Table 3. Dry matter production, and N utilization as influenced by turkey manure, fertilizer and residual manure treatments - 1993.

Treatments	Dry Matter 8-leaf	Dry Matter silking	N-Concentration 8-leaf	N-Concentration silking	N Uptake 8-leaf	N Uptake silking
	--------T/A--------		------ % N --------		----lb/A-----	
Control	0.34	1.57	3.33	1.12	23	35
70 lb N/A in '91,'93	0.32	2.04	3.21	1.41	20	57
140 lb N/A in '91,'93	0.35	2.17	3.68	2.09	25	91
TM 4 T/A in'91,'93	0.56	3.30	3.62	2.00	40	131
TM 8 T/A in'91, '93	0.61	3.23	3.47	2.23	42	144
TM 4 T/A TM'92 none '93	0.42	2.48	3.64	1.84	30	91
TM 8 T/A TM'92 none '93	0.54	3.08	3.85	2.03	42	124
TM 4 T/A in '93	0.49	3.04	3.64	2.18	35	133
TM 8 T/A in '93	0.58	3.20	3.72	2.31	42	147
P-Valve	99	99	33	99	99	99
LSD (0.05)	0.11	0.24		0.41	9	21

* TM is turkey manure.

Table 4. Grain and stover yields as influenced by turkey manure, fertilizer and residual manure treatments - 1993.

Treatments	Grain yield	N-Concentration Stover	N-Concentration Grain	Dry Matter Production Stover	Dry Matter Production Grain	Dry Matter Production Total	N-Removal Stover	N-Removal Grain	N-Removal Total
	bu/a	------%------		-------T/A-------			--------lb/a---------		
Control	66	0.85	1.03	5.76	1.57	7.33	98	32	130
70 lb N/A in '91,'93	87	1.06	1.17	5.64	2.06	7.70	119	48	167
140 lb N/A in '91,'93	90	1.14	1.39	5.93	2.15	8.08	135	59	195
TM 4 T/A in'91,'93	118	0.96	1.46	5.83	2.81	8.64	111	82	193
TM 8 T/A in'91, '93	115	1.07	1.52	5.83	2.73	7.84	109	83	192
TM 4 T/A TM'92 none '93	94	0.77	1.24	5.11	2.24	7.90	87	55	142
TM 8 T/A TM'92 none '93	109	1.08	1.35	5.66	2.60	7.87	113	69	183
TM 4 T/A in '93	116	0.94	1.36	5.27	2.75	8.20	102	74	177
TM 8 T/A in '93	114	1.29	1.62	5.46	2.71	8.28	143	88	231
P-Valve	99	99	99	99	99	99	99	99	99
LSD (0.05)	8	0.10	0.06	0.39	0.20	0.39	14	6	14

* TM is Turkey Manure

Fertilizer and manure treatments had no influence on the amount of water that percolated through the soil profile in 1993, but did influence the concentration and the amount of nitrate-N leached. Concentration of nitrate-N in the percolate water from manure applied in 1991 and 1992, reflected increased concentrations of nitrate-N in proportion to the rate of manure applied. Turkey manure and commercial fertilizer applied in 1993 had relatively the same concentration of nitrate-N. Data collected to date would suggest a relatively long impact associated with manure application as compared to fertilizer N. Turkey manure contains a relatively large amount of N in the organic form. This organic N must be broken down before it is available for crop utilization and/or leaching. Better methods for estimating available N from manure are needed, both during the year of application and in subsequent years.

Table 5. Water percolation amount during 1993.

Treatments	Planting 5/3	Planting to harvest 5/26	6/29	7/12	11/3	Total
	Inches of H_2O					
Control	1.2	1.5	1.7	1.2	0.0	7.4
70 lb N/A in '91,'93	1.6	1.6	2.2	1.4	0.4	8.1
140 lb N/A in '91,'93	1.0	2.3	1.7	1.1	0.2	7.2
TM 4 T/A in'91,'93	1.5	1.9	2.0	1.1	0.6	7.3
TM 8 T/A in'91,'93	1.3	2.3	2.0	1.2	0.5	9.5
TM 4 T/A TM'92, none'93	1.2	2.4	2.4	1.3	0.3	6.3
TM 8 T/A TM'92, none'93	2.3	2.6	2.0	1.3	0.6	6.7
TM 4 T/A in '93	1.2	2.7	2.2	1.0	0.3	7.4
TM 8 T/A in '93	1.8	1.7	2.0	1.0	0.3	6.8
P-Value	99	99	30	43	61	51
LSD (0.05)	0.7	0.7				

* TM is Turkey manure.

Table 6. Concentration of NO_3^--N in leachate as influenced by manure, fertilizer and residual manure treatments in 1993.

Treatments	Planting 5/3	Planting to harvest 5/26	6/29	7/12	11/3	Ave
	ppm NO_3^--N					
Control	5.6	6.4	9.0	10.0	0.0	7.7
70 lb N/A in '91,'93	5.1	6.3	6.2	8.7	9.8	7.2
140 lb N/A in '91,'93	3.5	7.4	8.0	4.5	3.2	5.3
TM 4 T/A in'91,'93	3.9	6.5	9.0	8.8	4.8	6.6
TM 8 T/A in'91,'93	9.2	14.5	14.6	14.1	6.7	11.8
TM 4 T/A TM'92 none '93	5.7	11.5	13.8	10.8	9.1	10.2
TM 8 T/A TM'92 none '93	16.8	21.2	17.2	14.6	6.3	15.2
TM 4 T/A in '93	3.9	9.8	9.6	6.5	5.0	6.0
TM 8 T/A in '93	6.5	5.1	7.3	6.3	4.1	5.9
P-Value	99	99	99	99	72	
LSD (0.05)	2.7	3.0	3.9	3.8		

* TM is Turkey manure.

Table 7. Nitrate-N leached as influenced by manure, fertilizer and residual manure treatments in 1993.

Treatments	Planting 5/3	Planting to harvest 5/26	6/29	7/12	11/3	Total
	lb/A NO_3^--N					
Control	5.0	5.8	8.0	8.9	0.0	27.7
70 lb N/A in '91,'93	4.6	5.6	5.6	7.7	8.8	32.3
140 lb N/A in '91,'93	3.1	6.6	7.1	4.0	2.9	23.7
TM 4 T/A in'91,'93	3.5	5.8	8.0	7.8	4.3	29.4
TM 8 T/A in'91,'93	8.2	12.9	13.1	12.6	6.0	52.8
TM 4 T/A TM'92 none'93	5.1	10.3	12.3	9.6	8.1	45.4
TM 8 T/A TM'92 none'93	15.0	18.9	15.4	13.0	5.6	67.9
TM 4 T/A in '93	5.8	8.7	8.5	5.8	4.4	33.2
TM 8 T/A in '93	5.8	4.6	6.6	5.6	3.7	26.3
P-Value	99	99	99	99	72	93
LSD (0.05)	2.4	2.7	3.5	3.4		

* TM is Turkey manure.

Table 8. Soil N levels sampled before planting and at harvest 1993.

Treatments	Depth	Ammonium Planting	Ammonium Harvest	Nitrate Planting	Nitrate Harvest	Total Inorg. Planting	Total Inorg. Harvest
		-----ppm-----		-----ppm------		------ppm------	
Control	1	3.8	2.0	7.1	2.3	10.9	4.3
	2	2.8	1.6	5.1	1.8	7.9	3.4
	3	2.9	2.1	3.4	0.8	6.3	2.9
70 lb N/A in '91, '93	1	5.2	2.3	5.9	2.9	11.1	5.3
	2	3.8	2.5	4.2	1.6	8.0	4.1
	3	3.7	2.3	2.9	0.9	6.6	3.1
140 lb N/A in '91,'93	1	4.8	3.1	6.2	4.4	11.0	7.4
	2	3.1	2.5	5.5	3.2	8.6	5.6
	3	2.9	2.1	3.9	1.4	6.9	3.5
TM 4 T/A in'91, '93	1	4.2	2.9	7.3	5.7	11.5	8.6
	2	3.5	1.8	5.6	3.6	9.2	5.4
	3	3.1	1.8	4.1	1.7	7.2	3.5
TM 8 T/A in'91,'93	1	4.4	2.9	8.3	27.1	12.8	30.0
	2	3.5	2.5	7.1	11.6	10.6	14.1
	3	3.4	2.3	4.4	8.7	7.8	11.0
TM 4 T/A TM'92 none'93	1	3.1	3.6	9.6	4.1	12.8	7.7
	2	2.7	2.2	7.1	2.2	9.8	4.4
	3	2.4	2.0	4.8	1.3	7.2	3.2
TM 8 T/A TM'92 none'93	1	4.4	2.7	13.9	5.9	18.2	8.5
	2	3.0	2.6	10.9	2.7	14.0	5.3
	3	3.2	2.5	10.1	1.8	13.2	4.3
TM 4 T/A in '93	1	4.1	1.6	7.6	5.0	11.6	6.6
	2	2.7	1.7	5.5	2.3	8.2	4.1
	3	3.7	1.7	4.0	1.5	7.7	3.2
TM 8 T/A in '93	1	4.1	1.9	7.0	31.0	11.2	32.9
	2	3.4	2.4	6.2	12.5	9.6	14.9
	3	2.9	2.7	3.8	12.8	6.7	15.4

* TM is turkey manure. Depth 1 ,2 and 3 correspond to (0-6), (6-12), and (12-18) inches.

EVALUATION OF LIMING MATERIALS AND RATE OF APPLICATION FOR ALFALFA PRODUCTION ON IRRIGATED SANDY SOILS

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

ABSTRACT: The need for lime for profitable production of alfalfa on acid sandy soils is well established. There are several materials that can be used to meet these lime requirements. This study was conducted to evaluate the effect of various liming materials for the production of irrigated alfalfa and subsequent change in soil pH values. Lime increased the yield of alfalfa all sources had an equal effect on yield if applied to supply the same rate of ENP per acre.

Introduction:

The cost of lime needed for profitable alfalfa production is substantial in many parts of Minnesota. There are some alternatives to the use of what is usually described as "normal ag lime." These alternatives, however, need to be evaluated in field situations. Therefore, this study was conducted to measure the effect of liming materials and rate of application on alfalfa yield and soil pH.

Experimental Procedures:

This study was established in an irrigated field in Wadena County in the spring of 1990. Four liming materials (ag lime, finely ground ag lime, sugarbeet lime, Pel-Lime) were applied to supply 3 rates of ENP per acre (4,321; 8,640; 12,960 lb./acre). A control treatment was included but was not part of the complete factorial design. To provide another comparison, Pel-Lime was applied at a rate to supply 2,160 lb. ENP per acre. Each treatment was replicated four times. Plot size was 10 ft. x 15 ft.

The liming materials as well as adequate rates of phosphate, potash, and sulfur were broadcast and incorporated before planting. Alfalfa was seeded without a companion crop in April at a rate of 16 lb. per acre. Irrigation water was applied as needed for establishment and throughout the growing season.

Soil samples (0-6 in.) were collected from the experimental site in early April. The results are summarized in Table 1. Two cuttings were harvested in 1990. Soil samples were collected from each plot in the fall and pH (soil and water paste) was measured.

Procedures for harvest and soil sample collection were quite similar in 1991, 1992, and 1993. The first cutting was taken in early June. Two additional cuttings were harvested each year before September 6. Soil samples (0-6 inches) were taken from each plot periodically to monitor changes in soil pH. Appropriate statistical analysis procedures were used to separate treatment effects.

