	**7.9(4.2)**	**8.3(4.5)**

The significant P>F:tillage=0.001(n=59-72),application=0.004(n=135-138); tillage*application=0.094(n=29-36);application*row=0.011(n=67-69);depth=0.001(n=91);tillage*depth=0.001(n=19-24);application*depth=0.061(n=45-46);application*row*depth=0.04 n=(22-23);tillage*method of P-application*row position*soil depth interaction=0.093 (n=5-6)

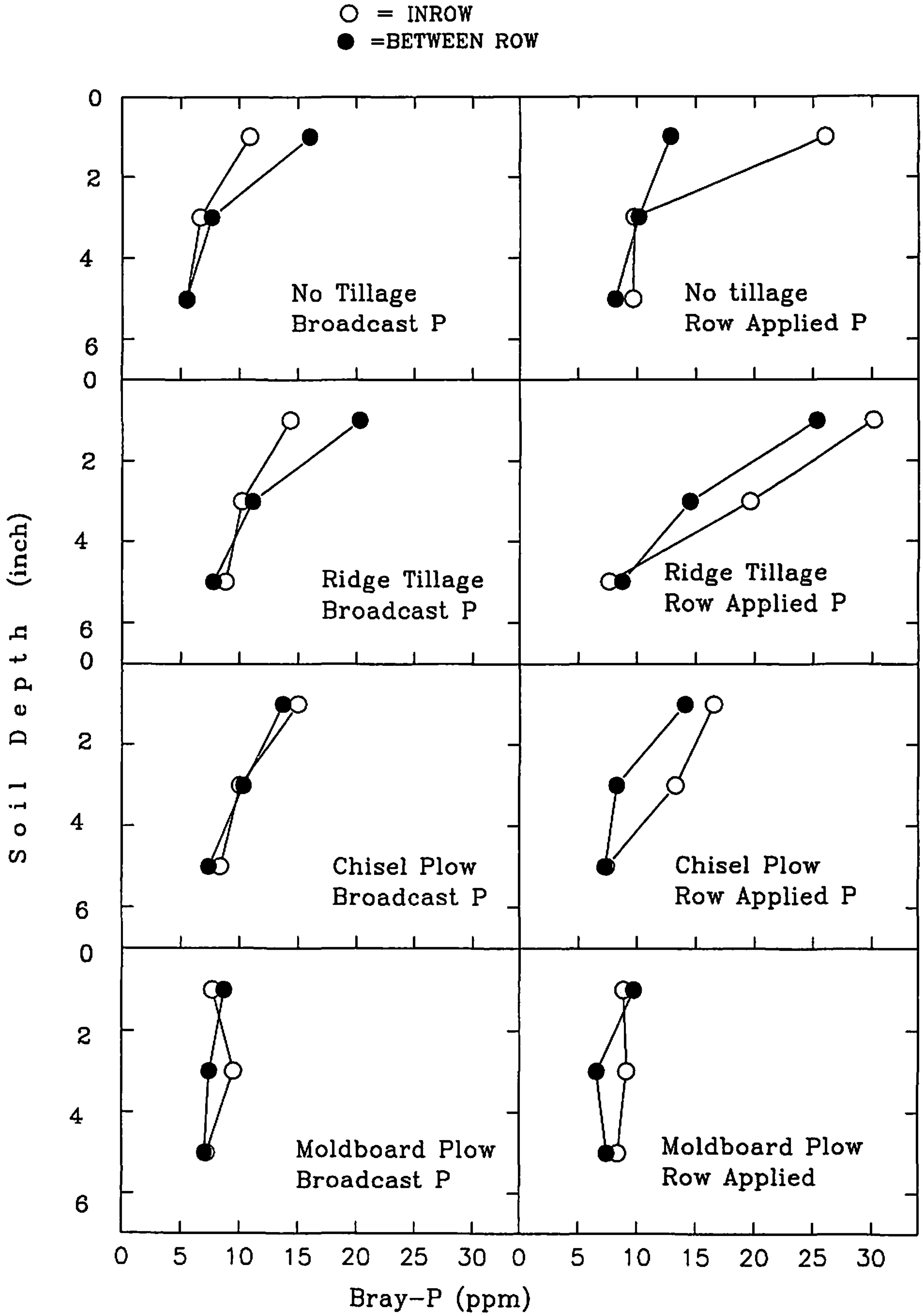


Fig. 1. Effects of tillage, phosphorus application methods and row position on soil profile P (Kuechle farm) MN.

EVALUATION OF RESIDUE MANAGEMENT SYSTEMS FOR WHEAT, CORN, AND SOYBEANS IN WEST CENTRAL MINNESOTA[1]

J.F. Moncrief, H.J. Stanislowski, and B.J. Johnson[2]

Evaluation of tillage system, planter mounted row cleaners, and drill type was evaluated for spring wheat, corn, and soybeans on five farmer cooperator fields. Generally, tillage did not affect grain yields or quality. Rolling finger and disc row cleaners were about equally effective at removing residue from the row area. A conventional drill equipped with a coulter cart performed comparable to a no till drill with disc openers.

This the first year of a three year project evaluating residue management systems for corn, wheat, and soybeans in West Central Minnesota. Plots are located on five farmer cooperator fields. They are large to accommodate tillage equipment (50 to 100 ft. by 300 to 1400 ft.). The soils are highly erosive at most sites and the intent is to evaluate these systems for erosion control but with crop production as a priority. Each site has tillage main plots and are split with variables of interest at each site such as row cleaner type, manure source, drill type, etc.

The first site is described in table 1. This is the corn year in a corn, soybean, spring wheat crop sequence. The previous crop was spring wheat. The straw was not removed and the combine was equipped with an effective straw spreader. Two tillage systems were evaluated at this site (no till and chisel plowing followed with field cultivation). The planter was equipped with two types of row cleaners (rolling fingers and clearing discs). Weed control was excellent.

The affect of tillage and row cleaner type on soil cover with spring wheat straw is shown in table 2. Six days after planting the soil cover in the row was less than 10% with the rolling fingers with both no till and chisel systems. Clearing discs were not as effective under no till conditions and soil cover in the row was 18.5%. Soil cover measured diagonally or calculated as a weighted average is marginal for erosion control. Soil cover increased by June 1 in and between the row. Cover apparently blew back into the row area. The cover in the row is much higher than ideal for minimal effect on corn growth.

The corn response is shown in table 3. There is no affect of tillage or row cleaner type on stand establishment. The growth of corn was reduced an average of .4 leaves per plant with the no till system. Under no till conditions the clearing discs resulted in about .3 leaves per plant higher growth than chisel plowing system. There was about a 2.5 bushel per acre difference in grain yield due to tillage. Although this difference is small it is statistically significant. Test weight and grain moisture were not affected by treatments.

Cultural practices and treatment summary for the Julian Sjostrom farm are shown in tables 4 and 5. Tillage system and row cleaner type are evaluated at this site for corn planted into oat residue. Liquid dairy manure from a pit below the barn is also being evaluated at this site. No till plots were split with field cultivation to evaluate manure incorporation effects on corn response.

Following planting the soil cover in the row was 14 and 6% for the no till and chisel systems. Soil cover between the row or made diagonally showed adequate soil cover for erosion control with both systems. Several weeks later measurement of soil cover by crop residue in the row had increased to 20 and 36% for the chisel and no till systems respectively. This level of cover in the row would be expected to adversely affect corn development. As the season progresses, and the canopy closes, the soil cover in the row has less impact on corn development. Soil cover between the row had also increased to 50 to 60%.

There was no affect of tillage on stand establishment or early growth. Stands tended to be higher with clearing disc type row cleaner. This type of row cleaner appeared to cut oat straw and manure

---

[1] This project is supported by the Minnesota Department of Agriculture, the Minnesota Extension Service, Soil Conservation Service, the Ottertail County Soil and Water Conservation District, Interstate Incorporated, and Fergus International. Their support is greatly appreciated.

[2] John F. Moncrief, Harold J. Stanislowski, and Brian J. Johnson are Extension Soil Scientist, West Ottertail County Extension Educator, and Assistant Scientist in the Soil Science Department respectively, all at the University of Minnesota. Assistance in the data collection was provided by Brian Peterson, Plot Assistant, John A. Schmidt, Soil Conservation Service, District Conservationist and Paul Weyrens, West Ottertail Soil and Water Conservation District.

residues more aggressively and clear the row area more effectively. This may have been the reason for the stand response. The finger type row cleaner had significantly higher early corn growth however (.7 leaves per plant).

Yield and grain moisture was not affected by tillage system. The grain moisture content showed higher levels for the finger type row cleaner. This contradicts the early growth data. The ear leaf concentrations of nutrients were above sufficiency levels and not affected by tillage.

Table 1. Cultural practices for 1992 production season on the Dan Jennen farm, Fergus Falls, Mn.

Design A randomized complete block design with a split plot and 3 replications was used in this demonstration (tillage main plots and row cleaner subplots).

Tillage treatments

1. No Till-corn planted in wheat stubble.
2. Chisel plowed in fall of 1991; Field cultivated 5/6/92 with 27' Wil-Rich cultivator, 7" sweeps/harrow.
3. Two types of row cleaners (three rolling fingers and three clearing discs on six row planter) were evaluated.

All plots were row cultivated on 6/10 and 6/23 with a Yetter no till C-shank and John Deere S-tine cultivators respectively.

Fall moldboard plowed chisel plots 11/9/92 with John Deere 6-bottom 22" moldboard plow.

Planting and Harvesting Date

The planter is a John Deere 7000, 6-row 36" with rolling fingers (Yetter Residue Manager) and clearing discs (Trash Master). The corn hybrid was 85 day Agripro 077.

Planting			Harvested	
Crop	Date	Rate	Grain	chopped corn stalks
corn	May 8,1992	26,000seeds/A	10/22/92	11/9/92 (chisel plots)

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

Starter 9-23-30- 120 lb/acre applied on 5/8/92
NH_3 on fall chisel- 100 lb/acre applied on 10/23/91
NH_3 on No till- 120 lb/acre applied on 10/23/91

Weed control Dual 2 lb/acre at planting 5/8/92; Buctril 1.5 pt/acre on 6/13/92

Rainfall April-Nov. 14.58"

Table 2. The effect of tillage and planter mounted tillage tools on soil cover by wheat residue[1].

	5/14/92[2]					6/1/92[3]							
	Fingers[4]				Disc[5]	Fingers				Disc			
Tillage	In	Betwn	Diagn	Wtavg[6]	In	In	Betwn	Diagn	Wtavg	In	Betwn	Diagn	Wtavg
						%							
NoTill	9.2	81.2	72.9	65.2	18.6	61.2	86.7	72.0	80.4	47.0	73.7	66.3	68.5
Chisel	5.7	35.6	20.9	29.0	6.8	37.8	59.9	44.3	54.7	34.2	40.4	26.3	36.4

1. Column headings represent "in row" defined as a 8 inch strip centered over the row, the second column is the remainder of the area or "between the row", the next column is the cover made by a line transect measurement diagonal to the row, and the last column is a weighted average of the "in" and "between the row" measurements.
2. The p values for the analysis of variance for cover for the fingers treatment only, for tillage, row position, and the tillage by row position interaction are .022, <.001, and <.001 respectively.
3. The p values for the analysis of variance for cover for tillage, row position, and the tillage by row position interaction are .028, <.001, and <.001 respectively.
4. This row cleaner is a pair of discs oriented in a V shape with the concave outward.
5. This row cleaner is a pair of interlocking spiked wheels oriented in a V shape.
6. The weighted average =[(in row x 8") + (between x 28")]/36.

Table 3. Corn response to tillage and planter mounted tillage tools.

Tillage	Stand[1] Fngr	Stand[1] Disc	Stand[1] **avg.**	Growth[2] Fngr	Growth[2] Disc	Growth[2] **avg.**	Ear Leaf[3] (8/29/92) N[4]	Ear Leaf[3] P[5]	Ear Leaf[3] K[6]	Ear Leaf[3] Zn[7]	Yield[8] Fngr	Yield[8] Disc	Yield[8] **avg.**	Testwt[9] Fngr	Testwt[9] Disc	Grain Moisture[10] Fngr	Grain Moisture[10] Disc	Grain Moisture[10] **avg.**
	--plts/ac--			--lvs/plt--			-------%------			-ppm	---bu/ac---			-lbs/bu-		-----%------		
NoTill	25.2	25.9	**25.6**	8.97	9.30	**9.14**	2.81	.275	1.45	16.5	63.8	66.0	**64.9**	47.8	47.8	27.1	26.8	**27.0**
Chisel	25.3	25.0	**25.2**	9.52	9.58	**9.55**	2.66	.254	1.46	18.8	69.0	66.0	**67.5**	48.2	48.2	26.4	27.0	**26.7**
average	**25.2**	**25.4**		**9.24**	**9.44**		**2.74**	**.264**	**1.46**	**17.6**	**66.4**	**66.0**		**48.0**	**48.0**	**26.8**	**26.9**	

1. Measurement taken on 6/1/92. The p values for the tillage, row cleaner, and the tillage by row cleaner interaction are .514, .684, and .389 respectively.
2. Measurement taken on 7/1/92. The p values for tillage, row cleaner and the tillage by row cleaner interaction are .112, .035, and .096 respectively.
3. Ear leaf samples were taken on 8/29/92. Fertilizer was applied at planting placed 2" below and 2" beside the seed (5/8/92) at 120 lbs/a as 9-23-30. The soil test is: pH=7.9, Olsen P=20ppm,and Ammonium Acetate Extractable K=178ppm.
4. The p value for tillage is .682. Sufficiency value for corn ear leaf N is 2.75%.
5. The p value for tillage is .350. Sufficiency value for corn ear leaf P is .25%.
6. The p value for tillage is .992. Sufficiency value for corn ear leaf K is 1.80%.
7. The p value for tillage is .150. Sufficiency value for corn ear leaf Zn is 20.0ppm.
8. Yields were measured on 10/19/92. The p values for the tillage, row cleaner, and the tillage by row cleaner interaction are .028, .823, and .169 respectively.
9. The p values for tillage, row cleaner and the tillage by row cleaner interaction are .422, 1.00, and 1.00 respectively.
10. The p values for tillage, row cleaner and the tillage by row cleaner interaction are .756, .831, and .461 respectively.

Table 4. Cultural practices for 1992 production season on the Julian Sjostrom farm, Pelican Rapids, Mn.

Design A randomized complete block design with 3 replications was used for this demonstration.

Tillage treatment

1. No Till split with and without manure incorporation with field cultivator 5/12/92
2. Fall chiseled 9/15/91 15" spacing, 4" twisted shovel. Field cultivated 5/12/92

Planting and Harvesting Date

The planter is a John Deere 7000 4-36"row with rolling fingers and clearing discs. Hybrid was 85 day Sigco 1885. Previous crop oats with straw removed.

