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.

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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**	

			Leaf % N Concentrations					
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	Relative Chlorophyll Meter Reading 5-leaf	9-leaf	12-leaf	silking	blister	milk	Rel. Yield
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.

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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.

	Planting	Planting to harvest				
Treatments	5/6	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
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ABSTRACT: Studies are being conducted on the silt loam soils of southeastern Minnesota to evaluate specific N and tillage practices for their role in providing profitability (BENEFIT) while minimizing NO_3 occurrences in the water below the root zone (RISK). In 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.

Goodhue Co.

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.

Tillage	N Treatment[1/]		Grain	
	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.

Winona Co.

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	1.166	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/]

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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.

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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/cm³ - - - - - -			
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/cm³ - - - - - - - -			
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/cm³*	- - - - - - - - - -	- - - - - - - - - -
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/cm³	- - -
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/cm³ - - - - - -			
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.

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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	Year 1990	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	Sampling Time Fall 1990	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 Aq-Lime on the total yield of five forage legumes.

Legume	Aq-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_2O 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.

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[1] This is report is for the second year of this study which has been partially funded by Minnesota Wheat Research and Promotion funds.

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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)

						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} ----------			---------- % ----------		
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.