Results and Discussion:

Alfalfa yields for 1990 through 1993 are reported in Table 2. Yields are expressed on the basis of tons of dry matter per acre. Total growing season yields are reported. Total yields reflect the response shown by individual cuttings.

Except for the year of establishment (1990), the use of lime produced a substantial increase in alfalfa production. This increase was consistent for 1991, 1992, and 1993. When totaled over the four years of production the yield increase, due to the initial application in 1990, was approximately 2.5 tons/acre.

The application of 4,321 lb. ENP per acre was adequate for optimum production. Higher yields were expected from the higher rates applied. This, however, was not the case in any production year. The use of Pel-Lime at a half rate was not adequate for optimum yields.

Table 1. Relevant soil properties (0-6 inches) at the experimental site.

Property	Value
pH	5.4
phosphorus (Bray #1)	66 ppm
potassium	144 ppm
calcium	995 ppm
magnesium	128 ppm
sulfur	5.8 ppm
organic matter	3.0%

[1/] Extension Soil Scientist, Junior Scientist, and Assistant Scientist, Soil Science Department, University of Minnesota, respectively.

Table 2. The effect of lime source and rate of application on the dry matter yield of irrigated alfalfa.

Liming Material	ENP Rate	Year 1990	1991	1992	1993	Total
	lb./acre	pH				
-	0	1.45	4.17	4.10	4.13	13.85
ag-lime	4,321	1.62	5.05	4.64	5.20	16.51
	8,640	1.62	4.88	4.91	5.32	16.73
	12,960	1.47	4.96	4.64	4.82	15.89
firmly ground ag lime	4,321	1.75	4.87	4.53	4.97	16.12
	8,640	1.76	4.91	5.08	5.12	16.87
	12,960	1.39	5.11	4.63	5.00	16.13
sugarbeet lime	4,321	1.71	5.02	4.72	4.95	16.40
	8,640	1.54	4.97	4.49	5.08	16.08
	12,960	1.56	5.22	5.03	5.07	16.88
Pel-Lime	2,160	1.39	4.44	4.41	4.76	15.00
	4.321	1.54	4.96	4.64	5.27	16.41
	8,640	1.53	4.68	4.73	5.19	16.13
	12,960	1.40	4.73	4.44	5.07	15.64

When liming materials are considered, all were equally effective if applied to supply equivalent amounts of ENP per acre. Even though there were substantial differences in particle size of the materials, these differences had no impact on alfalfa yields. If differences did exist, they could not be measured in this study. There are several materials that can be used for liming purposes. These results indicate that their effectiveness can be equal to the effectiveness of ag-lime if particle size and a measurement of Total Neutralizing Power is considered.

Soil samples were collected from each plot to a depth of 6 inches at 5 different times throughout the four years of the study. The results of the analysis are listed in Table 3.

Table 3. The effect of lime source and rate of application on soil pH measured at a depth of 0-6 inches.

Liming Material	ENP Rate	Fall 1990	Fall 1991	Spring 1992	Fall 1992	Fall 1993
	lb./acre	pH				
-	0	5.6	5.5	5.5	5.5	5.5
ag-lime	4,321	6.0	5.6	5.7	5.7	5.7
	8,640	6.1	5.9	6.0	5.9	5.8
	12,960	6.1	6.1	5.9	6.2	6.0
firmly ground ag lime	4,321	6.2	5.7	5.8	5.8	5.9
	8,640	6.2	5.7	5.9	5.8	5.8
	12,960	6.5	5.9	6.1	5.9	6.0
sugarbeet lime	4,321	6.2	5.5	5.9	5.6	6.0
	8,640	6.4	6.1	6.1	5.7	6.0
	12,960	6.6	6.5	6.3	5.8	6.5
Pel-Lime	2,160	5.8	5.5	5.5	5.6	5.8
	4.321	5.9	5.8	5.8	5.7	5.8
	8,640	6.2	5.7	5.9	5.7	6.1
	12,960	6.2	5.8	5.9	5.6	6.0

Lime treatments were applied in mid-April and incorporated with a disk. In the fall of the same year (1990), there had been some change in soil pH. Except for the Pel-Lime source, the pH increased as the rate of ENP increased. This was expected. There were also expectations that soil pH would go higher with the application of 12,960 lb. ENP per acre. In the fall of 1990, there may not have been adequate time to reach an equilibrium.

It's obvious that there was a substantial drop in soil pH from the fall of 1990 to the fall of 1991. There were no substantial changes from the fall of 1991 through the summer of 1993 regardless of the treatment that was applied. This rapid decrease was not expected and could not be explained by our current understanding of the concepts of soil fertility and liming.

Through conversations with the cooperating farmer, it was learned that the irrigation well had been treated with acid in the spring of 1991 to improve pumping capacity. The irrigation system, itself, was immediately over the plot area when the irrigation system was started following the acid treatment. Consequently, water that was very acid was applied to the experimental area. This pumping caused a substantial decrease in soil pH.

Even though there was a substantial decrease in soil pH from the fall of 1990 through the summer of 1993, there was still an economic response to the liming materials that had been applied in the spring of 1990. Plots that did not receive lime were invaded by weeds and there was a considerable reduction in alfalfa stand. This is strong evidence that liming, when needed, can affect the stand as well as the seasonal growth of alfalfa.

Summary:

The results of this study, conducted over four growing seasons, illustrate the importance of liming for profitable alfalfa production. Total dry matter yield was increased by about 2.5 ton per acre when lime was applied. Neither the rate of application in excess of amounts of 4,321 lb. ENP per acre nor the source of lime had any significant effect on yield.

The soil pH, measured in the fall of 1990, changed as expected. However, this change did not last long because of the acid treatment of the irrigation well. After the pH reached a new equilibrium, it remained relatively constant through the 1993 growing season.

Even though there was a substantial decrease in soil pH, the early benefits were carried through the 1993 growing season. These results show that there are clearly residual benefits from the appropriate application of a liming material.

EVALUATION OF RATE OF LIME NEEDED FOR OPTIMUM PRODUCTION OF FIVE LEGUMES IN NORTH-CENTRAL MINNESOTA

G. Rehm, T. Sellie, A. Scobbie, C. Sheaffer, and N. Martin[1/]

ABSTRACT: Little is known about the lime requirements for legume crops that might be useful for hay and/or pasture crops in North-Central Minnesota. This study was conducted to measure the response of five legumes (alfalfa, birdsfoot trefoi, cicer milkvetch, kura clover, red clover) to the application of Ag-Lime (0, 2, 4 tons per acre). Total forage produced during the 1992 and 1993 growing season was affected by both legume and lime use. A rate of 2 tons per acre was optimum for each year for all legumes.

Introduction:

Legumes are a major component of a large number of farm enterprises in North-Central Minnesota. Therefore, it's essential that farmers use management practices that provide for optimum production of all legumes.

The majority of the soils in the region also have an acid pH. This means that lime will be needed for optimum production. Lime requirements for alfalfa are reasonably well established. Yet, there are other legumes that might be satisfactory substitutes for alfalfa in either pasture or hay situations. The lime requirements for these alternative legumes are not well defined. Therefore, this study was established to evaluate the need of alternative legumes for lime and compare these needs to those of alfalfa.

Experimental Procedure:

This study was established on an irrigated sandy soil in Wadena County in the spring of 1991. Results of the soil tests taken before lime application are listed in Table 1.

For this study, three rates of Ag-Lime (0, 2,000, 4,000 lb. ENP/acre) were broadcast and incorporated before legume seeding in early May. Five legumes were seeded on May 8, 1991 in each liming rate. Adequate phosphate, potash, and sulfur were also broadcast and incorporated before seeding. Forage yields were not measured in 1991.

The phosphate, potash, and sulfur rates were topdressed to the established stands in early spring of 1992 and again in early spring of 1993. The harvest schedules were the same for both years. The alfalfa was cut three times with the first cutting taken in early June. Subsequent cuttings were taken at 35-day intervals. The other legumes were harvested two times during each growing season. The first cutting was taken in mid-June. The second cutting was harvested in late August. All forage yields are reported on a dry matter basis.

Soil Samples (0-6 inches) were collected from each plot in the fall of both 1992 and 1993. These samples were dried and pH was measured with routine procedures.

Results and Discussion:

The forage yields for the 1992 growing season are summarized in Table 1. Total production was reduced by excessively dry weather in May and June combined with an irrigation system that did not function correctly. Even though total production was lower than anticipated, the application of lime increased the yield of all legumes. The yield increases were highest for alfalfa and red clover.

Table 1. The effect of rate of Ag-Lime on the total forage yield of five legumes. Wadena County. 1992.

	Lime Rate (lb. ENP/acre		
Legume	0	2,000	4,000
	------ ton dry matter/acre -----		
alfalfa	3.0	3.8	3.5
birdsfoot trefoil	2.8	3.0	3.1
cicer milkvetch	2.0	2.2	2.4
kura clover	1.7	2.1	2.0
red clover	3.0	3.6	3.8

Forage yields measured for the 1993 growing season are summarized in Table 2. The data from each cutting are included because the effect of liming varied with cutting.

[1/] Extension Soil Scientist, Junior Scientist, Assistant Scientist, Professor, Extension Forage Specialist, University of Minnesota, respectively.

Table 2. The effect of rate of Ag-Lime on forage yield of five legumes. Wadena County. 1993.

Legume	Cutting		Lime Rate (lb. ENP/acre) 0	2,000	4,000
			------ ton dry matter/acre -----		
alfalfa	1		1.23a*	1.81b	2.04b
	2		2.42a	2.98a	2.10a
	3		1.01a	1.25b	1.32b
		Total:	4.66a	6.04b	5.46ab
birdsfoot trefoil	1		2.09a	2.55b	2.39ab
	2		2.10a	2.33b	2.34b
		Total:	4.19a	4.88b	4.73ab
cicer milkvetch	1		1.84a	1.84a	2.16a
	2		1.67a	1.90a	1.92a
		Total:	3.51a	3.74a	4.08a
kura clover	1		2.23a	2.60b	2.48b
	2		1.47a	1.61a	1.51a
		Total:	3.70a	4.21b	3.99ab
red clover	1		1.68a	1.97a	2.13a
	2		2.16a	2.74b	2.47b
		Total:	3.84a	4.71b	4.60b

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

When considering the legume yields averaged over the rate of lime applied, alfalfa produced the highest yield. Lowest yields resulted from the planting of both cicer milkvetch and kura clover. Yields resulting from the harvest of red clover and birdsfoot trefoil were intermediate.

First cutting yields of alfalfa were improved substantially by the use of lime. This was also true for the third, but not the second cutting. When total seasonal production is considered, the use of 2,000 lb. ENP per acre increased dry matter yield by approximately 1.5 ton per acre. Additional lime did not produce additional dry matter for this crop.

The response of birdsfoot trefoil was similar to the response of alfalfa. The application of 2,000 lb. ENP per acre was adequate for optimum yield. Compared to alfalfa, the lime increased dry matter production by about .7 ton per acre for this crop.

The application of lime had no effect on the yield of cicer milkvetch. This legume is apparently able to tolerate low soil pH values.

Lime usage increased the yield of the first, but not the second cutting of kura clover. Because of yield increases for the first cutting, lime had a significant effect on total forage produced for the season. The rate of 2,000 lb. ENP per acre was adequate for optimum production.

In contrast to other responsive legumes, the first cutting yield of alfalfa was not affected by the use of lime. The rate of 2,000 lb ENP per acre was adequate for optimum yield of the second cutting and this was also reflected in total yield.