Crop	**Planting** Date	Rate	**Harvested** Grain
corn	May 12,1992	25,200seeds/A	10/17/92

Soil Chappett-Sisseton loam complex 100% slope 12-20, average = 15%

Fertilizer Starter 30-10-10 94 lb/acre applied on 5/12/92

Weed control

Accent/Banvil 2/3 oz and 3/4 pt/acre on 6/11/92
Ranger 1.4 qt./acre on 8/12/92

Rainfall April-Nov. 17.21"

Manure analysis and rate of applied nutrients

sample [1]	**Total**	**Volatile**	**Fixed**	**pH**	**Tot-N**	**Org-N**	**Min-N**	**Amm-N**	**Nit-N**	**Avail-N**[2]	P_2O_5	K_2O
	-------percent---------				--------------Pounds per 1000 gals.------------							
Sjostrom 1.	7.84	81.25	18.75	6.6	32	17	16	15	.36	21	17	32
Sjostrom 2.	11.38	82.58	17.42	6.9	39	22	17	17	.02	24	24	34
Average	**9.61**	**81.92**	**18.08**	**6.8**	**36**	**19**	**16**	**16**	**.19**	**22**	**21**	**33**

1. Each sample was run in duplicate. Samples were taken in April and early summer or 1992 respectively.
2. Estimated available Nitrogen = Organic-N x .30 (mineralization factor) + Total mineral-N.

Table 5. The effect of planter mounted tools and tillage system on soil cover by oat residue on the Julian Sjostrom farm, Pelican Rapids, Mn. 1992

	5/14/92[2]				6/2/92[3]					
	Row position[1]				Fingers[4]			Disc[5]		
	In	Betwn	Diagn	Wtavg[6]	In	Betwn	Diagn	In	Betwn	Diagn
Tillage	----------%----------				------%------			------%------		
NoTill	14.0	40.0	32.0	34.0	37.2	59.0	48.0	36.0	57.8	50.0
Chisel	6.0	49.0	39.0	40.0	20.8	59.0	39.7	21.2	47.6	47.7

1. Column headings represent "in row" defined as a 8 inch strip centered over the row, the second column is the remainder of the area or "between the row", the next column is the cover made by a line transect measurement diagonal to the row, and the last column is a weighted average of the "in" and "between the row" measurements.
2. The p values for the analysis of variance for the fingers treatment only, for the tillage, row position, and the tillage by row position interaction are .945, .021, and .643 respectively.
3. The p values for the analysis of variance for tillage, row cleaner, and the tillage by row cleaner interaction are .531, .941, and .894 respectively.
4. This row cleaner is a pair of discs oriented in a V shape with the concave outward.
5. This row cleaner is a pair of interlocking spiked wheels oriented in a V shape.
6. The weighted average =[(in row x 8") + (between x 28")]/36.

Table 6. The effect of planter mounted tillage tools and tillage system on corn response.

	Stand[1]			Growth[2]			Ear Leaf[3](8/29/92)				Grain Yield[8]			Testwt[9]		Moisture[10]		
	Fngr	Disc	**avg.**	Fngr	Disc	**avg.**	N[4]	P[5]	K[6]	Zn[7]	Fngr	Disc	**avg.**	Fngr	Disc	Fngr	Disc	**avg.**
Tillage	--plts/ac--			--lvs/plt--			------%-------			ppm	---bu/ac---			-lbs/bu-		-----%-----		
NoTill	20.4	23.5	**22.0**	11.4	10.8	**11.1**	2.72	.373	1.97	23.9	55.6	57.5	**56.6**	47.5	47.8	27.8	26.5	**27.2**
Chisel	21.3	22.4	**21.8**	11.4	10.6	**11.0**	2.84	.358	1.94	21.5	62.7	63.2	**63.0**	47.5	47.5	27.9	27.3	**27.6**
average	**20.8**	**23.0**		**11.4**	**10.7**		**2.78**	**.366**	**1.96**	**22.7**	**59.2**	**60.4**		**47.5**	**47.6**	**27.8**	**26.9**	

1. Measurement taken on 6/1/92. The p values for tillage, row cleaner, and the tillage by row cleaner interaction are .957, .173, and .468 respectively.
2. Measurement taken on 7/6/92. The p values for tillage, row cleaner, and the tillage by row cleaner interaction are .584, .005, and .734 respectively.
3. Ear leaf samples were taken on 8/29/92. Fertilizer was applied at planting placed 2" below and 2" beside the seed (5/12/92) at 94 lbs/a as 30-10-10. The soil test is: pH=7.8, Olsen P=>50ppm,and Ammonium Acetate Extractable K=233ppm.
4. The p value for tillage is .639. Sufficiency value for corn ear leaf N is 2.75%.
5. The p value for tillage is .687. Sufficiency value for corn ear leaf P is .25%.
6. The p value for tillage is .735. Sufficiency value for corn ear leaf K is 1.80%.
7. The p value for tillage is .304. Sufficiency value for corn ear leaf Zn is 20.0ppm.
8. Yields were measured on 10/17/92. The p values for the tillage, row cleaner, and the tillage by row cleaner interaction are .322, .137, and .304 respectively.
9. The p values for tillage, row cleaner and the tillage by row cleaner interaction are .423, .374, and .374 respectively.
10. The p values for tillage, row cleaner and the tillage by row cleaner interaction are .834, .107, and .461 respectively.

Table 7. Corn response to spring applied manure incorporation on oat stubble with field cultivation[1]

	10/17/92								
	Yield[2]			Testwt[3]			Moisture[4]		
	Fingers	Disc	avg	Fingers	Disc	avg	Fingers	Disc	avg
Manure	----bu/a----			----lb/bu----			-----%------		
No Incorp.	55.2	56.2	**55.7**	47.5	48.0	**47.8**	27.5	27.0	**27.2**
Incorp.	66.0	65.0	**66.0**	47.5	47.5	**47.5**	27.5	28.0	**27.8**

1. Liquid manure was applied to all plots on 5/4/92 at a rate of 4800 gal/a. Manure was incorporated on half of the no till plots with a field cultivator. Analysis of N,P, & K- (36 lbs, 21 lbs, & 33 lbs)/1000 gallons. As total N, P_2O_5, & K_2O respectively.
2. The p values for the analysis of variance for manure, row cleaner, and the manure by row cleaner interaction are .187, .979, and .347 respectively.
3. The p values for the analysis of variance for manure, row cleaner, and the manure by row cleaner interaction are .500, .423, and .423 respectively.
4. The p values for the analysis of variance for manure, row cleaner, and the manure by row cleaner interaction are .295, 1.00, and .184 respectively.
5. This row cleaner is a pair of interlocking spiked wheels oriented in a V shape.

Incorporation of spring applied dairy manure with field cultivation on plots with no other tillage did not affect corn yields, test weight, or moisture.

Data collected on the Orland Ohe farm are presented in tables 8 and 9. At this site two different drills are evaluated with two levels of spring tillage (none and discing). Although discing reduced soil cover by crop residue it was not affected by drill type. Stands were higher under no till conditions although plant stands are high enough to not be expected to influence yields. Soybean yields, test weight, and moisture were not affected by tillage or drill type. There was a significant affect of tillage, drill type, and tillage by drill type interaction for soil cover by lambsquarter. Lambsquarter were more prevalent under discing and Haybuster treatments.

Table 8. Cultural practices for 1992 production season on the Orland Ohe farm, Rothsay, Mn.

Design A randomized complete block with split plots with tillage main plots and drill type subplots was used on this demonstration. The number of replications is three.

Tillage treatment 1. No Till; 2. Spring disced 5/14/92 with 12' offset disc; fall chiseled 10/18/92 with 12" spacing and 3" twisted shovels.

Drill treatments Tillage plots were split with two drills: 1)International Harvester (IH) with Yetter 5/8" coulter cart with 7" row spacing and 2) Haybuster (HB) no till drill double disc openers, row spacing 7". Soybean variety Glenwood.

Planting			Harvested
Crop	Date	Rate	Grain
soybean	May 19,1992	56 lbs/acre	10/12/92

Soil
Formdale-Buse Udic Haploboroll-Udorthentic Haploboroll complex 60% clay loam slope 2-6, avg.= 4%
Formdale-Langhi clay loam Udic Haploboroll- complex slope 6-12 9 20%
Aazdahl clay loam Aquic Haploboroll slope 0-3 1 20%

Fertilizer None

Weed control
Basagran + Poast Plus .5 lb/acre and .25 lb/acre on 6/20/92
Blazer on 6/28/92

Rainfall April-Nov. 15.10"

Table 9. The effect of tillage and drill type on soil cover by corn residue and soybean response.

	Soil cover																
	Drill type[1]			Row postn.[2]			Yield[3]			Stand[4]		Testwt[5]		Moisture[6]		
	IH	HB	avg.	IN	BET	WTX[10]	IH	HB	avg.	avg.	sdev.	IH	HB	IH	HB	avg.
Tillage	----%-----			----%----			----bu/acre----			-10^3plts/ac-		-lbs/bu-		------%------		
No Till	76	76	**76.0**	79	88	**86**	17.9	15.3	**16.6**	232	64.9	59.1	59.0	10.2	10.4	**10.3**
Disced	33	33	**32.8**	37	54	**50**	21.8	18.0	**19.9**	175	56.8	59.1	59.1	10.2	10.1	**10.2**
average	**54**	**54**		**58**	**71**		**19.8**	**16.6**		**204**		**59.1**	**59.0**	**10.2**	**10.3**	

Table 9 (cont.) Weed response to tillage system and drill type.

	Weeds								
	Lambsqtr.[7]			Thist.[8]			Ragweed[9]		
	IH	HB	**avg.**	IH	HB	**avg.**	IH	HB	**avg.**
Tillage	---% cover---			---% cover--			--% cover---		
No Till	17.3	19.7	**18.5**	1.5	3.0	**2.2**	3.0	5.3	**4.2**
Disced	18.3	28.3	**23.3**	1.7	3.3	**2.5**	2.0	3.0	**2.5**
	17.8	**24.0**		**1.6**	**3.2**		**2.5**	**4.2**	

1. Measurement on 5/19/92. The p values for tillage, drill type, the tillage by drill type interaction are .006, .336, and .444 respectively. The two drills used were: 1)International Harvester (IH) with Yetter coulter cart and 2)Haybuster (HB) no till drill.
2. Measurement on 6/9/92. The p values for tillage, row, tillage by row interaction are .128, .143, and .652 respectively.
3. Measurements taken on 10/12/92 for variables 3-8. The p values for tillage, drill type, and the tillage by drill type interaction are .134, .152, and .737 respectively.
4. Measurement on 6/9/92. The p value for tillage is .076.
5. The p values for tillage, drill type, and the tillage by drill type interaction are .184, 1.00, and .230 respectively.
6. The p values for tillage, drill type, and the tillage by drill type interaction are .539, .696, and .276 respectively.
7. The p values for tillage, drill type, and the tillage by drill type interaction are .066, .018, and .074 respectively.
8. The p values for tillage, drill type, and the tillage by drill type interaction are .889, .305, and .954 respectively.
9. The p values for tillage, drill type, and the tillage by drill type interaction are .038, .298, and .658 respectively.
10. WTX represents the weighted average of = [(in row x 2") + (between x 5")]/7".

The cultural practices and spring wheat response to tillage system on the Evert Gilbertson farm are shown in tables 10 and 11. There was no affect of tillage on wheat stand, tillering, or yield. Protein levels were higher under disc system. Broadcast urea on soil covered with about 50% residue may have resulted in volatilization losses and a reduction in grain protein.

Table 10. Cultural practices for 1992 production season on the Evert Gilbertson farm, Battle Lake, Mn.

Design A randomized complete block design with 3 replications.

Tillage

1. No Till
2. Spring disced 4/30/92; disc is 22' and has 11" spacings with a spike toothed harrow pulled behind.

Fall chisel plowed 1992

Planting and Harvesting Date

The planter was a Haybuster 107 7"spacing
The spring wheat variety is Gus.
Previous crop soybeans.

Planting			Harvested
Crop	Date	Rate	Grain
wheat	May 1,1992	1.5 bu/acre	9/17/92

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 (46-0-0) spread 150 lb/acre 4/29/92.

Weed control

Roundup + surfactant at 1 qt/a on 4/20/92
Curtail for thistle 2 pt/a on 6/1/62

Rainfall April-Nov. 11.06"

Table 11. Wheat response to tillage system in soybean residue.

	5/12	5/29	7/2	7/2	9/17			
	Residue	Stand	Heads	Tiller	Yield	Moist.	Tst.wt.	Protein
Tillage	--%--	10^3/a	10^6/a	hds/plt	bu/a	--%--	lb/bu	--%--
NoTill	44.1a	455a	1.59a	3.49	55.7a	18.6a	61.0a	13.0a
Disced	8.4b	476a	1.68a	3.52	55.9a	19.1a	60.3a	14.0b

1. Means in the same column followed by different letters are statistically different, α =.10.

The results of a study evaluating fall chisel plowing and no tillage on a loamy sand soil are shown in tables 12 and 13. Although residue levels were lower than the study on the Evert Gilbertson farm the results were similar. There was no effect of tillage on yield, stand, or protein. No tillage conditions did result in higher tillering.

The effect of stalk chopping on soil cover with corn stalks was evaluated at this site. Stalk chopping doubled soil cover after drilling no till soybeans with a John Deere 750 no till drill (36 to 70%). An additional chisel plowing followed with secondary tillage only slightly reduced soil cover.

Table 12. Cultural practices for 1992 production season on the Dave Holt farm. Elizabeth, Mn.

Design A randomized complete block design with 3 replications.

Tillage treatments

1. Fall chiseled in 1991. Spring field cultivation 1992 on chisel plots.
   Fall chiseled 9/10/92 12" spacing with John Deere Mulch chisel.
2. No Till

Planting and Harvesting Date

The planters were 1) John Deere 750 No-till 7" spacing on no-till plots and 2) John Deere 9300 drill on chiseled plots with 6" spacing.
The wheat variety is Butte 86.
Previous crop soybeans.

Planting			Harvested
Crop	Date	Rate	Grain
wheat	April 8,1992	2.0 bu/acre	8/19/92

Soil Sandberg loamy sand on 100% of the plot area; slope 4-9%

Fertilizer

NH_3 72 lb/acre on 10/27/91
Starter 15-38-10 100 lb/acre on 4/8/92
0-0-60 bulk spread 80 lb/acre by spin spreader applied on 4/7/92.

Weed control MCPA ester 3/4 pt/acre on 5/21/92

Rainfall April-Nov. 16.75"

Table 13. The effect of tillage system on soil cover by soybean residue and wheat response.