Soil pH values are summarized in Table 3. The pH at the start of the study was 5.6. The application of lime did increase soil pH, but rates were not adequate for a pH of 6.5 The optimum yields, however, were associated with pH values in the range of 6.0.

The data also show that there was a consistent decrease in soil pH from the fall of 1992 to the fall of 1993. This decrease, however, was very small and was consistent for all legumes. The legume that was grown had no effect on the decrease in soil pH.

Table 3. The effect of rate of Ag-Lime on soil pH when five legumes were grown on an irrigated sandy soil.

Legume	Sampling Time	Lime Rate (lb. ENP/acre) 0	2,000	4,000
		pH		
alfalfa	1992	5.5	5.9	6.2
	1993	5.3	5.8	6.1
birdsfoot trefoil	1992	5.5	6.0	6.1
	1993	5.3	5.9	6.1
cicer milkvetch	1992	5.6	6.0	6.2
	1993	5.5	5.9	6.1
kura clover	1992	5.6	6.0	6.4
	1993	5.4	5.9	6.2
red clover	1992	5.4	5.9	6.0
	1993	5.3	5.7	6.2

Summary:

The results of this study conducted for a period of two years show that forage legumes that are adapted to the sandy soils of North-Central Minnesota will respond to the application of lime and a subsequent increase in soil pH. The magnitude of the response, however, varied with legume. Therefore, application of Ag-Lime should be a major consideration when all legumes are grown on the acid sandy soils of the region.

The application of Ag-Lime resulted in a change in soil pH. With the rates used, the pH did not rise above 6.5. There is every reason to believe that the use of higher rates would have produced higher pH values. There was no major drop in pH from one year to another. The data indicate that soil pH should remain relatively constant over a period of time if the recommended rate of lime is used.

DETERMINING POTASSIUM REQUIREMENTS OF ALTERNATIVE LEGUMES

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

ABSTRACT: This study was conducted to determine the need for potassium for five forage legumes grown on the sandy soils of North-Central Minnesota. Four rates of K_2O (0, 75, 150, 225 lb. per acre) were applied to five legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover). Forage yields were recorded and the concentration of potassium in plant tissue was measured. Potassium uptake was computed from yield and concentration data. Even though the soil test for potassium was considered to be low (87 ppm), there was no yield response to applied K in 1993. Potassium concentration and potassium uptake increased with rate of K_2O applied.

Background:

The sandy soils of North-Central Minnesota usually have a low soil test value for potassium (K). Past research has shown that alfalfa will respond to potash fertilizers applied to these soils. There are other legumes that might be adapted to the region and suitable for pasture and/or hay production. There is, however, very little information that describes the potassium requirements for these legumes. Therefore, this study was conducted to determine the response of alternative legumes to potassium.

Experimental Procedure:

This study was conducted in the field of a cooperating farmer in Todd County from 1991 through 1993. Soil samples (0-6 inches) were collected prior to planting and the results of the analysis are summarized in Table 1. Adequate amounts of lime, phosphate, and sulfur were broadcast to each plot and incorporated with a disk prior to planting.

Table 1. Selected soil test values for the experimental site.

Soil Property	Value
pH	6.6
P (Bray & Kurtz #1), ppm	92
K (1N ammonium acetate), ppm	87

Four rates of K_2O (0, 75, 150, 225 lb. per acre) were used. These rates were applied to alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, and red clover.

The experimental area was planted to corn in 1990 and a disk was used to prepare a uniform seedbed prior to seeding. The legumes were seeded on May 6, 1991. They were allowed to establish under irrigation in 1991. Appropriate post emergence herbicides were used for weed control.

The potash rates were topdressed to the established stand in early spring of 1992 and 1993 along with adequate phosphate and sulfur. The alfalfa was harvested 3 times. All other legumes were harvested twice. Whole plant samples were collected from each plot at each cutting and analyzed for K. Potassium uptake was computed from the dry matter yield and K concentration data. Soil samples (0-6 in.) were collected from each plot in September, but have not been analyzed for K.

Results and Discussion:

Dry matter yields are summarized in Table 2. Yield was not affected by the application of K_2O. This statement applies to yields of individual cuttings as well as total yield. With a soil test for K of 87 ppm, a response to potash fertilization would be expected. There is no apparent, easy explanation for this lack of response.

Considering the legumes, alfalfa produced the largest amount of dry matter. The kura clover produced the lowest amount of dry matter. The other legumes produced intermediate yields.

The effect of rate of applied K_2O on the K concentration in the legume tissue was highly significant (Table 3). In general, the K concentration increased linearly with rate of K_2O applied. From this data, it would appear that luxury consumption of K is a characteristic of all legumes included in the study.

As would be expected, the effect of rate of K_2O applied on K concentration is consistent with the effect of rate of K_2O applied on K uptake (Table 4). Potassium removal was highest for alfalfa followed by cicer milkvetch. The kura clover and red clover crops removed the lowest amounts of K.

[1/] Professor, Junior Scientist, Assistant Scientist, Soil Science Department, University of Minnesota, respectively.

Table 2. Effect of rate of applied potash on dry matter yield of five legumes grown on an irrigated sandy soil.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		----- ton dry matter/acre -----			
alfalfa	1	1.50	1.46	1.53	1.46
	2	1.41	1.69	1.57	1.60
	3	1.26	1.12	1.80	1.16
	Total	4.17	4.26	4.28	4.22
birdsfoot trefoil	1	2.02	1.96	1.92	1.90
	2	1.73	1.73	1.66	1.78
	Total	3.75	3.71	3.58	3.68
cicer milkvetch	1	2.04	2.01	2.07	2.44
	2	1.47	1.45	1.39	1.39
	Total	3.51	3.46	3.46	3.83
kura clover	1	2.05	1.99	2.03	2.14
	2	.59	.65	.76	.75
	Total	2.64	2.65	2.78	2.89
red clover	1	1.44	1.62	1.43	1.44
	2	1.63	1.69	1.71	1.59
	Total	3.07	3.31	3.14	3.02

Table 3. Effect of rate of applied potash on % K in the tissue in five legumes grown on an irrigated sandy soil.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		---------- % K ----------			
alfalfa	1	2.07	2.66	2.87	3.04
	2	1.99	2.32	2.62	3.01
	3	2.25	2.81	3.09	3.31
birdsfoot trefoil	1	1.92	2.70	2.68	2.83
	2	1.95	2.45	2.79	2.77
cicer milkvetch	1	1.91	2.67	3.03	3.65
	2	2.20	3.07	2.96	3.93
kura clover	1	1.75	2.45	2.92	3.39
	2	2.27	2.89	3.13	3.57
red clover	1	1.71	2.24	2.71	2.86
	2	1.67	2.34	2.54	2.84

Table 4. Effect of rate of applied potash on potassium uptake by five legumes grown on an irrigated sandy soil.

Legume	Cutting	K_2O Applied (lb./acre) 0	75	150	225
		-------- lb. K/acre --------			
alfalfa	1	62.5	77.2	87.6	90.3
	2	56.6	78.4	82.2	94.8
	3	56.3	63.4	73.2	76.6
	Total	175.3	219.0	243.0	262.7
birdsfoot trefoil	1	77.8	106.0	103.0	107.3
	2	67.1	85.8	92.0	98.7
	Total	144.9	191.8	195.0	206.0
cicer milkvetch	1	77.7	107.6	125.4	179.6
	2	65.6	89.0	82.7	109.2
	Total	143.3	196.6	208.1	288.8
kura clover	1	72.1	99.2	120.6	145.9
	2	27.1	37.9	47.7	53.5
	Total	99.2	137.1	168.3	199.4
red clover	1	49.2	72.7	76.9	82.0
	2	55.4	79.8	87.0	89.9
	Total	104.6	152.5	163.9	171.9

With K removal by unfertilized alfalfa of approximately 175 lb. per acre and a soil test of 87 ppm K, a response to potash fertilization would be expected. The identity of the source of K used by the crop from this irrigated sandy soil is open to speculation. The release of K from the feldspar minerals in an accelerated weathering process under irrigation is, at this time, the most probable explanation.

Soil samples (0-6 inches) were collected from each plot in the fall of 1993. These samples are currently being analyzed for K and the results were not available at the time of preparation of this report.

SULFUR FERTILIZATION AND GROWTH OF FORAGE LEGUMES

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

ABSTRACT: The sulfur (S) requirements of forage legumes other than alfalfa are not well defined. This study was conducted to evaluate the effect of the application of three rates of fertilizer S (0, 25, 50 lb./acre) on the yield of five forage legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover) grown on an irrigated sandy soil. Total dry matter production for the 1992 growing season was affected by legume but not the rate of S applied. The same conclusions were reached from the analysis of yield data for 1993.

Sulfur (S) is known to be essential for fertilization of several crops grown on the sandy soils of Minnesota. Several research trials have shown that an annual application of 25 lb. S per acre is needed for optimum alfalfa production when soils are sandy. However, the S requirements of several alternative legumes have not been clearly defined. Therefore, this study was conducted to determine the response of birdsfoot trefoil, cicer milkvetch, kura clover, and red clover to S fertilization. Alfalfa was included as a standard for comparison.

Experimental Procedure:

This study was initiated in the field of a cooperating farmer in Wadena County in the spring fo 1991. Soil samples (0-6 inches) were collected prior to planting. The pH was 5.6; the Bray & Kurtz #1 soil test for P was 49 ppm; K by ammonium acetate extraction was 126 ppm; the SO_4-S measured was 1.7 ppm, and the organic matter content was 2.4%. Adequate amounts of Ag-Lime, phosphate, and potash were broadcast to the plot area and incorporated with a disk prior to planting.

Three rates of S (0, 25, 50 lb. per acre) were applied to each of five legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, kura clover, red clover) in a complete factorial design with four replications. A moldborad plow and disk were used for seedbed preparation. The legumes were seeded on May 6, 1991. The legumes were allowed to establish under irrigation in 1991 and no yields were recorded. Weed control was achieved with appropriate use of post emergence herbicides.

The S rates were reapplied to the established plots in the spring of 1992 and 1993. Granular gypsum was used to supply the S. Adequate rates of phosphate and potash were also topdressed to the established stand each year.

The alfalfa was harvested three times. The other legumes were harvested twice. Whole plant samples were collected from each plot at harvest, dried, and ground for analysis for S. That analysis has not been completed at the time of this writing.

Results and Discussion:

The total amount of forage produced in 1992 was significantly affected by legume, but not by the rate of S applied (Table 1). In 1992, the alfalfa and red clover produced the highest yield. Lowest yields resulted from the cicer milkvetch and kura clover. Yields from birdsfoot trefoil were intermediate.

Table 1. Effect of rate of applied sulfur on total dry matter production of five forage legumes in 1992.

	S Applied (lb./acre)		
Legume	0	25	50
	- - - - - - - ton dry matter per acre - - - - - - -		
alfalfa	3.08	3.30	3.20
birdsfoot trefoil	2.77	3.20	3.00
cicer milkvetch	1.63	1.73	1.98
kura clover	1.53	1.80	1.75
red clover	3.33	3.11	3.45

In 1993, yields were significantly affected by legume, but not the rate of S applied (Table 2). The lack of a response to fertilizer S is difficult to explain. This is especially true for alfalfa. Apparently, the excessively wet weather combined with widely fluctuating temperatures accelerated mineralization of soil organic matter. If mineralization is accelerated, more S is released and available to the crop.