	4/28	5/14	7/6	7/6	8/19			
	Residue	Stand	Heads	Tiller	Yield	moist.	Tst wt.	Protein
Tillage	--%--	-10^3/a-	10^6/a	hds/plt	-bu/a-	--%--	lb/bu	--%--
No Till	17.2a	444a	2.35a	5.29	47.4a	15.6a	63.0a	13.6a
Chisel	6.9b	555a	1.78b	3.21	48.5a	15.4a	62.7a	13.7a

Cover with corn stalks	
Chopping	--%--
1.chop	70.0a
2.nonchop	36.3b
3.chop, chisel multiweed	27.2b

1. Means in the same column followed by different letters are statistically different, α =.10.
2. This was a separate field study to look at residue amounts form several chopping. Soybeans were planted with a John Deere 750 No till planter.

TILLAGE COMPARISON AT ROSEMOUNT
ROSEMOUNT, 1992

T.L Hansmeyer, D.R. Linden, K.L. Walter,
R.H. Dowdy, R.R. Allmaras and C.E. Clapp

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 objective of the study is 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. Temperature and precipitation was collected at the Rosemount experiment station table 2.

Experimental Procedure The site was separated into 36 plots of 0.4 acre each. A continuous corn (CC), soybean/corn (SC) *[corn 1992]*,and corn/soybean (CS) *[soybean 1992]* rotation was 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 seed bed 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 re-establish ridges.

MINIMIZED 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.

Corn (Pioneer 3751) was planted in the CC and SC plots across all tillage systems on May 13. The seeds were planted at a population of 28,000 seeds/acre. Force insecticide was banded over the row at a rate of 9 oz./1000 ft of row. Soybeans (Sibley) were planted into the T1, T2, and T3 tillage systems on May 13 and tillage T4 on May 21. All soybeans were planted at the rate of 60 lbs/acre. Alachlor (Lasso) was broadcast at a rate of .75 lb ai/ac on all CC and SC plots May 13. A mix of 2.5lb ai/ac alachlor (Lasso) and .75 lb ai/ac metribuzin (Sencor) was applied on all CS plots May 15. 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. A 28% solution of Nitrogen at 125 lbs N/acre was applied on all CC and SC plots during cultivation June 15. Cultivated all CS plots except T4 (Minimized tillage) plots, since corn residue prevented cultivation. Applied 3/4 pt/ac sethoxydim (Poast) with 2 pt/ac crop oil on all CS plots June 29. Broadcast 1 lb ai/ac bentazon (Basagran) across all plots July 1. Created ridges in all ridge-till (T3) plots planted to corn on July 6. Cultivated all soybean plots except T4 July 10. Created ridges in soybean T3 plots July 28. Observed and recorded stands during the season and recorded final plant populations in all plots on Oct. 2.

Combined 12 center rows in all soybean plots Oct. 26. Combined 12 center rows in all corn plots Nov. 11. Corn stalks chopped and fall tillage performed Nov. 12-14.

Results Grain yields from all tillages and rotations are given in figures 1-3 and table 1. Grain moisture contents, final plant stand and a Crop Stress Rating (CSR) are also shown in figure 1-3. The crop stress rating is a qualitative estimate of potential yield reduction. All crop stress conditions including grass and/or broadleaf competition and frost damage are evaluated for each cropping system. The crop stress conditions occurring in each system are then tallied creating the CSR values. Larger CSR values indicate a higher potential of yield reduction.

Within the continuous corn system, grain yields from the ridge-till plots out yielded all other tillages followed by conventional, conservation and minimum-till in that order. Statistically, ridge-till yields were significantly higher than yields from the conservation and minimum-till plots. Yields from the conventional tillage plots were significantly higher than yields from the minimum-till plots (fig. 1).

Corn grain yields in the various tillages under the Soybean/Corn rotation were not significantly different (Fig 2). The same was true when comparing the soybean yields in the Corn/Soybean rotation (Fig 3).

The mean yield for each tillage indicates that ridge-till produced the highest yield followed by conventional, conservation and minimum-till, respectively. The grain yields from ridge and conventional tillage are significantly higher than the yields from conservation or minimum-till (figure 5). Also, the mean corn grain yields for each rotation in 1992 indicates that the rotation soybean/corn (CS) with a mean yield of 148 bu/ac had a significantly higher yield than continuous corn (CC) at 116 bu/ac (figure 4). Ridge-tillage reacted much more favorably under the continuous corn yielding 18.5% above the mean yield for that rotation, whereas ridge-till out yielded the mean yield under the Soybean/Corn rotation by only 3%.

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 recent 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 soybeans stubble on the surface. Ridge-till provided sufficient residue to qualify under the corn/soybean rotation, but only produced 28% residue cover under the continuous corn rotation. Ridge-till buried a majority of the soybean stubble under the soybean/corn rotation leaving only 12% 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 24% residue cover at planting.

Analysis of variance has shown that a significant difference exists between the soybean and corn residue cover of each tillage. Statistically, an interaction effect occurs between the rotation and tillage. The interaction effect is caused by the unusually high amount of soybean residue remaining immediately after planting under the conventional and conservation tillage systems (fig. 5). In the conventional system, the soybean stubble is chisel plowed whereas corn stubble is plowed burying a higher percentage of the residue. A similar situation occurs under the conservation system. Corn is no-tilled into the soybean stubble leaving all soybean residue on the surface whilst corn residue is chisel plowed.

Table 1 Grain yields for the tillage study at Rosemount Study, 1992.

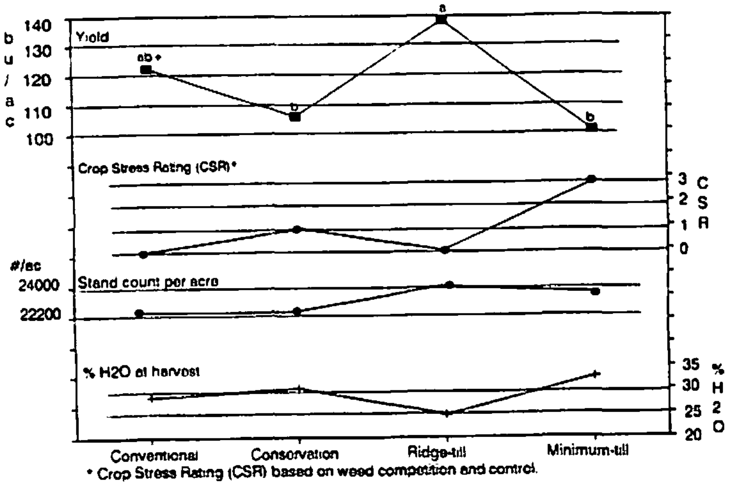
Treatment			Yield	
Tillage	Rotation		bu/ac	mt/ha
Conventional (T1)	Cont.Corn	(CC)	122	6.49
	Corn 92	(SC)	152	8.08
	Soybean 92	(CS)	41	2.38
Conservation (T2)	Cont.Corn	(CC)	106	5.61
	Corn 92	(SC)	143	7.58
	Soybean 92	(CS)	41	2.39
Ridge-Till (T3)	Cont.Corn	(CC)	138	7.33
	Corn 92	(SC)	153	8.13
	Soybean 92	(CS)	38	2.23
Minimum-Till (T4)	Cont.Corn	(CC)	101	5.35
	Corn 92	(SC)	145	7.69
	Soybean 92	(CS)	37	2.18

Table 2
Growing season precipitation and degrees days at Rosemount, Minnesota (1992).

	Precipitation			Degree Days 2/		
	Normal 1/	1992	Departure from normal	Avg	1992	Departure from normal
	cm			°C		
May	9.37	2.46	-6.91	156	233	+77
June	12.12	12.50	+0.38	270	264	-8
July	9.09	15.80	+6.71	385	268	-117
Aug.	10.9	10.95	+0.05	328	264	-64
Sept.	8.05	14.61	+6.56	160	205	+45
Totals	49.53	56.32	+6.79	1300	1234	-66

1/ Normal monthly precipitation for Rosemount, MN (1951-1980).
2/ Base temperature = 10°C.

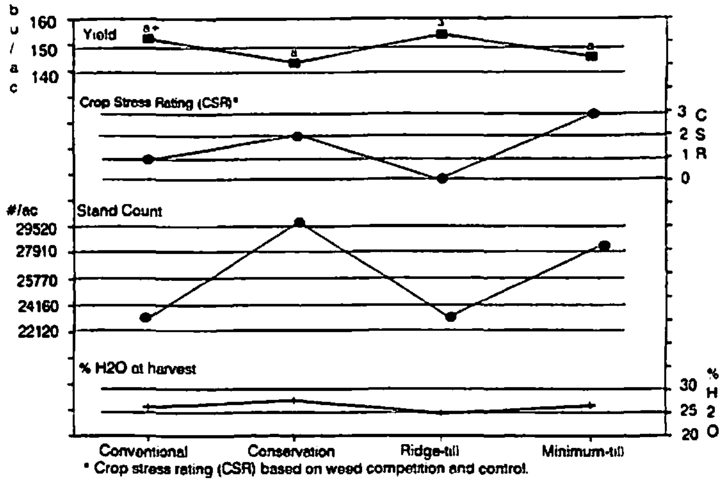
Figure 1 CONTINUOUS CORN (CC)



* Crop Stress Rating (CSR) based on weed competition and control.

\+ Letters represent significant differences at the 5% significance level using the Student Newman Kouls Test.

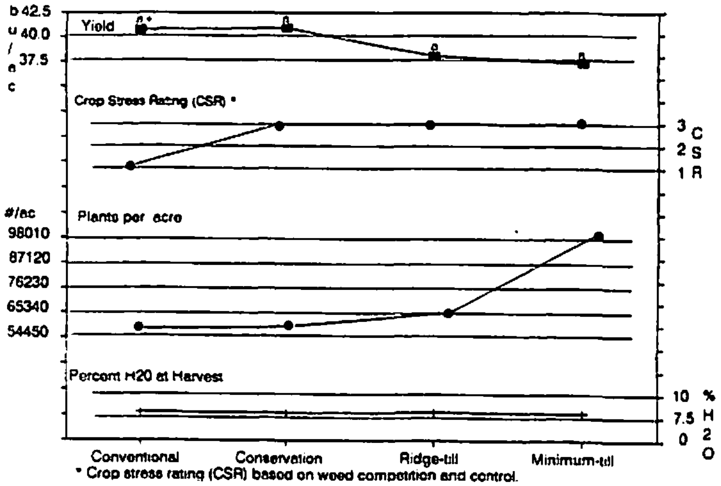
Figure 2 CORN FOLLOWING SOYBEANS (SC)



* Crop stress rating (CSR) based on weed competition and control.

\+ Letters represent significant differences at the 5% significance level using the Student Newman Kouls Test.

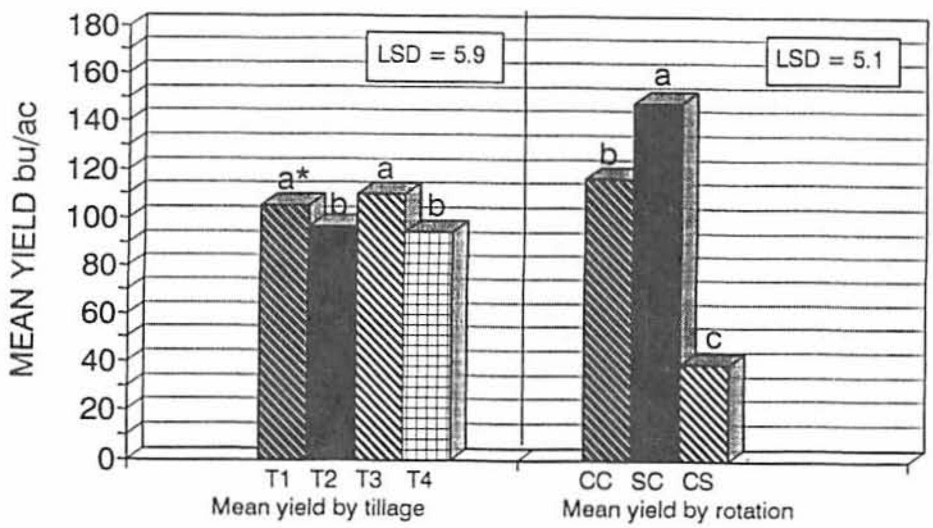
Figure 3 SOYBEANS FOLLOWING CORN (CS)



* Crop stress rating (CSR) based on weed competition and control.

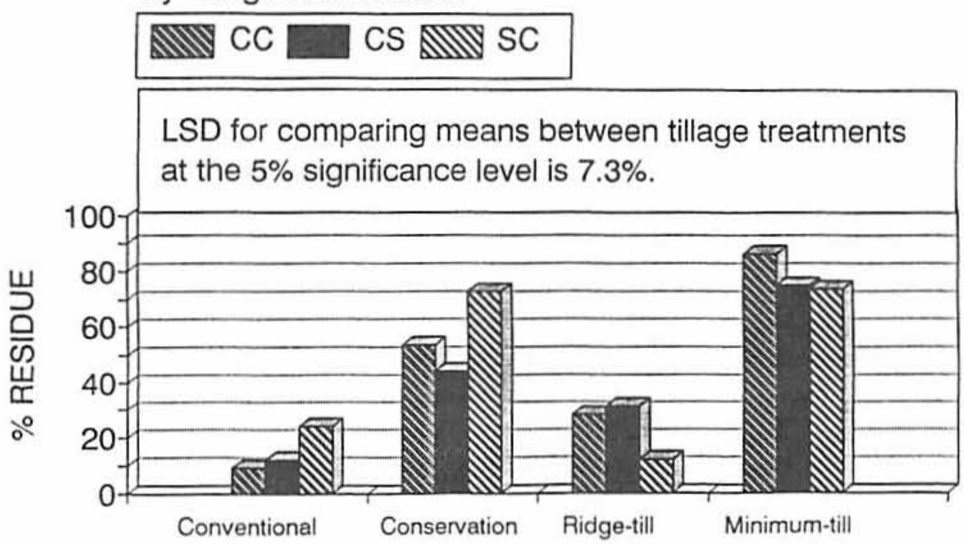
\+ Letters represent significant differences at the 5% significance level using the Student Newman Kouls Test.

Figure 4
MEAN YIELD COMPARISON
by Tillage and Rotation



* Letters represent significant differences at the 5% significance level using the Student Newman Keuls Test.

Figure 5
RESIDUE COMPARISON
by Tillage and Rotation



THE EFFECT OF TILLAGE AND NUTRIENT SOURCE ON CORN YIELD AND SOIL PHOSPHORUS DISTRIBUTION[1]

P. M. Bongard, T. L. Wagar, J. F. Moncrief, R. B. Hamer, and T. J. Arlt[2]

Abstract. Two sites were selected in the south central Minnesota to demonstrate nutrient contributions from turkey manure. Applications rates were based on anticipated nitrogen needs for a corn crop following soybeans, and the manure was spring incorporated with a disc or a field cultivator. Soil phosphorus (P) levels in the top four inches of the manured treatments were increased two-fold over the check. Phosphorus distribution between the incorporation techniques did not differ significantly at the Morristown site. However, soil P of the disc-incorporated manure at Medford showed a more even distribution from the surface to a six-inch depth. At Morristown, manured treatment ear leaf nitrogen (N) contents and yields were at least as high as those in the fertilizer treatment. In contrast, fertilizer treatment ear leaf N contents and yields were significantly better than manured treatments and the check at Medford. While turkey manure can provide significant amounts of nutrients to crops, relying on the manure as the only nitrogen source may be risky under certain environmental conditions.

Introduction

Animal wastes can contribute substantial amounts of nutrients to crops, thus reducing producers' reliance on chemical fertilizers to maintain yields and profitability. Since turkey production has become a major industry in Minnesota, opportunities for wisely utilizing this animal waste are increasing. The objective of this demonstration was to show nutrient contributions to corn and to compare incorporation techniques of turkey manure. This demonstration is a follow-up to a study reported in the "Report on Field Research in Soils - 1991" that demonstrated nutrient contributions from tom-finish and brood turkey manures.

Materials and methods

Two sites which had no previous history of manure applications were selected near Morristown and Medford, Minnesota, for this demonstration. Soil classification and spring soil test results can be found in Table 1.

Turkey tom-finish manure with wood chip litter was taken from a storage pile for use in this demonstration. The tom-finish barns are skimmed after every flock (every 14-15 weeks), cleaned yearly and roto-tilled regularly.

The turkey manure was applied to meet the anticipated nitrogen (N) needs of the corn crop. The resulting rates were based on manure analysis (Table 2), previous crop, soil organic matter contents, and corn yield goals. The manure was applied at eight tons per acre at Morristown, and at six-and-a-half tons per acre at Medford on May 5 and incorporated immediately.

Two incorporation techniques of the manure were compared at each site: 1) incorporation with a disc; and 2) incorporation with a field cultivator. An untreated plot and a pre-plant commercial fertilizer treatment were also included in the demonstration. The fertilizer nitrogen, phosphate and potash rates can be

---

[1]Funding provided by the Board of Soil and Water Resources through Environmental Agriculture Education Program Challenge Grant of County Cluster 16 (Freeborn, Mower, Rice, and Steele counties), Minnesota Extension Service.

[2]Environmental Agriculture Educator, Cluster 16; Area Extension Agent, Crops and Soils; Extension Specialist; Extension Educators, Rice and Steele counties, respectively; Minnesota Extension Service.

seen in Table 3. Fertilizer was applied on May 6 and incorporated immediately. Rainfall records and additional cultural practices can be seen in Tables 4 and 5.

The demonstrations were arranged in a randomized complete block with four replications. The fourth replication was dropped at Medford because of uneven manure spread. Plots were eight-row plots wide and 150 feet long at Morristown and six-rows wide and 200 feet long at Medford.

Soil P stratification was measured in the two manured treatments and the untreated plots at the end of July. Ten core composite samples were taken in two-inch increments from the soil surface to a depth of six inches both in and between the row. Ear leaves were sampled for total N (Kjeldahl with nitrate reduction) in these treatments at this time, also. Corn grain yields were measured at Morristown by hand harvesting and shelling ears from thirty-five feet of row, weighing the samples, and oven drying sub-samples to measure dry weight. At Medford, plots were machine combined with the farmer's eight-row equipment, weighed, and adjusted to 15.5% moisture. Rainfall amounts for the season are recorded in Table 5.

Results and discussion

Soil P levels in the top four inches were doubled in the turkey manure treatments over the untreated check at both sites (Figures 1 and 2), while there were no significant increases at the four-to-six inch depth increment. Soil P was distributed more evenly in the disc-incorporated treatment than in the field cultivator treatment at Medford, while there were no significant differences between incorporation methods at Morristown. Only 39% of the total P was found in the top two inches in the disc-incorporated manure treatment at Medford, while 50% of the total P remained in the top two inches in the rest of the manured treatments at the sites. The more even soil P distribution of this treatment could be expected from the large disc used at Medford (Table 4).

Ear leaf N contents were statistically equal between the manured and fertilizer treatments at Morristown, but these levels were significantly higher than those in the check (Table 6). In contrast, N contents differed significantly in all treatments at Medford. Nitrogen contents of the fertilizer treatment were significantly better than manured treatments, and all treatments had higher N contents than the control.

At Morristown, manured treatment yields were equal to or better than the fertilizer treatment, and all treatments with additional N were significantly better than the check (Figure 3). In contrast, the manured treatments at Medford yielded less than the fertilizer treatment and were statistically equal to the control (Figure 4). At this site, plants in the check and manured plots exhibited stunting and the typical leaf chlorosis and necrosis which is symptomatic of N stress. The cool summer may have limited mineralization of the organic nitrogen, thus reducing the expected N contribution from the manure. It is also possible that there was more denitrification in the finer soil at Medford than in the loam soil at Morristown. The cool summer, mid-season and early frosts also delayed development of the corn, as evidenced by the grain moisture contents at harvest (Figure 4). These combined factors may explain the poor performance of the turkey manure at the Medford site. Corresponding returns over the nutrient costs can be seen in Figure 5.

Conclusions

Turkey manure can contribute substantial amounts of nutrients to corn. Grain yields from the 1990 study and the Morristown site in 1992 were at least as high as those in the commercial fertilizer treatments. However, relying on turkey manure as the only source of nitrogen may be risky, as evidenced by the results at Medford. At these rates of turkey manure (6-8 tons/acre), phosphorus and potassium are often applied in significant excess of crop needs. While these minerals are immobile in the soil, nutrient displacement could occur with soil runoff and should be examined. Future work could also examine a range of turkey manure rates for optimum nutrient utilization.

Acknowledgements

The authors would like to thank Dan Morris of Morristown and Jeff Bruessel of Medford for the use of their land, equipment, and labor to conduct these demonstrations. We would also like to thank Gene Morris of Morristown for providing seed, and George Raab at Jerome Foods, Inc. for providing the turkey manure.

Table 1. Soil classification and spring soil test results for turkey manure field demonstrations at two sites, April 1992.

LOCATION	SOIL CLASSIFICATION SERIES	SUBGROUP	ORDER	SOIL TEST O.M.	P	K
					ppm	
Morristown	Clarion- Storden (loam)	Typic Hapludoll Typic Udorthent	Mollisol Entisol	Med	32	166
Medford	Maxcreek (sicl)	Typic Haplaquoll	Mollisol	High	20	119

Table 2. Turkey manure analysis, application rates and estimated nutrients applied to demonstration sites, 1992.

LOCATION	TURKEY MANURE ANALYSIS MOISTURE	N_{TOT}	N_{MIN}	N_{ORG}	P_2O_5	K_2O	RATE	ESTIMATED MANURE NUTRIENTS APPLIED[1] N_{TOT}	N_{AVAIL}	P_2O_5	K_2O
	%						ton/A	lb./A			
Morristown	44.3	2.25	1.58	0.68	2.7	1.8	8.0	360	184	432	264
Medford	44.3	2.25	1.58	0.68	2.7	1.8	6.5	292	150	351	214

[1]First year N availability based on 30% organic N and 100% mineral N contents.

Table 3. Fertilizer application at demonstration sites, May 6, 1992.

NUTRIENT	MORRISTOWN[1]	MEDFORD
	lb./A	
N	191	150
P_2O_5	29	0
K_2O	38	60

[1]125 lb. 9-23-30 applied as starter to all treatments.

Table 4. Rainfall records for demonstration sites, 1992.

MONTH	MORRISTOWN[1]	MEDFORD
	inches	
April	1.5	not
May	0	avail-
June	3.6	able
July	3.6	
Aug.	5.0	
Sept.	3.2	

[1]Frost dates: 5/28, 6/21, and 9/21.

Table 5. Management practices used at turkey manure demonstrations sites, 1992.

	MORRISTOWN	MEDFORD
Variety	DeKalb 501	DeKalb 501
Planting date	May 6	May 8
Population	27,500	26,600
Primary tillage	none	none
Disc	14' Oliver	24' Kewanee Tandem
Field cult.	28' Case Int. digger 6"spacing w/ 7" sweeps	27' Kewanee 6" spacing w/ 7.5" shovels

Herbicide	Partner[3] pre-em (2.5 lb. ai/A) Bladex (3 lb. ai/A) Marksman post. (1.2 lb. ai/A)	Accent post. (0.031 lb. ai/A) Marksman post. (1.4 lb. ai/A)

Table 6. Ear leaf nitrogen contents for turkey manure demonstrations at Morristown and Medford, July 28, 1992.

SOURCE	EAR LEAF NITROGEN	
	MORRISTOWN	MEDFORD
	%	
Check	2.2 b[1]	2.3 d
Fertilizer	3.0 a	3.0 a
Manure-disc	2.8 a	2.8 b
Manure-F.C.	2.8 a	2.6 c

[1]Data followed by the same letter in the same column are not significantly different at the 0.05 level.

[3]Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Minnesota Extension Service is implied.

Figure 1. In-row soil P distribution at three two-inch depth intervals at Morristown, July 28, 1992.

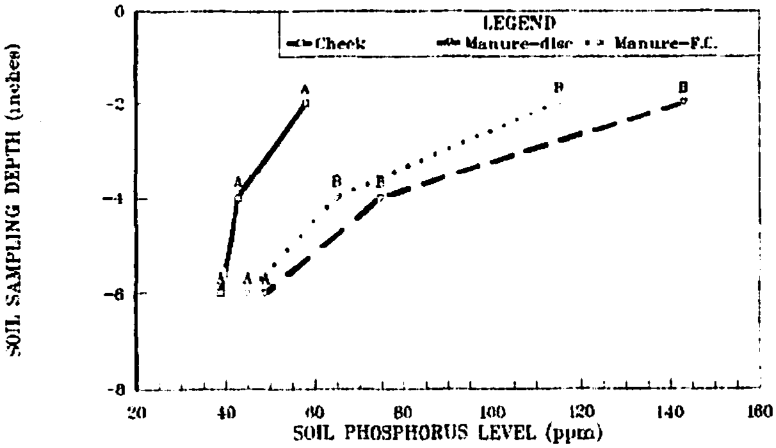
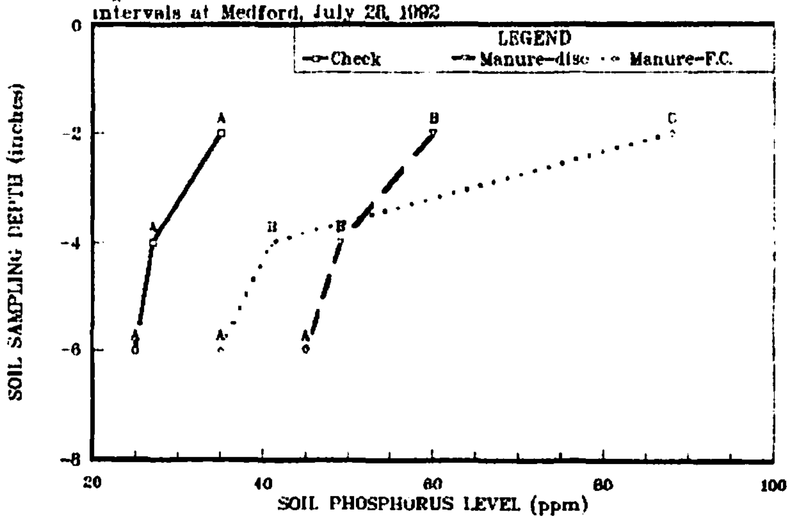
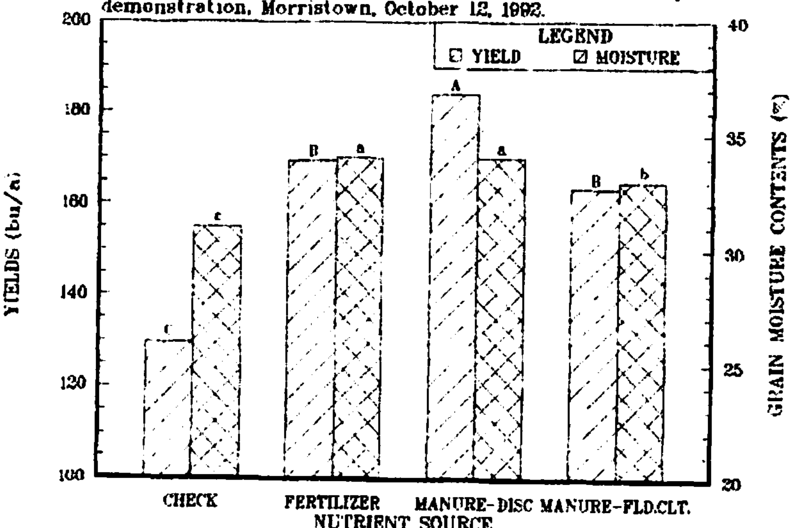


Figure 2. In-row soil P distribution at three two-inch intervals at Medford, July 28, 1992



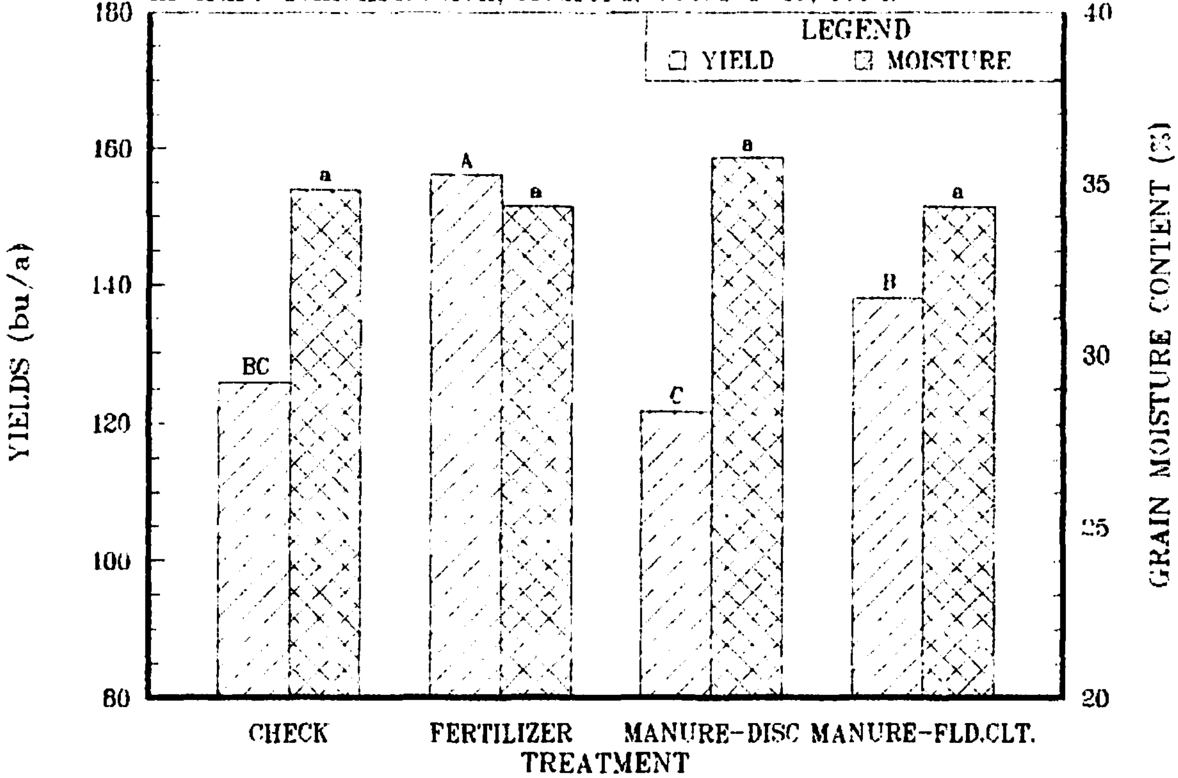
Data followed by the same letter at the same sampling depth and site are not significantly different at the 0.05 level.