[1/] Extension Soil Scientist, Assistant Scientist, Junior Scientist, Professor, and Extension Specialist-forage crops, University of Minnesota, respectively.

Table 2. Effect of rate of applied sulfur on forage yields of five legumes measured in 1993.

Legume	Cutting	0	25	50
		---------- ton dry matter/acre ---------		
alfalfa	1	1.06	.86	.94
	2	1.34	1.40	1.22
	3	1.14	1.18	1.51
	Total	3.54	3.44	3.67
birdsfoot trefoil	1	2.58	2.59	2.48
	2	2.03	2.26	2.08
	Total	4.61	4.85	4.56
cicer milkvetch	1	2.09	1.94	2.18
	2	1.72	1.58	1.60
	Total	3.81	3.52	3.78
kura clover	1	2.67	2.73	2.50
	2	1.28	1.40	1.41
	Total	3.95	4.13	3.91
red clover	1	2.04	2.23	1.96
	2	2.39	2.73	2.27
	Total	4.43	4.96	4.23

MATCHING PLANT POPULATION AND FERTILIZER MANAGEMENT FOR PROFITABLE CORN PRODUCTION

D. Allan, G. Rehm, J. Johnson, A. Scobbie, T. Sellie, and D. Hicks[1/]

ABSTRACT: This study was initiated to investigate the relationship between plant population and fertilizer management. The results from the 1993 growing season are summarized in this report. The response of corn to planted population and potash fertilizer management in 1993 was consistent with the response measured in 1992 even though corn growth and development was hindered by the excessively cool and wet growing season. A planted population of 33,000 plants per acre was adequate for optimum silage and grain yield. When soil test values were low, there was a strong response to K_2O use with 40 lb. K_2O per acre applied in a starter equivalent to the broadcast application of 200 lb. K_2O per acre. Root density at the low K site was affected by both planted population and potash fertilization. There was a general decrease in average root length per plant when the planting density was increased. The potash fertilization caused higher root densities and deeper development of roots in the inter-row area. Even though root development was probably hindered by cooler than normal soil temperatures, this observation has important implications for root development in dry years.

Introduction:

Corn plant populations used by Minnesota farmers have increased slightly during recent years. Research conducted in the Department of Agronomy and Plant Genetics over the last five years showed marked increases in grain yield when populations were increased to 40,000 plants per acre with high soil fertility levels. This population represents a 70% increase over current averages. Before recommendations can be made for higher plant populations, it is necessary to fine tune the plant density and fertilizer management interactions for a range of fertility conditions.

Objectives:

The broad objective of this research project is to determine the fertilizer use strategies that result in the most efficient use of P and K over a range of plant densities when corn is grown on soils testing either low or high for either P and/or K.

Specific objectives are to determine the effect of plant population and fertilizer management strategies on:

- total dry matter yield
- grain yield
- early growth of corn
- root distribution and density
- nutrient uptake early in the growing season
- residual NO_3-N in the soil after maturity

Results and Conclusions:

In 1993, the study was limited to the evaluation of potash fertilizer management in combination with five plant densities. Two sites with widely different soil test values for K were selected in Goodhue County. The results of analysis of soil samples collected before fertilizer application are summarized in Table 1.

Table 1. Relevant soil test values for the experimental sites used in 1993.

Test Parameter	Depth	Site: High K	Site: Low K
	in.		
pH	(0-6)	7.3	7.1
P (Bray #1,) ppm	(0-6)	70	21
K (1N $NH_4C_2H_3O_2$), ppm	(0-6)	226	92
	(6-12)	146	68
	(12-24)	98	96
	(24-36)	89	94

Soil test values for K were substantially different to a depth of 12 inches after which they were nearly equal for both sites. Broadcast fertilizer treatments were applied in late April and corn was planted on May 7. Each treatment received some phosphate (23 lb. P_2O_5/acre) in a starter band at planting. The N was supplied as 46-0-0 at a rate to supply 180 lb. N/acre that was incorporated along with the broadcast 0-0-60 before planting. Corn followed a 1992 soybean crop at both locations. The hybrid used at both sites was Asgrow RX578.

A detailed soil sampling pattern was used at 58 and 72 days after emergence in an effort to measure root density. Whole plants were also collected when root samples were taken. These samples were dried, weighed, ground, and analyzed for K. Potassium uptake was computed.

[1/] Associate Professor, Professor, Graduate Research Assistant, Assistant Scientist, Junior Scientist, Soil Science Department; Professor, Department of Agronomy and Plant Genetics, University of Minnesota.

Total dry matter at physiological maturity and grain yields were measured. Soil samples were collected to a depth of 3 feet after harvest and analyzed for NO_3N.

The stand count was taken approximately 50 days after planting and the results are summarized in Table 2.

Table 2. Measured stand at approximately 50 days after emergence.

Desired Population	Site Low K	Site High K
plants/acre	- - - plants/acre - - -	
23,000	22,542	23,850
28,000	28,641	29,730
33,000	31,418	33,324
38,000	35,120	37,462
43,000	39,912	42,689

For most densities, the measured emerged stand was close to the desired population.

Dry matter yields for the 1st and 2nd samplings for the site having a low soil test for K are summarized in Table 3. Similar yields for the site having the high K test are listed in Table 4.

Table 3. The effect of plant population and management of potash fertilizer and dry matter production of young plants at the low K testing site.

K_2O Applied	Placement	Desired Population (plants/acre) 23,000	28,000	33,000	38,000	43,000
lb./acre		- - - - - - - - - - - lb./acre - - - - - - - - - - -				
1st sampling:						
0	-	300	386	386	449	324
40	starter	342	412	426	493	481
100	broadcast	369	451	432	449	533
200	broadcast	309	380	472	435	528
2nd sampling:						
0	-	1948	2360	2026	2483	2256
40	starter	2074	2385	2468	2741	2522
100	broadcast	2023	2466	2673	2537	2909
200	broadcast	2126	2416	2171	2289	2931

At the low testing site, dry matter at the time of the 1st sampling was affected by both planted population and management of the potash fertilizer. When averaged over all fertilizer management options, the use of K_2O increased the dry matter production at the first sampling. When compared to the control, addition of potash increased dry matter production with starter being equivalent to broadcast applications.

For the 2nd sampling, treatment effects were similar to those measured for the first sampling. Again, use of 40 lb. K_2O per acre (Table 4) in a starter fertilizer produced dry matter that was equivalent to dry matter production resulting from broadcast applications. For both samplings, there was no significant interaction between planted population and management options for potash fertilizer.

Table 4. The effect of plant population and management of potash fertilizer and dry matter production of young plants at the high K testing site.

K_2O Applied	Placement	Desired Population (plants/acre) 23,000	28,000	33,000	38,000	43,000
lb./acre		- - - - - - - - - - - lb./acre - - - - - - - - - - -				
1st sampling:						
0	-	313	367	402	425	597
20	starter	307	425	454	499	564
2nd sampling:						
0	-	2265	2884	2777	2923	3438
20	starter	2445	2808	2784	3110	3383

Dry matter production by young plants was affected by the planted population, but not the use of K_2O in a starter, at the site with the high soil test for K (Table 4). There was no significant interaction between planted population and potash fertilizer use at this site.

All plant samples have been ground and submitted to the Research and Analytical Laboratory for K analysis. This analysis has not been completed at the time of preparation of this report.

Dry matter yields measured at physiological maturity are summarized in Tables 5 and 6. At the site with the low K test, both potash fertilization and planted population increased the total amount of dry matter produced (Table 5). Optimum dry matter production was achieved with a planted population of 33,000 plants per acre. When averaged over all planted populations, the use of 40 lb. K_2O per acre in a starter fertilizer was equivalent to the broadcast application of both 100 and 200 lb. K_2O per acre.

Table 5. The effect of planted population and application of potash fertilizer on total dry matter production at the site having a low soil test value for K.

K_2O Rate	Placement	Planted Population (plants/acre)				
		23,000	28,000	33,000	38,000	43,000
lb/acre		- - - - - - - - ton dry matter/acre - - - - - - - -				
0	-	5.15	5.34	5.55	5.77	5.47
40	starter	6.22	6.34	6.16	6.53	6.14
100	broadcast	5.50	5.92	6.36	6.14	5.93
200	broadcast	5.41	6.19	6.77	6.70	6.23

For the site with the high K soil test, total dry matter yield was affected only by planted population (Table 6). As was the case with the site with the low K test, the optimum planted population was 33,000 plants per acre.

Table 6. The effect of planted population and use of potash in a starter fertilizer on total dry matter production at the site having a high soil test for K.

K_2O Rate	Placement	Desired Population (plants/acre)				
		23,000	28,000	33,000	38,000	43,000
lb./acre		- - - - - - - ton dry matter/acre - - - - - - -				
0	-	6.63	7.06	7.01	7.68	7.67
20	starter	7.00	6.93	7.41	6.95	7.21

The treatment effects on grain yield were consistent with the effects on total dry matter production at the site with the low soil test for K (Table 7). The highest yields were associated with a planted population of 33,000 plants per acre. Yields resulting from the use of 40 lb K_2O per acre in a starter were equivalent to yields resulting from the broadcast application of 100 and 200 lb. K_2O per acre. At this site, the effect of K_2O management option on early growth of corn was reflected in final dry matter and grain yields.

Table 7. The effect of planted population and application of potash fertilizer on corn grain yield at the site having a low soil test for K.

K_2O Rate	Placement	Planted Population (plants/acre)				
		23,000	28,000	33,000	38,000	43,000
lb/acre		- - - - - - - - - - bu./acre - - - - - - - - -				
0	-	111.4	119.2	124.1	115.7	114.7
40	starter	122.0	123.7	130.6	130.3	124.4
100	broadcast	124.1	126.5	124.8	118.5	110.8
200	broadcast	122.2	128.9	129.2	125.5	112.5

Yields in 1993 were not as high as expected because of the cool, wet growing season. Yet, effects of plant population were consistent over three years including the highly productive year of 1991.

Grain yield at the site with the high soil test for K was not affected by either the plant population or the use of 20 lb. K_2O per acre in the starter fertilizer (Table 8). These results are not consistent with those of the previous two years. However, the excessively cool and wet growing season may have affected the yield response to plant population.

Table 8. The effect of planted population and use of potash in a starter fertilizer on corn grain yield at the site having a low soil test for K.

K_2O Rate	Placement	Desired Population (plants/acre) 23,000	28,000	33,000	38,000	43,000
lb./acre		- - - - - - - - bu./acre - - - - - - - -				
0	-	138.3	141.5	144.8	141.8	133.5
20	starter	145.8	142.5	132.8	135.5	134.3

In 1993, core samples were taken at 58 and 72 days after planting for measurement of root density. At each sampling, cores were taken to a depth of 24 inches at 3, 6, and 12 inches from the row. The cores were subdivided into depth increments of 0-3, 3-6, 6-12, and 12-24 inches. Soil was washed from the roots and root length was measured. Root density was not measured for each treatment. Two plant densities (23,000, 33,000 plants per acre) were selected at both sites. At the low K site, the control, 100 lb. K_2O per acre, and 200 lb. K_2O per acre broadcast management options were sampled for each density. The control only at each of the two plant densities was sampled at the high K site. Sampling date was based on stage of growth rather than days after planting. The cool weather delayed growth in 1993. Consequently, the days after planting used for sampling were not consistent with those in 1992.