Figure 3. Yields and grain moisture contents for turkey manure demonstration, Morristown, October 12, 1992.



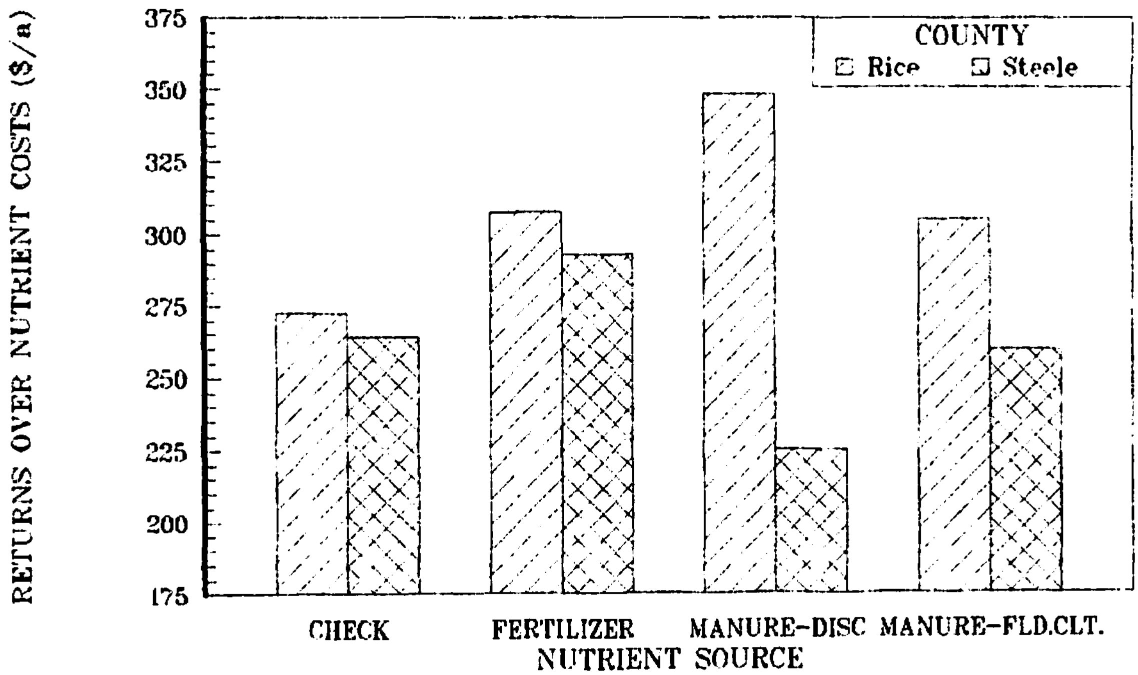
Data followed by the same upper- or lower- case letter are not significantly different at the 0.05 level.

Figure 4. Yields and grain moisture contents for turkey manure demonstration, Medford, October 29, 1992.



Data followed by the same upper- or lower-case letter are not significantly different at the 0.05 level.

Figure 5. Returns over nutrient costs for turkey manure demonstrations, 1992



**Using $2.10/bu; $4.75/T manure; $0.18/#N; $0.30/# P2O5; $0.13/# K2O*

MECHANICAL AND CHEMICAL WEED CONTROL DEMONSTRATIONS IN CORN AND SOYBEANS[1]

P. M. Bongard, F. Breitenbach, R. B. Hamer, T. J. Arlt, and K. D. Langseth[2]

Abstract. Three sites (one corn and two soybean) were selected in south central Minnesota to demonstrate optimum mechanical and chemical weed control practices. Low-label and below-label rates of Lasso and Pursuit were effective in controlling weeds at these high weed pressure sites. Mechanical practices (rotary hoe and cultivation) did not enhance yields within the herbicide treatments. However, these mechanical treatments did reduce yield losses where no herbicide had been applied.

Introduction

Results from 1990 demonstrations conducted in south central Minnesota suggested that timely mechanical weed control practices can reduce or eliminate the need for herbicides at low-weed pressure sites, thus reducing the inherent risk of pesticide contamination to the environment. As a follow-up, the demonstrations in 1992 focused on below- or low-labelled rates of herbicides in combination with mechanical practices. These demonstrations were part of the Environmental Agriculture Education Program of County Cluster 16 of the Minnesota Extension Service.

Materials and Methods

One corn and two soybean demonstration sites were selected in the Cluster 16 area. All demonstrations were arranged in a split-plot design and replicated four times. Management practices used by the farmer cooperators can be seen in Table 1.

Corn demonstration

The corn demonstration was located in Freeborn County near London on a Mayer loam (Table 2). The herbicide main plots included the following treatments: 1) No herbicide; 2) Lasso[3] (alachlor) at 3 lb. ai/A; and 3) Lasso at 2 lb. ai/A. The pre-emergence herbicide application was made on May 8. The mechanical practices (split plots) included in each of the herbicide treatments were the following: 1) No mechanical control; 2) Rotary hoe and cultivation; and 3) Cultivation only. The schedule of mechanical practices can be seen in Table 3. Each sub-plot was four rows wide (36-inch spacing) and 150 feet long.

Early season weed densities and species compositions were measured June 19. Plots were also visually rated for weed control on a scale from 1 (no control) to 10 (excellent control) shortly before harvest (September 22). The demonstration was machine combined with the farmer's 6-row equipment on November 10, weighed, and yields were adjusted to 15.5% moisture.

Soybean demonstrations

The soybean demonstrations were located in Rice County near Faribault and

---

[1]Funding provided by the Board of Soil and Water Resources through Environmental Agriculture Education Program Challenge Grant of County Cluster 16 (Freeborn, Mower, Rice, and Steele counties), Minnesota Extension Service.

[2]Environmental Agriculture Educator, Cluster 16; Area Extension Agent, Crop Pest Management; Extension Educators, Rice, Steele and Freeborn counties, respectively; Minnesota Extension Service.

[3]Reference to commercial products or trade names in made with the understanding that no discrimination is intended and no endorsement by the Minnesota Extension Service is implied.

in Steele County near Owatonna. Soil classification and spring soil test results are listed in Table 2. The herbicide main plots included the following treatments: 1) No herbicide; 2) Lasso (alachlor) pre-emergence at 2.5 lb. ai/A (omitted at Faribault site); 3) Lasso (2.5 lb. ai/A) and Pursuit (imazethapyr) at 0.032 lb. a.i./A; and 4) Pursuit (0.032 lb ai/A). The Pursuit was applied at one-half the labelled rate. Lasso was applied pre-emergence at both sites on May 13, and Pursuit was applied postemergence on June 10. The mechanical split-plot treatments were the same as those used in the corn demonstration (Table 3). Plots were 8 rows wide and 100 feet long at Faribault, and 6-rows wide and 150 feet long at Owatonna.

Early season weed counts were taken June 24 and 30 at Faribault and Owatonna, respectively. A final visual evaluation was made before harvest. These demonstrations were machine combined between October 15 and 22 with the farmer's equipment, weighed and adjusted to 12.2% moisture.

Results and discussion

Corn demonstration

Lasso at the 2 lb./A and 3 lb./A rates significantly improved weed control over the no herbicide treatment throughout the 1992 growing season (Tables 4 and 5). During the early season, mechanical practices did not significantly enhance weed control in the herbicide treated areas. Later in the season, however, cultivation with or without rotary hoeing provided better control than using no mechanical practice. These mechanical differences in visual control did not translate into final plot yields (Figure 1). At this relatively high weed pressure site, the mechanical practices performed equally where Lasso had been applied, regardless of the herbicide rate. As a result, returns over weed control costs were highest for Lasso-treated plots where there had been no mechanical control (Figure 2). In the no-herbicide treatment, yield losses were reduced by using mechanical weed control.

Soybean demonstrations

Herbicide usage at both soybean sites significantly improved weed control throughout the season (Tables 4 and 6). At the Faribault site, mechanical practices did not significantly improve weed control either early or late in the season where herbicide had been applied. This was reflected in plot yields (Figure 3). Overall plot yields from both herbicide treatments were better than using no herbicide, and mechanical control practices performed equally within these herbicide-treated areas. The highest returns over weed control costs were found in the cultivated herbicide-treated plots and the Lasso and Pursuit plot where no mechanical control was used (Figure 4).

At the Owatonna site, the best visual evaluation for late season weed control was in the Lasso and Pursuit combination treatment. Evaluations of the individual Pursuit and Lasso treatments ranked second and third, respectively. All herbicide treated areas provided significantly better control than the no herbicide treatment. Cultivation alone provided better visual weed control late in the season than cultivation with rotary hoeing or no mechanical control. Yields of the herbicide treatments reflected the late season weed control evaluation pattern (Figure 5). However, mechanical control practices did not significantly enhance yields in herbicide treated areas. The resulting returns over weed control costs for this site can be seen in Figure 6.

Conclusions

All demonstration sites in 1992 had significant weed pressure. As a result, herbicides were needed to maintain yields and profitability. Although herbicides were needed, low-label (Lasso) and below-label (Pursuit) rates were as effective in controlling weeds as higher herbicide rates. When herbicides have been effective in controlling weeds, mechanical practices have not significantly enhanced yields at high weed pressure sites (1990-1992 demonstrations). However, when no herbicide has been used or when a herbicide failed in these situations, cultivation has reduced losses.

Acknowledgements

The authors would like to thank Tony Mudra of London, Ron Keller of Faribault, and Tom Polacek of Owatonna for providing land, machinery and labor to conduct these demonstrations.

Table 1. Management practices used in weed control demonstrations, 1992

	LONDON (corn)	FARIBAULT (soybeans)	OWATONNA (soybeans)
Variety	Pioneer 3751	Hardin	Hardin
Planting date	May 4	May 7	May 11
Population	25,000	150,000	140,000
Previous crop	Corn	Corn	Corn
Primary tillage	Disc & soil finisher	None (Ridge till system)	Mulch tiller
Fertilizer			None
N	130	5000 gal.	
P_2O_5	32	hog manure	
K_2O	10	(winter application)	

Table 2. Schedule of mechanical weed control practices for demonstrations, 1992.

LOCATION	CROP	ROTARY HOEING ----DAP[1]----		CULTIVATION ----WAP[2]----	
London	Corn	6	-	4	7
Faribault	Soybeans	7	17	4	7
Owatonna	Soybeans	7	14	4	-

[1]Days after planting
[2]Weeks after planting

Table 3. Soil classification and spring soil test results for weed control demonstration sites, 1992.

SITE	SOIL CLASSIFICATION SERIES	SUBGROUP	ORDER	SOIL TEST RESULTS O.M.	pH	P ---ppm---	K
London	Mayer (loam)	Typic Haplaquoll	Mollisol	High	7.2	95	300+
Faribault	Maxfield (sicl)	Typic Haplaquoll	Mollisol	High	8.0	6	64
Owatonna	Lester (loam)	Mollic Hapludalf	Alfisol	High	6.6	36	200

Table 4. Weed densities and species composition in no mechanical treatment plots of herbicide treatments in corn and soybean weed control demonstrations in late June, 1992.

HERBICIDE	WEED DENSITY	SPECIES COMPOSITION[1] Fxt sp.	CoLQ	RRPW	Vele	PSW	CoRW	OTHER
London (corn)	plt/ft^2	----%						----
None	8.5 a[2]	63.0	5.2	30.7	-	-	-	1.2
Lasso-3 qt./A	1.8 b	96.8	0.2	1.6	-	-	-	1.5
Lasso-2 qt./A	1.8 b	85.2	-	14.6	-	-	-	0.2
Faribault (soybeans)								
None	27.5 a	84.5	0.6	0.3	14.6	-	-	-
Lasso+Pursuit	2.5 b	91.6	4.2	-	4.2	-	-	-
Pursuit	4.3 b	91.2	-	-	8.5	-	-	0.3
Owatonna (soybeans)								
None	7.8 A	37.6	19.0	22.7	3.0	15.2	2.5	-
Lasso+Pursuit	0.6 C	-	46.0	-	24.8	29.2	0.1	-
Lasso	4.0 B	22.2	12.4	12.4	2.8	37.2	2.8	-

Pursuit	1.5 BC	32.7	51.8	-	-	15.5	-	-

[1]Fxt sp.=Foxtail species; CoLQ=Common lambsquarters; RRPW=Redroot pigweed; Vele =Velvetleaf; PSW=Pennsylvania Smartweed; and CoRW=Common ragweed.
[2] Data followed by the same letter at the same site are not significantly different at the 0.05 level.

Table 5. Visual evaluations of early (6/24) and late (9/22) season weed control in corn demonstration, 1992.