In both 1992 and 1993, there was a general increase in root density (root length per unit volume of soil, cm/cm^3) with the higher planted population for the first sampling date. The percentage increase was less in 1993 (20%) compared to 1992 (50%) at the low K site. This trend, however, was reversed at the high K site in 1993. At this site, the root density was 30% higher at the planted population of 23,000 plants per acre.

Root density can also be computed on an individual plant basis. When this calculation is made, there is a very different trend (Table 9). At 46 days after planting in 1992, the average length of root per plant increased only a few percent with the higher planted population. At 59 days after planting in the same year, the average root density decreased by 14% (high K site) to 41% (low K site) when the planted population increased from 23,000 to 33,000 plants per acre.

At 58 days after planting in 1993 (first sampling), root length per plant decreased by 16-18% when planted population increased from 23,000 to 33,000. The average root length per plant decreased by 30% (low K site) to 47% (high K site) sampling as planted population was increased. Thus, while there were more roots per unit volume of soil when population increased from 23,000 to 33,000 plants per acre, there were generally fewer roots when root length was expressed on an individual plant basis.

Table 9. Mean root length per plant as affected by plant population and relative soil test level in 1992 and 1993.

Year	Planted Population	Time of Sampling and Soil Test Level: 46 DAP High K	46 DAP Low K	59 DAP High K	59 DAP Low K
	plants/A	- - - - - - - - - - - m/plant* - - - - - - - - -			
1992	23,000	47.5	116.1	89.7	168.9
	33,000	51.5	121.4	77.3	99.3
		58 DAP		72 DAP	
1993	23,000	100.3	116.1	216.4	110.9
	33,000	84.6	95.7	114.1	77.3

*Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position, then calculating the mean root length per plant to a depth of 2 ft.

There was a significant interaction between planted population and root density measured at various positions in 1993. At the low K site and the 1st sampling, the higher planting density had higher inter row root densities in the top 6 inches but lower inter row root densities at 6-24 inches (Table 10).

Table 10. Root density at 58 DAP for the low K site in 1993 as affected by fertilizer application.

K_2O Applied	Distance from row	Depth of Sample (inches) 0-3	3-6	6-12	12-24
lb/A	inches	---------- cm/cm^3 ----------			
0	3	0.55	0.65	0.18	0.02
	6	0.20	0.35	0.19	0.02
	12	0.01	0.12	0.04	0.01
100	3	0.67	0.68	0.22	0.06
	6	0.23	0.17	0.13	0.04
	12	0.03	0.17	0.13	0.01
200	3	0.42	0.66	0.38	0.05
	6	0.21	0.67	0.18	0.06
	12	0.07	0.19	0.07	0.03

Fert X Position $p = 0.05$

There was also a significant interaction between potash management and root density at this site in 1993. In general, there was more root development to greater depths and further from the row when broadcast potash was used. Fertilizer use appeared to have a smaller effect on root density close to the plant.

The average root density was enhanced by potash application at the low K site in both 1992 and 1993 (Tables 11, 12). The application of 100 lb. K_2O per acre always maximized root density with a bigger response recorded in 1992 compared to 1993. The broadcast application of 200 lb. K_2O per acre also increased root density when compared to the control. The increase, however, was generally not as great as the increase produced by the 100 lb. K_2O per acre rate.

Table 11. Mean root density in 1992 as affected by soil test level and fertilizer applied at the low K site when sampled at 46 and 59 DAP.

Soil Test Level	Fertilizer Applied	Sampling Time 46 DAP	59 DAP
	lb. K_2O/A	--- cm/cm^3* ---	
High	-	.11*	.19
Low	0	.15	.20
Low	100	.38	.36
Low	200	.27	.28
	Pr>F	.001	.01

*Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Table 12. Mean root density in 1993 as affected by soil test level and fertilizer applied at the low K site.

Soil Test Level	Fertilizer Applied	Sampling Time 58 DAP	72 DAP
	lb K_2O/A	--- cm/cm^3* ---	
High	-	0.21	0.36
Low	0	0.20	0.15
Low	100	0.27	0.23
Low	200	0.25	0.25
	Pr>F	0.008	0.0001

*Values were obtained by averaging densities measured at 3 distances from the row and 4 depths at each position.

Considering planted populations in 1993, there was a larger increase in average root density produced by fertilization at the higher population (Table 13). This is in contrast to 1992 when the trend was for a greater effect of fertilization at the lower plant population.

Table 13. Mean root density as affected by fertilizer application and plant population at the early sampling times in 1992 and 1993.

Fertilizer Applied	1992 (46 DAP) Plant Population 23,000	33,000	1993 (58 DAP) Plant Population 23,000	33,000
lb K_2O/A	---------- cm/cm^3 ----------			
0	0.11	0.20	0.21	0.18
100	0.31	0.43	0.25	0.29
200	0.22	0.32	0.19	0.32

Fert X Pop p = 0.98 in 1992 and 0.002 in 1993.

Interpretive Summary:

The response of corn to planted population and potash fertilizer management in 1993 was consistent with the response measured in 1992 even though corn growth and development was hindered by the excessively cool and wet growing season. When the soil test for K was in the low range, early growth was increased as plant population increased to about 33,000 plants per acre. This early growth response was reflected in total dry matter production and grain yield. As might be expected, there was a strong response to potash fertilization. The use of 40 lb. K_2O per acre in the starter was highly efficient and yields from this potash management option were equivalent to yields produced by higher broadcast rates of K_2O.

Potash fertilizer use had no impact on early growth and yield when the soil test K was high. At this site, dry matter production, but not grain yield, was optimum when the planted population was 33,000 plants per acre.

Root density at the low K site was affected by both planted population and potash fertilization. There was a general decrease in average root length per plant when the planting density was increased. The potash fertilization caused higher root densities and deeper development of roots in the inter-row area. Even though root development was probably hindered by cooler than normal soil temperatures, this observation has important implications for root development in dry years.

USE OF IN-SEASON NIR PLANT N TEST TO PREDICT N REQUIREMENTS FOR HARD RED SPRING WHEAT[1/]

J.A. Lamb, G.W. Rehm, S.D. Evans, N. Martin, G.L. Malzer, G. Nelson, J. Cameron, and B.J. Holder[2/]

ABSTRACT: This report is on the third year of research to determine in-season nitrogen need for hard red spring wheat by utilizing a predictive plant or soil test. Nine locations in western Minnesota were established with three soil N levels (50, 100, and 150 lb A^{-1}; 0 to 2 foot nitrate-N plus fertilizer) and five topdress N application (0, 15, 30, 45, and 60 lb N A^{-1}) at tiller growth stage. Results indicate in seven of nine sites the topdress application of N did improve grain yield. Chloropyll meter readings did indicate grain responses in six locations. The relationship between chlorophyll meter readings and grain yield increase was -0.46. The soil nitrate-N test for the 0 to 1 foot depth did characterize the soil N levels. The correlation between soil nitrate-N and grain yield increase was -0.42.

Nitrogen fertilizer management is important for optimum grain yield and protein of hard red spring wheat in western Minnesota. Efficient use of nitrogen fertilizers has direct effects on farm profitability as well as environmental quality. Because of soils with silty clay loam textures and spring moisture conditions, nitrogen fertilizers are typically applied in the fall when soil conditions are more suited to application. Currently, the combination of a soil nitrate-N test and an estimated yield goal is used to arrive at fertilizer N recommendations. There are two problems with this method of arriving at nitrogen recommendations for this production system. First, it is very difficult to arrive at a realistic yield goal in the fall because of changing climatic conditions during the winter and before spring planting. Secondly, there is the potential for the loss of N either from poor application techniques, leaching, or denitrification. The use of a quick and simple diagnostic test shortly before tillering would allow the producers to adjust the amount of N fertilizer needed in the growing season based on a better knowledge of plant stand, soil moisture conditions, and a more accurate weather forecast. The diagnostic test would allow wheat growers to apply 50 to 60 percent of the N fertilizer in the fall and determine how much of the remainder to apply at the tiller stage.

The objective of this study is to develop the use of diagnostic tools such as NIR (near infrared reflectometry) plant analysis for N content, a soil nitrate-N test, or a chlorophyll meter to adjust N fertilizer application to spring wheat during the growing season.

Materials and Methods

Nine experimental sites were established in western Minnesota in 1993 (Table 1). The initial soil nitrate-N at the sites ranged from 14 to 118 lb A^{-1} at the 0 to 2 foot depth. To meet the objective the treatments included a factorial design of three soil nitrate-N levels (0 to 2 foot of 50, 100, and 150 lb A^{-1}) and five topdress N application rates (0, 15, 30, 45, and 60 lb N A^{-1}). The soil N levels were established by applying fertilizer preplant. This was ammonium nitrate (33-0-0) at all sites. At locations with initial soil nitrate-N contents greater than 50 lb/A 0-2 foot (Wagner and Brandt S) 20, 70, and 120 lb N/A were added. Norm hard red spring wheat was seeded at 100 lb A^{-1} in six inch rows with a double disk press wheel drill. Topdress application of ammonium nitrate was made at the late tiller growth stage. Just before application whole plant samples, soil samples, and chlorophyll meter measurements were taken. Whole plants were taken from two feet of row for Kjeldahl total N, NIR total N, and NIR crude protein analyses. Soil samples to a two foot depth were taken and divided into one foot increments. These soil samples were analyzed for nitrate-N. Chlorophyll meter readings were taken from random plants in each plot. Weed control was obtained with post emergence application based on weed species and density at each location. The plots were harvested with a plot combine. The grain yield was then corrected to 13.5 % moisture. All locations in 1993 were infected with scab. No attempt was made to separate scabby kernels from the yield sample.

Table 1. Initial characteristics of 1993 NIR wheat experiment locations.

	Nitrate-N 0-24 in.	Phosphorous	Potassium	pH 0 - 6 in.	Organic Matter
Location	lb A^{-1}	ppm	ppm		%
Bring	28	7	165	7.7	3.7
Widner	20	7	366	7.9	3.2
Knutson	14	13	326	8.0	3.6
Wagner	94	27	131	8.1	
Cassavan	16	14	313	7.7	4.2
Brandt N	37	16	173	7.8	5.2
Brandt S	118	43	149	7.9	
Morris N	18	12	226	7.7	4.8
Morris S	20	17	152	7.8	4.1

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

[2/] J.A. Lamb, G.W. Rehm, and G.L. Malzer are Associate Professor and Professors in the Soil Science Department at the University of Minnesota; N. Martin is a Professor in the Department of Agronomy and Plant Genetics at the University of Minnesota, St. Paul, MN; S.D. Evans and G. Nelson are Professor and Assistant Scientist at the West Central Experiment Station, University of Minnesota, Morris, MN; B.J. Holder and J. Cameron are Associate Professor and Field Plot Technician at the Northwest Experiment Station, Crookston, MN 56716.

Grain Yields

At five of the nine locations there was no interaction between the soil N level and topdress N application for grain yield (Table 2). At the Brandt S location soil N level did not effect grain yield and topdress N application significantly decreased grain yield. This location has had a history of manure application which caused the nonresponse to soil N. The other four locations had increases to grain yield from soil N level. These increases ranged from 2.7 to 9.4 bu/A.

Four locations had a significant soil N by topdress N interaction (Tables 3 and 4). At Wagner, Morris N, and Morris S, at the 50 soil N level, topdress N application of 30, 60, and 45 lb/A, respectively, was needed to maximize grain yield. Although 60 lb N/A was needed at Morris N for maximum yield, the largest part of the increase came with only 15 lb N/A. For the 100 and 150 soil N levels for Wagner, Morris N, and Morris S, topdress N did not significantly increase yields. At the Cassavan site, grain yield responses to topdress N application occurred at all soil N levels. The grain yields were the largest at 60 lb/A topdress N application for the 50 and 100 soil N levels. At the 150 soil N level, grain yield was maximized at 45 lb N/A.

Table 2. Grain yield at locations with no statistical significant interactions in 1993.

Soil N	Bring	Widner	Knutson	Brandt N	Brandt S
lb/A			bu/ A		
50	29.6	21.1	33.2	44.7	46.8
100	32.4	26.6	36.8	47.0	47.7
150	33.9	30.5	37.3	47.4	46.7
Topdress N					
0	30.2	22.2	31.4	43.4	49.7
15	31.4	23.9	34.3	47.2	47.4
30	32.0	26.2	36.3	46.7	47.7
45	33.1	27.6	38.4	47.7	46.1
60	32.9	30.5	38.6	46.9	44.4
Statistical Analyses					
Soil N (SN)	**	**	**	*	NS
Topdress N (TN)	+	**	**	*	**
TN linear	*	**	**	*	**
TN quadratic	NS	NS	+	*	NS
SN X TN	NS	NS	NS	NS	NS
C.V. (%)	9.4	21.8	9.7	7.0	6.5

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

Table 3. Grain yield at locations with a soil N by topdress N interaction.

		Topdress N (lb/A)			
Soil N	0	15	30	45	60
lb/A		Grain Yield (bu/A)			
		Wagner			
50	49.7	56.6	58.2	56.6	60.8
100	62.3	59.6	62.5	61.3	61.9
150	62.1	62.0	59.0	61.2	63.9
		Cassavan			
50	29.3	36.6	39.6	43.6	46.3
100	39.8	44.2	48.0	48.2	50.9
150	48.0	48.2	50.5	52.5	52.4
		Morris N			
50	33.0	39.6	40.3	42.1	42.8
100	40.3	42.8	43.3	40.7	40.3
150	39.8	38.1	40.1	39.5	35.9
		Morris S			
50	29.2	28.5	29.0	36.6	32.0
100	36.6	36.0	37.1	36.8	37.6
150	39.9	37.0	37.2	35.4	35.2

Table 4. Statistical analyses for grain yield at locations with soil N by topdress N interaction in 1993.

	Wagner	Cassavan	Morris N	Morris S
Soil N (SN)	**	**	NS	**
Topdress N (TN)	*	**	++	NS
TN linear	**	**	+	NS
TN quadratic	NS	+	**	NS
SN X TN	**	*	**	**
C.V. (%)	4.8	6.6	7.8	7.5

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

Table 5. Soil nitrate-N and chlorophyll meter readings at tiller in 1993.

Site		Soil N	Chlorophyll Meter	Soil Nitrate-N 0-1 ft.	1-2 ft.	0-2 ft.
		lb/A	units	lb/A		
Bring		50	43.2	20.8	10.3	31.1
		100	43.5	40.2	21.0	61.2
		150	45.3	104.4	20.3	124.7
	Statistic		**	*	NS	**
Widner		50	39.9	23.9	11.3	35.2
		100	41.3	43.3	13.2	56.5
		150	41.6	93.9	20.9	114.8
	Statistic		++	**	++	**
Knutson		50	36.9	14.9	5.9	20.8
		100	38.8	36.7	7.9	44.6
		150	39.1	79.8	8.0	87.8
	Statistic		NS	*	NS	*
Wagner		50	40.0	39.5	8.6	48.2
		100	40.9	149.8	17.4	167.2
		150	41.5	168.9	15.4	184.3
	Statistic		*	*	*	*
Cassavan		50	40.3	26.1	8.2	34.3
		100	41.4	46.5	14.6	61.1
		150	41.5	122.2	18.3	140.5
	Statistic		+	**	*	**
Brandt N		50	39.9	57.7	7.6	74.9
		100	40.8	55.5	9.5	65.0
		150	40.9	92.7	12.0	104.7
	Statistic		+	NS	NS	NS
Brandt S		50	41.2	23.6	8.4	32.0
		100	42.1	53.0	9.3	62.3
		150	42.9	105.7	13.4	119.1
	Statistic		++	**	++	**
Morris N		50		15.7		
		100		30.4		
		150		53.2		
	Statistic			**		
Morris S		50		30.6		
		100		36.9		
		150		45.9		
	Statistic			*		

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

In Season Tests

Chlorophyll Meter

Chlorophyll meter readings were taken at seven of the nine locations in 1993 at tiller stage before the topdress N application was made (Table 5). At six locations significant differences (P= 0.20) occurred. As the amount of soil N increased the chlorophyll (greenness of the plant) readings increased. The differences in the readings are smaller than expected and observations are depended on the location on the leaf that the reading is taken. The relationship between chlorophyll meter units and grain yield increase from topdress N has a correlation of -0.46.

Soil Nitrate-N at Tiller Growth Stage

Soil nitrate-N was also measured at tiller growth stage before the topdress N treatments were applied. A significant increase occurred at eight of nine locations from soil nitrate-N at the 0 to 1 foot depth. As soil N level was increased so was the soil nitrate-N content. The increase was best measured in the 0 to 1 foot depth. The 0 to 2 foot depth nitrate-N content was similar in response to soil N level. Figure 2. shows the relationship between soil nitrate-N and grain yield increase from topdress N application. Because of the prior manure history Brandt S was omitted from the analysis. The correlation between grain yield increase and soil nitrate-N at 0 to 1 foot depth is - 0.42.

IMPROVING FERTILIZER RECOMMENDATIONS FOR PRODUCTION OF EDIBLE BEANS IN MINNESOTA

George Rehm, Thor Sellie, and Andy Scobbie[1/]

ABSTRACT: This research project was initiated in 1991 in an effort to improve fertilizer recommendations for edible bean production. The results from sites at this Irrigation Center at Staples are summarized in this report. When N rates were studied, the application of 120 lb. N per acre produced optimum yield. This N was applied at two times during the growing season. There was no response to potassium and sulfur applied in a fertilizer program in 1993.

A research project was initiated in 1991 to improve fertilizer recommendations for the production of edible beans in Minnesota. The project was continued in both the 1992 and 1993 growing seasons. The information gathered during the 1993 growing season is summarized in this report. Data collection was curtailed by the excessively cool and wet growing season. Because of these conditions, information was not gathered from sites in Renville, and Yellow Medicine Counties. Treatments were applied at each site but the test sites were flooded and the edible beans were destroyed. Useful data were gathered from the experimental sites at the Staples Irrigation Center.

Objectives:

As in 1991 and 1992, the objectives of the research project are:

1. To improve nitrogen fertilizer recommendations for edible bean production. For much of the production area, this means improving N fertilizer recommendations by adjusting for residual or carryover NO_3-N. Where production occurs on sandy soils, improvement of nitrogen recommendations means that more emphasis should be placed on nitrogen credits from previous legume crops used in the rotation.
2. To determine the rate of phosphate needed when the crop is grown on fine-textured soils and relate the rate needed to soil test values for P.
3. To determine the response of edible beans grown on sandy soils to the application of both potash and sulfur.

Experimental Procedure:

Original plans called for an evaluation of nitrogen rates at 4 sites, an evaluation of phosphate rates at 3 sites, potash rates at 1 site, and sulfur rates at 1 site. Because of the excessively wet growing season, N rate evaluations were lost at 2 sites and phosphate rate evaluations were lost at all 3 sites. Yields were measured from a N rate site in Renville county, but they were variable and were of no use. Consequently, data from the plots at the Irrigation Center are summarized in this report.

For the potassium study, adequate rates of phosphate and sulfur were applied to each treatment. The various rates of potash supplied as 0-0-60 were also broadcast before planting. All materials were incorporated with a disk.

For the sulfur study, adequate rates of phosphate and potash were applied to each treatment. The various rates of sulfur supplied as granular gypsum were also broadcast before planting. All of these fertilizer materials were incorporated with a disk.

Each treatment in the nitrogen trial received adequate phosphate, potash, and sulfur. These fertilizers were broadcast and incorporated with a disk before planting.

For the potassium and sulfur studies, the N rate was constant for all treatments at 120 lb. per acre. A split application of nitrogen was used for all studies. The first half of the nitrogen was applied at approximately 2 weeks after emergence. The remaining half was applied at approximately 4 weeks after emergence.

Soil samples (0-6 in.) were collected from the site before fertilizer was applied. The relevant soil properties are summarized in Table 1. The red kidney beans were planted in late May, irrigated as needed throughout the summer, and harvested in September.

Table 1. Relevant soil properties for the experimental site at the Irrigation Center at Staples.

pH	6.8
Bray and Kurtz #1P, ppm	34
soil test K, ppm	100

Results and Discussion:

The excessively cool and wet conditions during the 1993 growing season destroyed the edible beans that were planted on the fine textured soils at the experimental sites in Renville and Yellow Medicine Counties. Therefore, results presented in this report are limited to the experimental site at the Irrigation Center at Staples.

Nitrogen fertilization produced a significant increase in yield. The rate of 120 lb. per acre was adequate for optimum yield (Table 2). These results are consistent with those recorded from nitrogen trials on the sandy soils in 1991. The major portion of the response occurs with the use of the first 30 lbs. N per acre.

[1/] Extension Soil Scientist, Junior Scientist, and Assistant Scientist, Soil Science Department, University of Minnesota, respectively.

Table 2. Effect of rate of fertilizer nitrogen on yield of red kidney beans in 1993. Irrigation Center.

N Applied	Yield
lb./acre	lb./acre
0	2353
30	2630
60	2830
90	2953
120	2999
150	2968

The yield of the red kidney beans was not significantly affected by the rate of K_2O applied (Table 3). Even though the soil test for K would be considered to be in the low range (Table 1), there was apparently enough K supplied by the soil to meet the needs of the crop. The results recorded in 1993 are consistent with those reported in both 1991 and 1992.

Table 3. Effect of rate of applied potash on yield of red kidney beans in 1993. Irrigation Center.

K_2O Applied	Yield
lb./acre	lb./acre
0	3058
60	3004
120	3015
180	2960
240	3071

Sulfur fertilization also had no significant effect on the yield of red beans (Table 4). These results are also consistent with the conclusions reached in 1991 and 1992. In the past, sulfur fertilization has increased the yield of corn and alfalfa grown on the sandy soil. However, sulfur uptake by edible beans is in the range of 5 to 10 lb./acre. This amount of sulfur can be easily mineralized from the soil organic matter. Therefore, a major response to sulfur fertilization should not be expected.

Table 4. Effect of rate of applied sulfur on the yield of red kidney beans in 1993. Irrigation Center.

S Applied	Yield
lb./acre	lb./acre
0	2813
10	2951
20	2952
30	2792

EVALUATION OF BROILER MANURE AS AN N SOURCE FOR POTATO[1]

C.J. Rosen, J.F. Moncrief, and M.J. Blaine[2]

Abstract: Broiler manure, on average, resulted in higher potato yields than a commercial nitrogen program. Manure reduced the amount of knobby potatoes and hollow heart. Scab was not affected by fumigation or manure. When manure was used in combination with fumigation yields were 100 cwt higher than without fumigation. However, This treatment also had significantly higher soil water concentrations of nitrate.

The objective of this experiment is to evaluate broiler manure as an N source for Russet Burbank potatoes. There has been some concern that manure will increase the incidence of scab on potatoes and is not as reliable a source of N as commercial fertilizer.