HERBICIDE	MECHANICAL	EARLY SEASON WEED CONTROL	LATE SEASON WEED CONTROL[1]
		--%--	-score-
None	None	-	1.0 e
	Rotary hoe + cultivation	68 b[2]	3.5 d
	Cultivation	68 b	3.3 d
Lasso	None	93 a	5.5 c
(3 lb./A)	Rotary hoe + cultivation	99 a	8.0 ab
	Cultivation	96 a	8.5 ab
Lasso	None	93 a	4.8 cd
(2 lb./A)	Rotary hoe + cultivation	98 a	7.8 b
	Cultivation	98 a	9.5 a

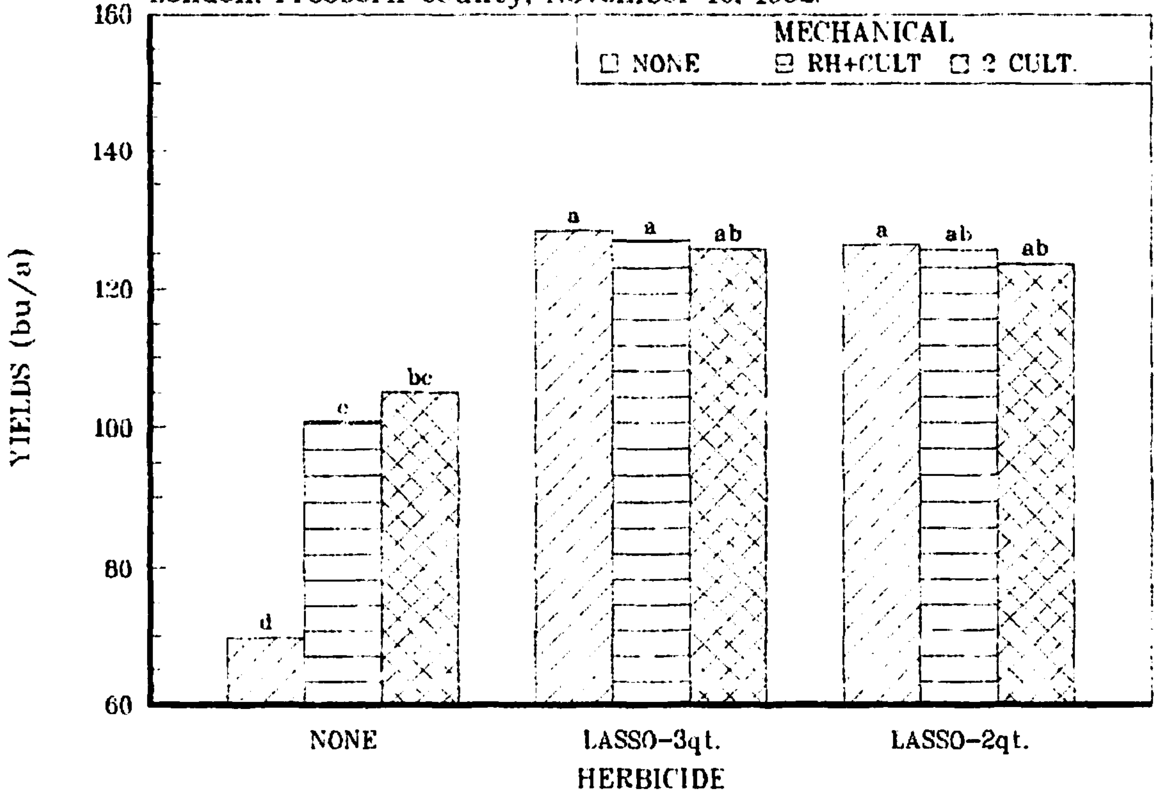
[1]Scale based on 1=no control to 10=excellent control
[2]Data followed by the same letter in the same column are not significantly different at the 0.05 level.

Table 6. Visual evaluations of early (6/24 & 6/30) and late (9/22) season weed control at two soybean demonstration sites, 1992.

		FARIBAULT SITE		OWATONNA SITE	
HERBICIDE	MECHANICAL	EARLY CONTROL	LATE CONTROL[1]	EARLY CONTROL	LATE CONTROL
		--%--	score	--%--	score
None	None	-	1.8 d[2]	-	1.0 h
	Rotary hoe + cultivation	68 b	2.8 cd	0 c	1.0 h
	Cultivation	64 b	3.0 cd	62 b	1.8 gh
Lasso +	None	73 b	6.8 ab	94 a	6.5 bc
Pursuit	Rotary hoe + cultivation	98 a	6.3 a	97 a	7.3 b
	Cultivation	95 a	8.5 a	98 a	8.5 a
Lasso	None	-	-	56 b	2.0 gh
	Rotary hoe + cultivation	-	-	68 b	2.8 fg
	Cultivation	-	-	90 a	5.3 d
Pursuit	None	96 a	6.5 ab	89 a	3.8 ef
	Rotary hoe + cultivation	98 a	5.0 bc	94 a	4.8 de
	Cultivation	98 a	9.0 a	98 a	6.0 c

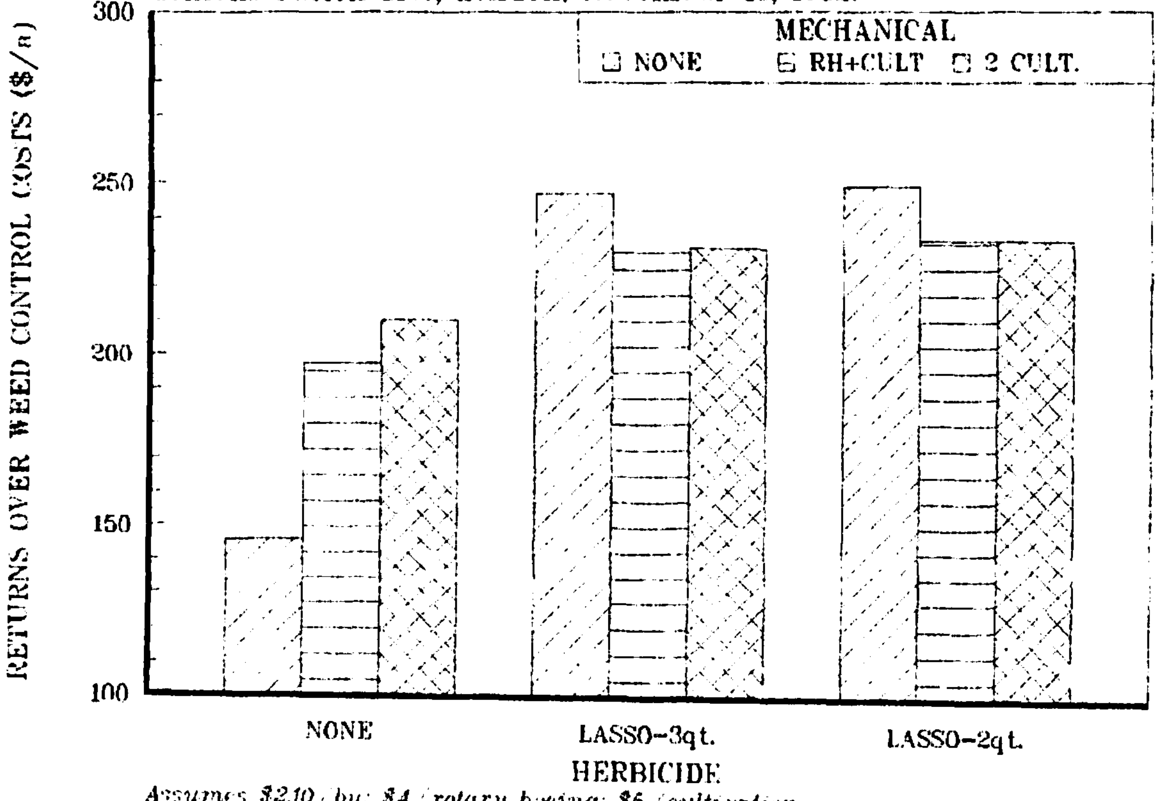
[1]Scale based on 1=no control to 10=excellent control.
[2]Data followed by the same letter in the same column are not significantly different at the 0.05 level.

Figure 1. Corn yields at weed control site near London, Freeborn County, November 10, 1992.



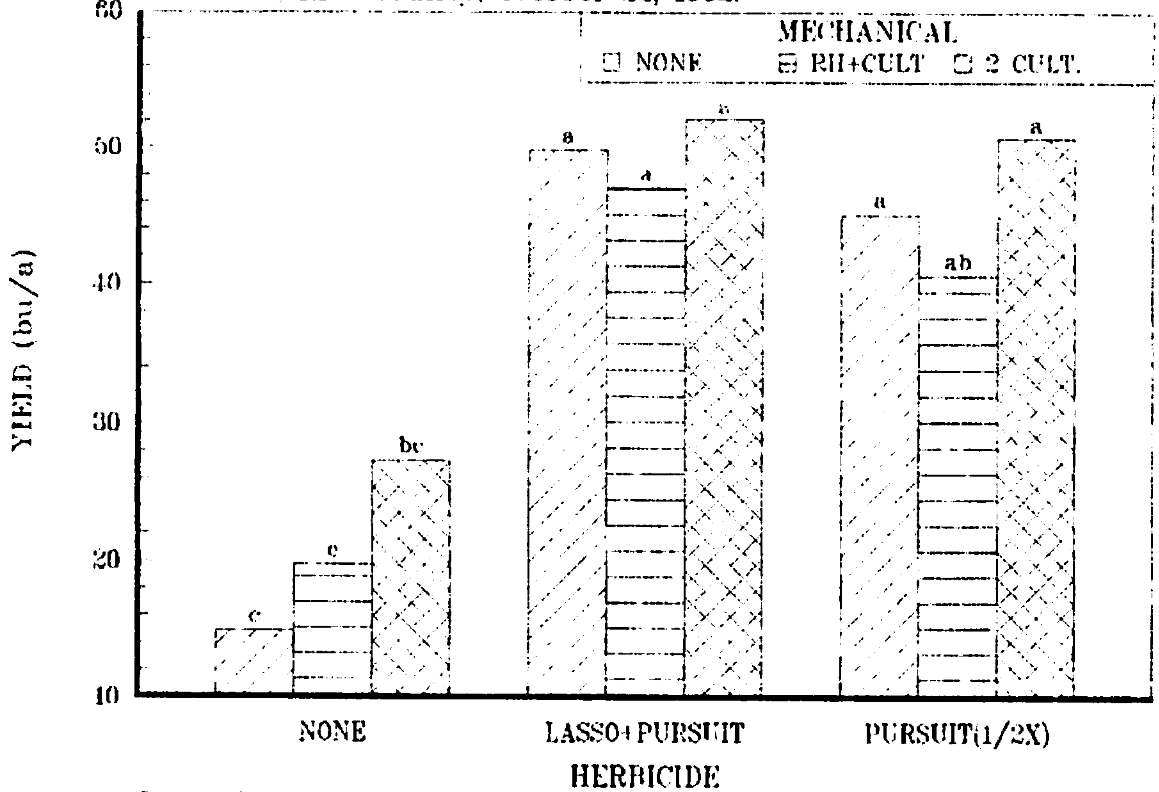
Yields followed by the same letter are not significantly different at the 0.05 level.

Figure 2. Returns over weed control costs at corn demonstration site, London, November 10, 1992.



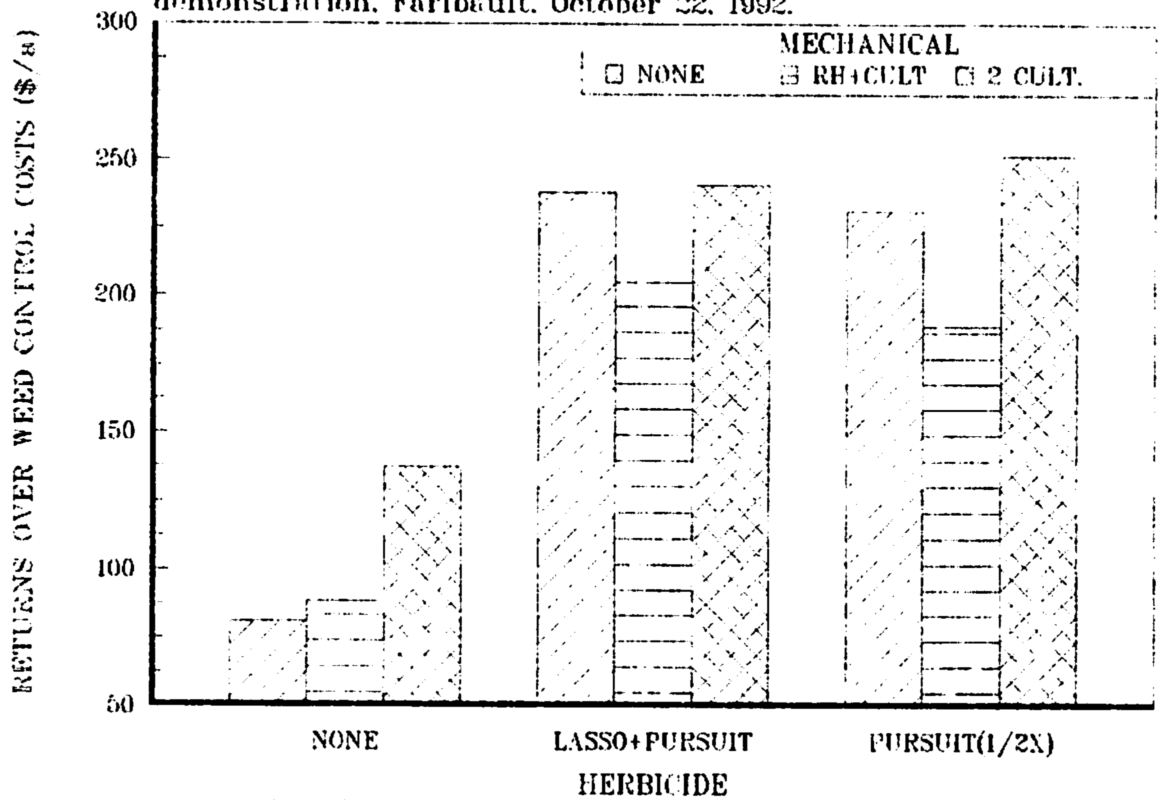
Assumes $2.10/bu; $4/rotary hoeing; $5/cultivation; $25.37/gal Lasso + $3/application

Figure 3. Soybean yields at weed control site in Faribault, Rice County, October 22, 1992.