Methods and Materials: Pen pack, scraped, and piled manure was applied in the spring (April 19, 1993) before discing. The previous crop was corn. The rate of manure was based on a chemical analysis to result in an estimated available N of about 200 pounds per acre. The analysis of samples taken the day of application are shown in Table 1. The moisture content was quite variable and responsible for most of the variability in the chemical analysis. Most of the N in the manure was in the organic form (75% vs 25% for organic and mineral N respectively). It is assumed that all of the mineral N is available in the year of application and 0.35 of the organic N. This results in an average of 26.5 pounds of estimated available N per ton of manure. Manure was applied with a beater type solid manure spreader. Three calibration checks over an area of 300 ft.x 27 ft. resulted in an application of 8.4, 7.8, and 8.9 tons per acre with an average of 8.4 tons per acre. This resulted in an application of **223 lbs/A of estimated available N** as broiler manure. The manure treatment also received 30 pounds of N at planting and 69 pounds of fertigation N resulting in a total N application of **322 lbs/A** (Table 2). The manure treatment was contrasted to a conventional fertilizer program with a total N application of **275 lbs/A**.

Nitrogen sources were evaluated on soil that had been fumigated in the fall of 1992 and soil that was not. It was hypothesized that fumigated soil would result in slowed microbial nitrogen transformations that could affect crop N availability and/or leaching losses. The experimental design was a randomized complete block with split plots. Main plots were fumigation, subplots were N source. Plots were 300 ft.x 54 ft. Ceramic suction samplers were placed in the row at a depth of 4 feet.

Results and Discussion: Potato yields are shown in Table 3. There was only statistical significance for fumigation for the 6-14 oz size. Generally, fumigation main effects were absent for potato yield and quality parameters. There was a consistent effect of manure and a manure by fumigation interaction for most of the measured yield categories. The manure N source resulted in higher potato yields when applied in combination with fumigation. A significant manure effect was absent when applied without fumigation. Precise reasons for this interaction are not known, but may be due to excessive N applications on the nonfumigated side due to an application error. Manure affected several quality parameters. When manure was applied with fumigation, knobby potatoes were significantly reduced. Manure with or without fumigation reduced hollow heart. The incidence of scab was not affected by fumigation or manure addition. This is contrary to common grower belief that manure increases scab. The effect of fumigation and N source on soil water concentrations of nitrate at 4 ft. depth are shown in Figure 1. The manure N source resulted in higher concentrations of soil water nitrate throughout the season. The manure in combination with fumigation showed a "spike" between 12 and 14 weeks after planting.

In addition to the manure/fumigation study, a comparison of N timing and amount was done on a split center pivot with the conventional grower program on one half and an N conservative program on the other half. Applications of N were generally reduced and the last application based on a petiole sap test for nitrate. The results of this study are shown in table 4. There was a 40 cwt increase in total yield with the alternative N program. Of course statistics can not be used due to the lack of replication.

---

1. This project was supported by the Legislative Commission on Minnesota Resources, the Anoka Sand Plain Project, the Soil Conservation Service, and the Minnesota Extension Service. Their support is greatly appreciated.

2. C.J. Rosen and J.F. Moncrief are Extension Specialists in the Soil Science Department, University of Minnesota, St. Paul, MN. M.J. Blaine is a Best Management Consultant with the Soil Conservation Service, Becker, MN.

Table 1. Nitrogen content of Jack Frost broiler manure applied on 4/19/93.

Slds	NH_4^+	NO_3^-	Min.	Org.[1]	Total	Est.Aval[2]
--%--	----------	----------	lbs/Ton	----------	----------	----------
54.3	18.2	-	18.2	48.0	66.3	32.6
51.9	18.3	-	18.3	49.7	68.0	33.2
67.5	13.9	-	13.9	41.7	55.6	26.4
82.3	13.3	-	13.3	50.6	63.9	28.5
74.6	9.4	-	9.4	33.7	43.1	19.5
81.9	10.2	-	10.2	27.4	37.6	18.5
68.8	**13.9**	**-**	**13.9**	**41.9**	**55.8**	**26.5**

1. Organic nitrogen = Total nitrogen - Total mineral nitrogen.
2. Estimated available nitrogen=(Org.-Nx.35) + Tot.Min.-N. It is assumed that all of the mineral N and 30% of the Org.N is available during the first year of application.
3. The rate of manure was 8.4 tons/acre.

Table 3. Tillage pesticide application at Becker MN, 1993, previous crop was corn and soil is Hubbard loamy sand.

date	operation
10/7/92	Fall Chisel
10/92	Fumigation on half of the plots with Vapam (Sodium methyldithiocarbamate)
4/19/93	manure applied
4/25/93	Disc finisher
4/30/93	planting 14-16,000 seeds per acre
5/15/93	Dual/Sencor
5/28/93	Row cultivator
6/8/93	Hilling
6/10 to 8/19/93	Monitor, Mancozeb, Bravo, and Ridomil applied in multiple applic.

Table 2. Timing, source, and amount of N applied to the fertilized check, Becker, MN, 1993.

date	application	rate of material	N rate
		------pounds per acre	-------
4/30/93	Starter at planting	455 of 6.5-29.2-19.5	30
5/28/93	Cultivation at Emergence	250 of 33.5-0-0	84
6/8/93	Cultivation at Hilling	200 of 46-0-0	92
7/5/93	fertigation	10.4 gpa of 28% UAN	31
7/16-17/93	fertigation	12.5 gpa of 28% UAN	38
		total	275

Table 3. Effect of Manure and fumigation on potato yield and quality.

Treatment		knobs	<6 oz	6-14oz	>14oz	total	gravity	% hollow heart	% Scab
		----------	----------	cwt/A	----------	----------			
Fumigated	Manure								
-	-	36	236	250	13	535	1.0821	9.3	15.9
-	+	34	251	200	23	508	1.0802	6.7	1.3
+	-	50	214	227	14	505	1.0827	16.0	9.3
+	+	10	295	292	21	618	1.0807	5.3	2.7
Statistics									
Fumigation		NS	NS	++	NS	NS	NS	NS	NS
Manure		*	*	NS	NS	++	NS	++	NS
Fum. x manure		++	++	**	NS	**	NS	NS	NS

NS = nonsignificant, ++ = significant at 10%, * = significant at 5%, significant at 1%.
Estimated N applied for each treatment:
- - = 275 lb N/A
- + = 400 lb N/A (some N fertilizer applied by mistake at emergence and hilling)
+ - = 275 lb N/A
+ + = 322 lb N/A

Table 4. Effect of nitrogen management on potato yield and quality.

Treatment	knobs	<6 oz	6-14oz	>14oz	total	gravity	% hollow heart
	----------	----------	cwt/A	----------	----------		
Conventional	33	217	255	11	516	1.0846	2.0
Alternative	24	201	299	32	556	1.0885	1.3

Timing of application	Conventional N management	Alternative N management
	---------- lb N/A	----------
Planting (April 20)	31	31
Emergence (May 28)	85	73
Hilling (June 7)	92	70
Post-hilling (July 16)	72	36
Total N applied	280	210

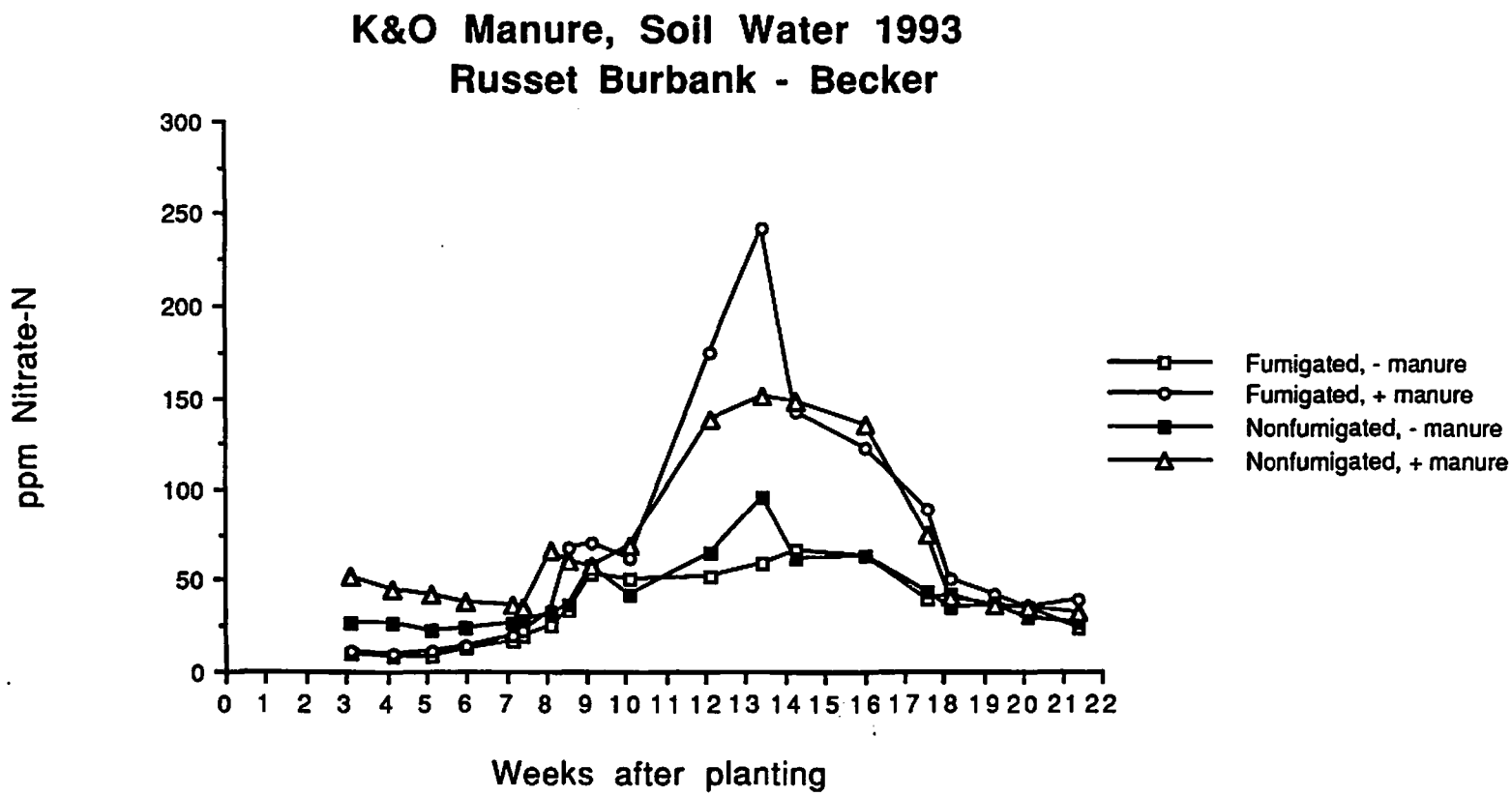


Figure 1. Nitrate-N concentrations in soil water at the 4 ft. depth through the 1993 growing season.

SITE SPECIFIC MANAGEMENT OF CORN HYBRIDS AND PLANT POPULATIONS[1]

D.J. Fuchs, D.R. Huggins, D. Fairchild, and P.C. Robert[2]

Abstract

A field experiment was conducted at the Southwest Experiment Station, Lamberton, MN to evaluate the effect of different soil types on the yields of two corn hybrids (Pioneer 3702 & 3563) and three populations (26,000, 32,000, and 38,000 seeds/ac). The lowest yields and stand counts occurred for both hybrids on the Webster soil when adjacent to the Ves (3-6 % slope) soil. Erosion in those areas reduced stands and yields. Stand counts were relatively consistent in areas without soil erosion. Higher yields across all treatments occurred on soils that had adequate drainage. Yields decreased with target populations greater than 32,000 seeds/ac.