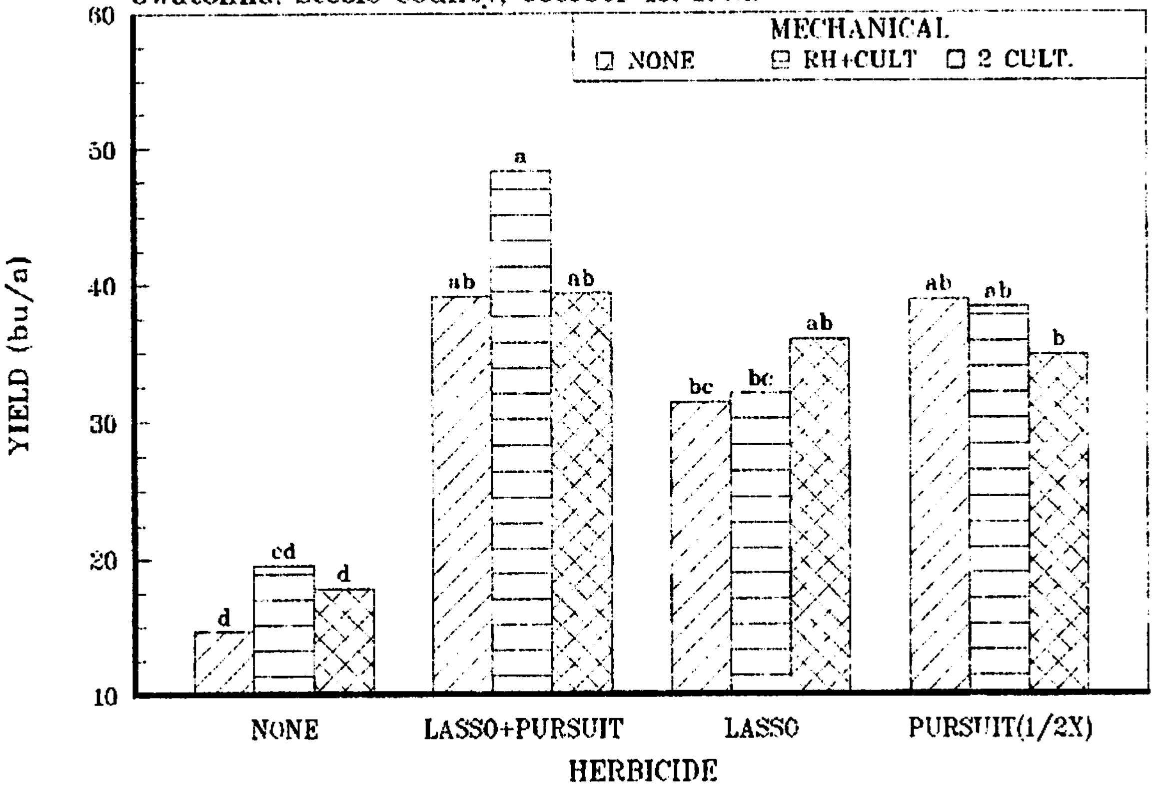
Data followed by the same letter are not significantly different at the 0.05 level.

Figure 4. Returns over weed control costs for soybean demonstration, Faribault, October 22, 1992.



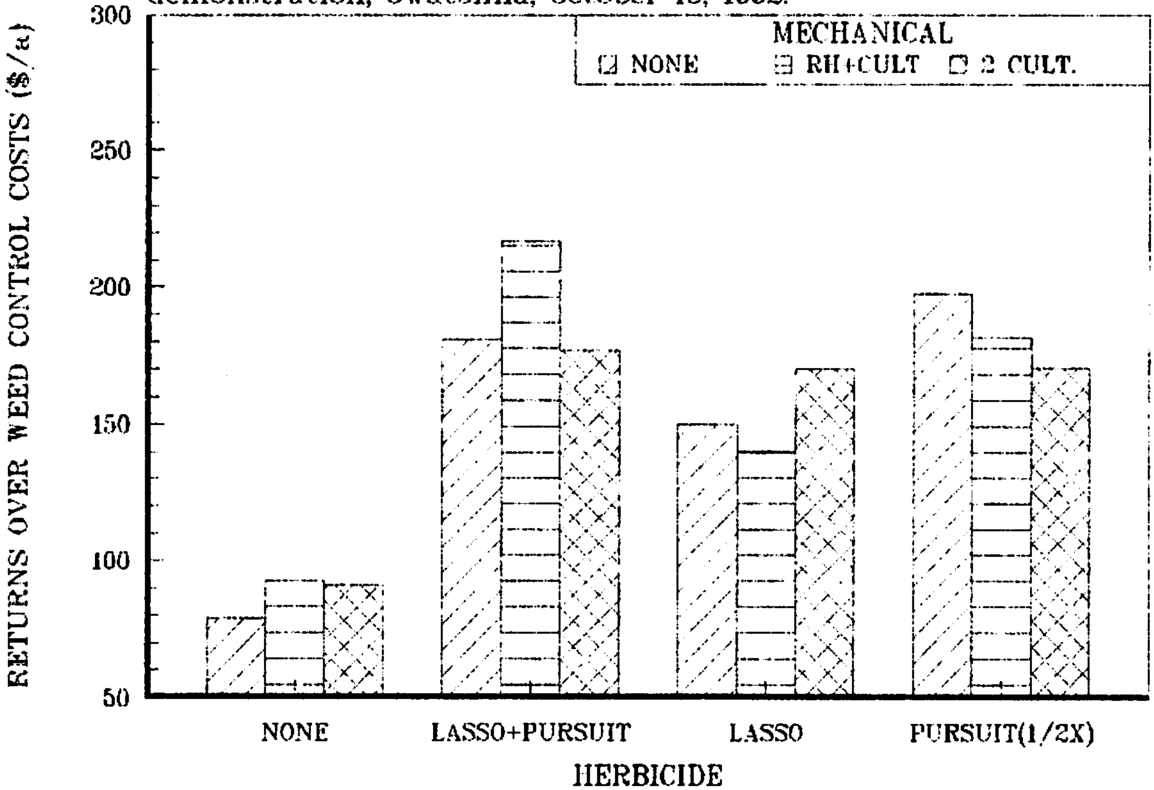
Assumes $5.40/bu; $4/rotary hoeing; $5/cultivation $25.37/g Lasso; $8.94/2 oz Pursuit; $3/appl.

Figure 5. Soybean yields at weed control site near Owatonna, Steele County, October 15, 1992.



Data followed by the same letter are not significantly different at the 0.05 level.

Figure 6. Returns over weed control costs for soybean demonstration, Owatonna, October 15, 1992.



Assumes $5.40/bu: $4/rotary hoeing; $5/cultivation $25.37/g Lasso: $8.94/2 oz. Pursuit: $3/appl.

CORN-TILLAGE RESIDUE MANAGEMENT, LANCASTER, WI. 1990

J. B. Swan, A. E. Peterson, W. H. Paulson, R. L. Higgs, J. F. Moncrief, and D. L. Linden[1/]

ABSTRACT: Growing conditions were generally favorable in 1990 and corn yields for continuous corn ranged from 137 bu/acre for no-till mulch coulter to 163 bu/acre for the no-till normal residue treatment. On chisel and moldboard treatments, surface additions of corn residue significantly reduced populations and consistently decreased yields. No-till mulch coulter had significantly lower plant population than chisel normal and moldboard normal treatments. Surface residue treatments emerged later, silked later, and had higher grain moisture at harvest than comparable tillage treatments without surface residue. Surface residue decreased planting depth on conventional (moldboard) and chisel tillage treatments. Depth to residuum had little effect on grain yields with lowest Rep. avg. yields (154 bu/acre) on the shallowest depth (29 inches in Rep. 1) and greatest Rep. avg. yields (157 bu/acre) on Reps. 3 and 4. Final 20-minute infiltration rates averaged 1.25 and 1.27 in/hour on treatments without surface cover, no-till bare and normal moldboard, respectively. For the mulch treatment, final Infiltration rates were 2.16 in/hour for moldboard mulch, 2.49 for no-till mulch, and 2.88 for chisel plow mulch treatments. This completes the tenth year of the tillage-residue management study. Since the major objectives of determining the effect of tillage and residue management on corn growth and yield at the Lancaster site have been achieved, the study will be terminated.

Summary of Results From Lancaster Tillage Research

Data from the corn tillage-residue management research at Lancaster were used to develop a method to estimate corn growth, yield and grain moisture from air growing degree days (Swan et al., 1987a). A simulation model (NTRM) was used in determining grain yields as a function of soil depth for specific probability levels based on simulated site-specific daily climatic values generated for a 100-year frequency (Swan et. al., 1987b). A model of the corn yield response to water stress, heat units, and management for the period 1972 through 1984 for the tillage-residue management research was developed, calibrated, and validated (Staricka, 1984 and Swan et al., 1990). The effect of tillage and residue management on seed depth, soil temperature, and corn growth was determined for the period 1984 through 1988 (Swan et al., 1988). Measurements on tilla[illegible] residue management treatments were part of a larger study to determine the presence of macropores under [illegible] tillage and moldboard tillage systems and their effect on soil water and solute movement. (Logsdon et al., 1990 and Swan et al., 1990).

Introduction

The driftless soil area has the greatest county average estimated soil losses from cropland in Minnesota, ranging from 4.0 to 6.6 t/A/year in the six counties involved. Typical soils of the region such as Fayette, Dubuque, Seaton, and associated soils, are highly erodible, form dense crusts if unprotected from raindrop impact, and consequently, have low final infiltration rates and high runoff from the intense storm events common to the region. New and improved tillage practices are increasingly being relied upon to meet environmental goals under more intense cropping systems. These systems modify the soil and water losses as well as the kind and concentration of the materials in the runoff. A more complete understanding of these tillage-residue management systems and of their effect on soil physical conditions will allow a more accurate prediction of their effect on the environment and will permit them to be more effectively incorporated into the overall farming systems of the region.

Experimental Procedures

The experimental site is located on the Lancaster Agricultural Research Station. Four tillage treatments are replicated four times (Table 1), the first replicate is located on Palsgrove silt loam: the other three replicates are on Rozetta silt loam. Each treatment is split into normal and mulched subtreatments. On the no-till plots an additional subtreatment (bare) is established by removing all residue prior to planting; this residue is then placed on the adjacent no-till mulched plot. Corn residue additions are made after tillage but before planting to obtain approximately 60 to 80 percent surface cover. Plots are approximately 90 to 100 feet in width and 80 feet in length. Row width was 36 inches in 1990. Pioneer 3747 was planted at 31,500 plants per acre. Residue was moved on the no-tillage plots on April 17-18 and all plots staked. Primary tillage on the conventional (moldboard) treatment was done prior to April 17 and spring chiseling was done on April 18. The chisel and moldboard plots were disked on April 25. On April 26, herbicide was applied to all treatments prior to addition of corn stalk residue on chisel and moldboard treatments. N[illegible] till treatments were planted April 26 with a 4-row John Deere 7000 Max-Emerge planter equipped with flute[illegible] coulters on one side and "trash whip" units on the other side which removed residue from an 8 to 9-inch area over the row. Fluted coulters were used on all rows of conventional and chisel treatments. Rain interrupted planting chisel and conventional treatments on April 27 after 16 rows were planted; planting was completed on April 30.

Nitrogen (200 lbs/A) was broadcast as urea. Starter fertilizer at planting was 200 lb/A of 6-24-24. The insecticide was 8 lb/A of counter. Pre-emergence herbicide was applied April 26 (2.5 qt/A of Bladex and 2.5 pt/A of Dual). On June 5, Banvel (0.5 pt/A) and Buctril (1.0 pt/A) were applied.

Percent cover was determined from slides taken June 6, 1990. Planting depth, rate of emergence, and silking date measurements were made on designated portions of each plot. Crop height measurements were also recorded. Hourly soil temperatures, leaf number, soil moisture, bulk density, and percent cover were measured on chisel and no-till treatments in Rep. 3 for mulch added, bare and normal treatments. Soil temperature was measured at depths of 1, 6, 11, 16, and 50 cm. Yields for individual plots were determined by hand harvesting 60-foot of row (two subsamples each consisting of paired 15-foot lengths of row) in October.

Ten plot frames (45 3/4 by 45 3/4 inches) were put in place following planting. Infiltration measurements were made on chisel mulch, no-till bare and mulch, and conventional normal and mulch treatments during the period June 5-8.

Results-Corn Yields and Crop Height

Precipitation was above normal in April, May, June and August, but was 2.04 inches below normal in July (Table 2). Precipitation was 0.68 inches below average for the months of April-October. Monthly air temperature in May averaged 3.3 deg. F below average and in July were 1.7 deg. F below average. Depth to residuum had little effect on yields in 1990 (Table 3).

Grain yields of individual plots ranged from 137 to 163 bu/A and were significantly different. Normal residue chisel and moldboard treatments were significantly greater than no-till mulch coulter. There were no significant differences among no-till treatments in yield or in plant population. Normal residue chisel and moldboard treatments had significantly greater plant population than all mulch treatments except no-till trash whip. Plant population was significantly different between treatments at the 1 percent level and was significantly different at the 5 percent level between reps. When subplots with less than 23,000 PPA were deleted from the analysis, treatment yields were not significantly different. Treatment yield differences were closely associated with differences in plant population.

Tillage and residue effects on grain moisture were significant at the 5 percent level. No-till bare treatments were significantly lower in percent grain moisture than no-till mulch treatments. Interestingly, grain moisture on normal residue and mulch moldboard plow treatments was not significantly different. Grain moisture on no-till normal residue coulter and bare coulter treatments also was not significantly different. Similarly, grain moisture for spring chisel normal residue and mulch treatments was not significantly different. The delay in emergence on mulch treatments was consistently expressed in differences in leaf number, silking date, and grain moisture at harvest.

Corn height reductions on mulch treatments were apparent by day 167 (June 15) and differences increased with time over the period of measurement ending day 200 (July 19) [Fig. 1 and 2]. By day 200 on the no-till mulch plots, the TW treatment was 20 cm taller than the coulter treatment. These results contrast markedly with the 1988 when a reversal of crop height for high and low cover treatments occurred on all treatments.

Seedbed Conditions and Corn Growth

Surface residue significantly reduced average planting depth on chisel and moldboard treatments but did not significantly affect planting depth on the no-till treatments. Compared to the no-till bare and normal residue treatments, no-till mulch slightly increased seed depth. The effect of mulch on reducing planting depths occurred only on tilled treatments.

The standard deviation (S_d) of planting depths was significantly different among treatments. Conventional mulch had significantly greater S_d than conventional normal. Similarly, S_d of no-till normal coulter was significantly greater than no-till normal TW. Conventional normal had significantly smaller S_d than all other treatments with the exception of no-till normal TW. Except for the conventional and no-till normal treatment, neither mulch nor TW significantly affected the S_d of planting depth. Emergence (75%) was delayed approximately 5 to 6 days by mulch additions, while silking (50%) was delayed 1 to 4 days by mulch additions (Tables 1 and 4).

Effect of Treatments of Infiltration Rate

Large differences in "final" (40-60) minute average infiltration rates were measured between treatments in 1990 (Tables 5 and 6). Final infiltration rates from conventional tillage mulch treatments were approximately 1.0 inches/hr greater than conventional tillage normal treatments. For the nine year period of measurement, mulch has approximately doubled the infiltration rate on conventional tillage. On the no-till treatments, double mulch increased final infiltration rates by a factor of 2. For the six years of data (1984-1989) double mulch on the no-tillage treatment increased the infiltration rate an average of 50 percent compared to the no-tillage bare treatment.

The results again illustrate the requirements for rapid infiltration of 1) a porous surface layer with high saturated conductivity, 2) a protective mulch cover, 3) absence of flow restricting layers within the depth of infiltration. Residue cover alone has not been sufficient to produce a high infiltration rate when significant restriction to flow occurs within the infiltrating profile.

Summary

Five year yield results (1979-1983) with continuous corn at Lancaster show nearly equal yields from conventional (moldboard) tillage, ridge till, and chisel treatments. Twelve year yield results (1979-1990) show nearly equal yields for conventional, chisel and no-till normal treatments (Table 7). In 1986, 1987, 1988, 1989, and 1990, no-till was the highest yielding normal treatment. Thus farmers in the driftless soil area can choose between a variety of tillage options which have yields comparable to conventional tillage, but which are superior in soil and water conservation and offer savings in time, labor, and fuel compared to the conventional moldboard plow tillage method.

List of References

Logsdon, S.D., R.R. Allmaras, L. Wu, J.B. Swan, and G.W. Randall. 1990. Macroporosity and its relation to saturated hydraulic conductivity under different tillage practices. Soil Sci. Soc. Am. J. 54:1096-1101.

Staricka, J.A. 1985. Tillage crop management model for corn production in southeastern Minnesota. M.S. Thesis, Univ. of Minnesota, St. Paul.

Swan, J.B., E.C. Schneider, J.F. Moncrief, W.H. Paulson, and A.E. Peterson. 1987a. Estimating corn growth, yield, and grain moisture from air growing degree days and residue cover. Agron. J. 79:53-60.

Swan, J.B., J.A. Staricka, M.J. Shaffer, W.H. Paulson, and A.E. Peterson. 1990 Corn yield response to water stress, heat units, and mangement: model development and calibration. Soil Sci. Soc. of Am. J. 54:209-216.

Swan, J.B., L. Wu, W.H. Paulson, and G.W. Randall. 1990. Hydraulic properties as effected by tillage management. p. 326 in Agronomy Abstracts. ASA, Madison, WI.

Swan, J.B., R.L. Higgs, W.H. Paulson, and A.E. Peterson. 1988. Effect of tillage and residue management on seed depth, soil temperature, and corn growth. p. 1286 in Agronomy Abstracts. ASA, Madison, WI.

Table 1. Effect of Tillage and Mulch Treatments on Percent Cover, Planting Depth, Emergence, Silking Date, Population, and Grain Yield. 1990 Lancaster, WI

Treatments Tillage	Treatments Residue	In-Row Residue Mgt.	% Cover In-Row	% Cover Ent. Area	Planting Depth Avg. mm	Planting Depth S.D. mm	Days Post Plant to 75% Emerg.	Avg. Date 50% silked July	Avg. popln. at harvest PPA in K	Avg Grain yield Bu/Ac	Avg Grain yield Pop. >23K* Bu/Ac	Avg/ Grain moist
No-till	NORMAL	C	51	69	33ab	7.9a	25	24	27.7 bcd	163a	163	18.1 bcdef
	(N)	Tw	46	63	32abc	4.6bc	27	-	26.0 abcd	160a	164	18.8 abcde
	BARE	C	3	5	32.5abc	5.4ab	24	24	26.7 ab	154ab	155	17.7ef
	(B)	Tw	4	3	35a	5.1ab	26	24	26.5	157a	157	17.5f
	MULCH	C	83	92	34ab	6.3ab	29	28	24.9 abc	137b	148	19.2ab
	(2X)	Tw	64	81	36a	4.9ab	31	26	26.1 abcd	147ab	151	19.3a
Fall	NORMAL	C	10	8	36a	2.6ab	24	24	28.1d	158a	158	17.9def
Chisel	MULCH	C	89	96	24cd	7.5a	31	28	23.7a	142ab	145	19.0abcd
Spring	NORMAL	C	8	12	36a	5.3ab	25	24	28.7bcd	161a	161	18.0cdef
Chisel	MULCH	C	87	90	20d	8.5a	30	25	24.9a	144ab	143	19.1abc
Conv.	NORMAL	C	3	3	38a	3.0c	25	-	28.0cd	162a	162	18.2abcdef
(MBD).	MULCH	C	87	87	26bcd	8.3a	30	-	24.5a	146ab	148	19.2ab
	AVG.				32	6.0			26.3	153	155	18.5
SIGNIFICANCE LEVEL					0.01	0.05			0.01	0.05	NS	0.05

*Subplots with population <23000 omitted.

Table 2. 1990 Weather Summary, University of Wisconsin Lancaster Agriculture Research Station.

Month	Precipitation Total	Precipitation Departure	Growing Degree Days 1990	Growing Degree Days Depart.	Air Temperatures Avg. Max.	Air Temperatures Avg. Min	Air Temperatures Avg. Daily	Air Temperatures Departure
	inches	inches	°F	°F	°F	°F	°F	°F
April	3.67	0.65	—	—	57.6	36.4	47.0	0
May	4.83	1.37	197	-101	64.5	44.7	54.6	-3.3
June	5.48	1.10	523	4	79.9	57.3	68.6	1.4
July	2.02	-2.04	615	-47	80.2	59.8	70.0	-1.7
August	5.87	1.37	604	11	80.5	58.8	69.6	0.6
September	0.68	-2.77	401	-44	74.0	52.1	63.0	2.0
October	2.02	-0.36	—	—	59.6	36.2	47.9	-2.0
Growing Season Totals	24.57	-0.68	2340	-89				

Last Date in spring with minimum temperature
32^{o} or less 5/10
28^{o} or less 4/18

First Day in fall with minimum temperature
32^{o} or less 10/11
28^{o} or less 10/11

Table 3. Average Yields and Depth to clay Residuum by Replicate and Monthly Precipitation for 1981 through 1990, Lancaster, WI

Year	Replicate Number 1	2	3	4	Monthly Precipitation May	June	July	August
	---------- Bu/ac			----------	---------- inches			----------
1981	146.8	146.7	142.1	147.1	0.85	4.28	2.91	11.35
1982	150.0	143.4	142.8	147.3	5.46	3.45	5.29*	4.06*
1983	72.8	85.2	96.4	111.2	5.18	3.28	3.34**	3.12**
1984	107.3	110.4	118.0	120.1	3.92	7.77***	2.57***	137
1985	118.5	121.1	129.6	130.6	4.95	1.32	2.11	3.34
1986	159.5	162.4	168.6	164.8	3.90	5.47	1.85	3.65
1987	168.3	167.7	170.9	168.0	3.78	4.15	6.71	6.78
1988	52.4	56.9	64.6	62.6	0.87	0.42	1.80	2.92
1989	152.8	159.3	165.0	157.1	2.34	2.44	2.51	5.16
1990	153.6	150.2	157.1	157.3	4.83	5.48	2.02	5.87
Avg. Depth to Clay Residuum Inches	29	41	46	62				

1981 - Subplots with population <17,000 omitted.
1982 - Missing values estimated for 8 plots out of a total or 48 plots.
1983 - Subplots with population <18,000 omitted Rep. II, III, IV.
* 1983 - 1.13 inches precipitation from July 3 to August 25 (53 days).
** 1984 - 1.52 inches precipitation from July 18 to August. 31 (45 days).
*** 1985 - 1.59 inches precipitation from May 28 to July 25 (57 days). Largest rain was 0.36 inches.

Table 4. Influence of Tillage Method and Residue Management on Rate of Emergence. 1990, Lancaster, WI

Treatment Tillage	Residue	In Row Residue Mgt.	June 11	17	21	23	26	29	June 1
No Till	Normal	C	0	22	80	90	96	100	100
		TW	1	20	62	77	86	100	100
	Bare	C	0	51	84	95	100	100	100
		TW	0	45	71	84	96	100	100
	Mulch	C	0	6	28	55	83	96	100
		TW	0	12	35	48	73	84	100
Fall Chisel	Normal	C	0	35	82	86	100	100	100
	Mulch	C	0	7	15	42	73	81	100
Spring Chisel	Normal	C	2	24	77	88	98	100	100
	Mulch	C	0	1	21	38	75	90	100
Convent. (MBD).	Normal	C	0	43	77	90	97	99	100
	Mulch	C	0	12	50	62	78	93	100

Table 5. 1990 Lancaster, WI Infiltration Rate Measurement

Tillage	Residue	Rep.	Application rate	Water applied before runoff	Infiltration rate x min. after runoff commences - in/hr											
					2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5
			in/hr	in.	Inches/hour											
No Till	Bare	E	4.16	0.28	1.76	1.52	1.04	0.80	1.28	1.04	1.28	1.04	1.04	1.28	1.52	1.52
		W	3.84	0.34	1.68	1.44	1.20	0.96	0.96	1.20	0.96	0.72	0.96	0.96	1.44	1.44
	Mulch	E	4.16	0.45	3.08	3.08	2.48	2.48	2.48	2.00	2.00	1.88	1.88	1.76	2.00	2.00
		W	3.84	1.15	3.12	3.12	3.12	3.00	3.00	3.12	2.88	2.88	3.12	3.12	3.12	—
Conv.	Normal	E	4.16	0.69	2.00	1.68	1.04	1.04	1.04	0.80	0.80	1.28	0.80	1.04	0.80	0.80
		W	4.40	0.46	3.20	2.24	2.00	1.52	1.52	1.28	1.28	1.76	1.52	1.76	1.52	—
	Mulch	E	4.48	6.72	NO Runoff											
		W	4.32	1.22	3.36	2.88	2.64	2.16	2.16	1.92	1.92	2.16	2.16	2.16	2.16	2.16
Sp. chisel	Mulch	E	4.80	1.16	3.84	3.12	2.88	2.88	2.64	2.40	2.64	2.88	2.64	2.88	2.64	2.88
		W	4.00	7.00	NO Runoff											

Table 6. Infiltration Rate 55 Minutes After Runoff Begins (paired Obvservations). Lancaster, 1990.

Tillage	Treatment Residue	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Avg. in/hr
		Inches/hour										
No Till	Bare	—	—	—	1.68	1.00	1.24	1.26	0.84	0.32	1.48	--
	Mulch	1.46	1.10	3.53*	0.60	3.02	2.10	1.22	0.82	1.75	2.56	1.82
Conventional	Bare	0.97	1.52	0.54	1.70	1.40**	1.83	1.15	1.80	0.45	1.22**	1.26
	Mulch	2.72	2.34	1.49	2.90	2.14**	2.25	4.81	2.58	2.21	2.16**	2.56
		Ratio										
Conv.Bare/ Conv.	Mulch	0.36	0.65	0.36	0.58	0.65	0.81	0.24	0.70	0.20	0.56	0.51
No Till Mulch/ Conv.	Bare	1.51	0.72	6.53	0.35	2.16	1.15	1.06	0.46	3.89	1.73	1.45+

* Soil disturbed prior to planting by anhydrous ammonia injection.

**One observation only.

\+ Omit 1983.

Table 7. 1979-1990 Continuous Corn Tillage Yield Results. Lancaster, WI

Tillage Treatment with normal residue	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1973-83	1979-90
	Bu/A												Bu/A	
Ridge Plant	162	157	157	147	100	--	--	--	--	--	--	--	145	--
No Till (slot plant)	163	146	151	141	85	108	120	165	177	59	171	163	137	137
Chisel	160	150	167	154	95	115	125	159	168	57	157	158	145	139
Conventional	169	159	168	151	89	121	133	164	168	43	159	162	147	141
Paraplow*	--	--	--	--	--	106	125	162	--	--	--	--	--	--
Ro Till	--	--	--	--	--	--	--	--	172	54	163	--	--	--

*Fall 1983 and Fall 1984.

FIG 1 CROP HEIGHT VS TIME FOR NO-TILLAGE TREATMENTS

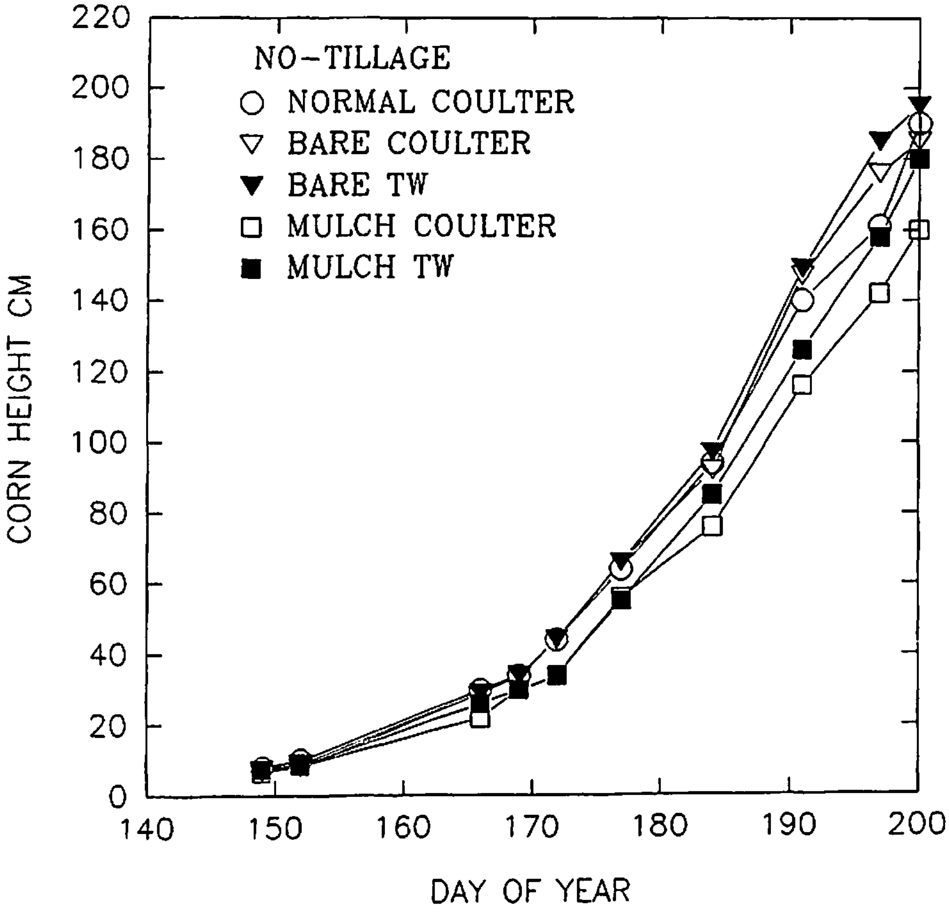


FIG 2 CROP HEIGHT VS TIME FOR CHISEL TREATMENTS