Introduction

Few studies have evaluated corn hybrid and plant population effects on yield across soil types that occur in a landscape setting. This is the second year of an ongoing experiment, the first year's data was corrupted by mechanical problems with the planter and will not be included in this report.

Materials and Methods

A six-row (30-inch spacing) John Deere 7000 planter was used to plant the treatments across a landscape with variable soil types. The main plots were four replications of three target plant populations of: 26,000 seeds/ac, 32,000 seeds/ac, and 38,000 seeds/ac. Each population was split into two corn hybrids, Pioneer 3702 (P3702) and Pioneer 3563 (P 3563), to give a subplot that was 3 rows wide. The area had three major soil types; 1) Ves loam (Udic Haplustols), with slopes ranging from 1-6 percent , 2) Canisteo clay loam (Typic Haplaquolls), and a Webster clay loam (Typic Haplaquolls).

Stand Counts were taken on July 29, 1993. All mechanical weed control was completed before this date, and no factors effected the stand counts after this date. Stand counts, measuring 40-feet of row (2 rows by 20 feet). were taken in 100 foot increments across the field for each subplot (hybrid). Two row plots were harvested on October 28 and 29, 1993 with an Almaco plot combine. The yield samples, approximately 50 feet in length, were collected continuously across the field for each subplot.

Figure 1 and 2 show the yields, stand counts, and soil map of soils for the area. Additional management information is shown in Table 1.

Results and Discussion

Hybrids

Hybrid stand counts and yields varied in a similar pattern across the landscape. Pioneer hybrid 3702 yielded higher at all population levels, averaging 10 bu/ac more than Pioneer 3563.

Plant Populations

The stand counts for both hybrids were less than the targeted population. The Pioneer hybrid 3563 averaged 1770 plants/ac more than Pioneer 3702. For both hybrids there was a trend of increasing yield loss with targeted populations greater than 32,000 plants/ac.

Soil

The soil type had an effect on both corn population and yield. The lowest stand counts and yields occurred where Webster was adjacent to Ves soil (3-6 % slope). Soil erosion occurred in the concentrated flow areas as a result of heavy rains that fell in May and June. Yields were also lower on the poorly drained Canisteo soil. Yields decreased as the transect transitioned into Webster and Canisteo. These poorly drained soils had high moisture levels for the first half of the growing

[1] Support for this project was provided by a grant from the USDA-CSRS, and Soil Teq Inc.

[2] D.J. Fuchs and D.R. Huggins are Scientist and Assistant Professor at the Southwest Experiment Station, Lamberton, MN 56152. D. Fairchild is president of Agri-information Services, Inc., White Bear Lake, MN, 55110. P.C. Robert is Associate Professor of Soil Science Department at the University of Minnesota, St. Paul, MN 55108.

season, which was correlated with poor corn yields. Under the wet conditions of 1993, soil drainage probably had a greater effect on yields than plant population.

Table 1. Management information.

Item	Type	Rate	Date
Primary Tillage	No tillage		
Secondary Tillage	Field Cultivator	2 passes	5/20/93
Fertilizer	Anhydrous	125 lbs N/ac	10/14/92
Herbicides	Eradicane and Bladex	2.5 lbs ai /ac 1.5 lbs ai /ac	5/20/93
Planting	JD 7000 6-row	Variable	5/21/93
Row Cultivation		1 pass	6/20/93
Soil Test	P_2O_5 K_2O pH	35 ppm 175 ppm 6.5	Fall 1992

Figure 1. Corn yields and stand counts across the landscape.

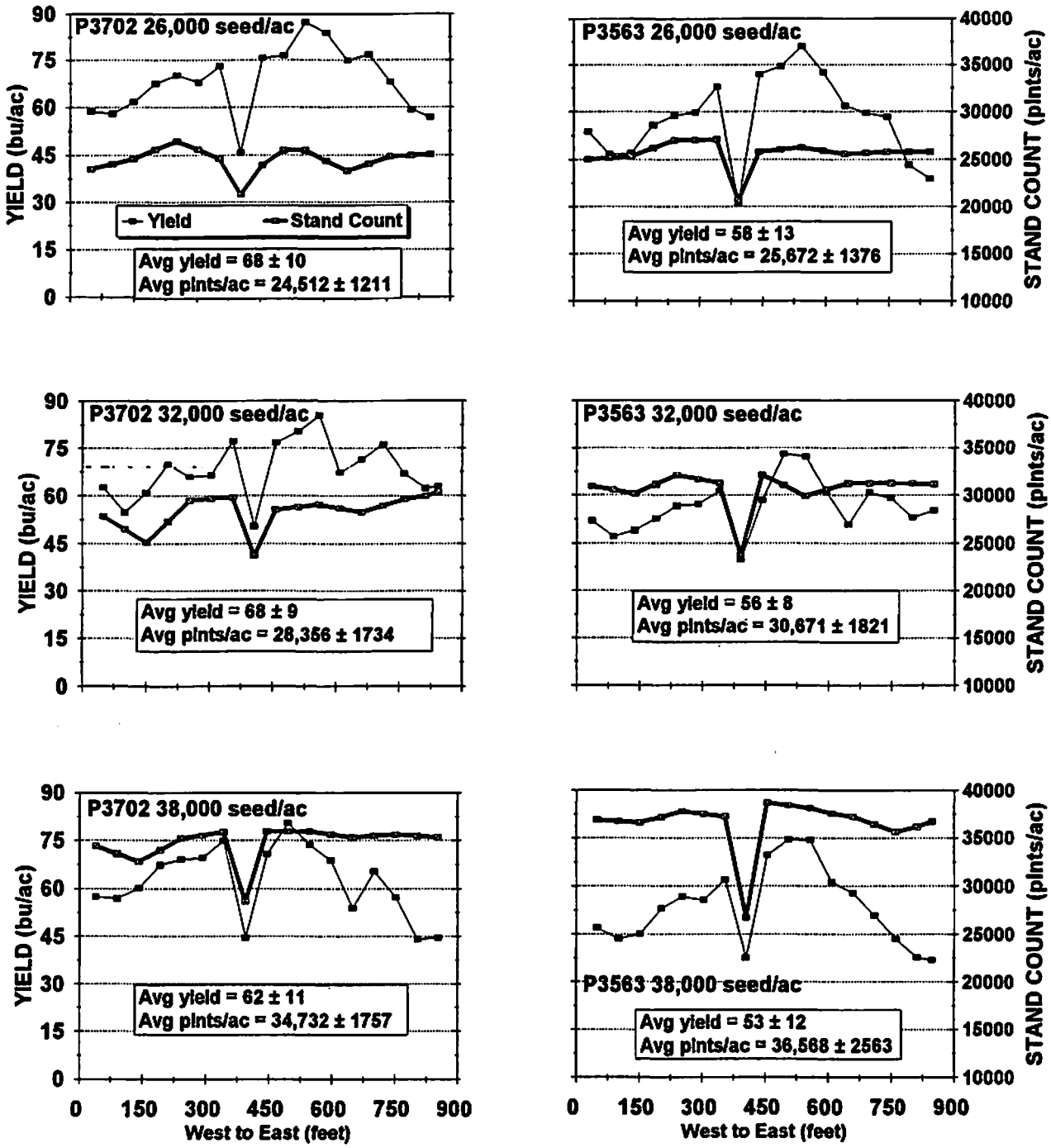
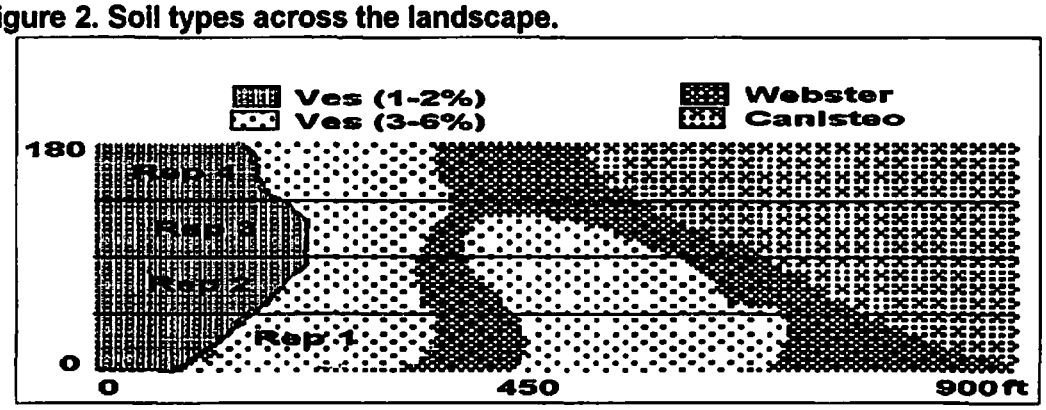


Figure 2. Soil types across the landscape.



SITE SPECIFIC CROP MANAGEMENT: N-SERVE RESPONSES AT HILDRETH SITE 1993[1]

G.L. Malzer, T.J. Graff, D.R. Huggins, D.J. Fuchs, P.C. Robert, W.H. Thompson, C.L. Gaalaas, S. Tomer and T.W. Bruulsema[2]

Abstract

Effectiveness of the nitrification inhibitor N-Serve is influenced by a number of soil factors. Soil specific management has potential for identifying these factors to predict where N-Serve may be useful in minimizing N losses. This study was conducted to relate corn yield response to N fertilizer with and without N-Serve to soil factors varying spatially within a field. Yields were extremely low due to excess moisture through the growing season. Both positive and negative yield responses to N-Serve occurred, and appeared to be spatially clustered. Positive N-Serve responses appeared to occur predominantly on well drained areas of the field.

Introduction

Soil factors including texture, pH, organic matter and temperature have been shown to influence the effectiveness of the nitrification inhibitor N-Serve. These factors vary within fields and may be mapped using soil specific management technologies to predict where N-Serve may be useful in minimizing losses of N in the nitrate form. The objective of this study was to determine how corn yield and N uptake response to N fertilizer with and without N-Serve was related to soil and landscape factors varying spatially within a field.

Experimental Procedures

The field was at the Southwest Experiment Station at Lamberton, MN. Five treatments, consisting of two N rates (60 and 120 lb acre^{-1}) with and without N-serve at 0.5 lb a.i. acre^{-1} and a control without N fertilizer, were applied preplant on May 21 across the field in strips (transects) 15 feet wide and 1240 feet long. Treatments were arranged in a nested randomized complete block design with 6 replications. N-Serve treatments were nested within the two N rates. Corn (Pioneer 3861) was planted on May 25 with 30 inch row spacing. Weed control was accomplished using Lasso plus Bladex (3 lb acre^{-1} + 2 lb acre^{-1}, respectively) at planting.

A detailed soil survey was obtained on a scale of approximately 1:5,000. Soil samples were taken on May 27 from the control treatment strips at 100 foot intervals to a depth of two feet in one foot increments. Soils were analyzed for NO_3-N, NH_4-N, total N, total carbon, mineralizable N and soil water. Grain yields were determined on September 29 by harvesting two rows in 50 foot increments down the entire strip with a plot combine, producing 24 yield samples per strip. Nitrogen uptake was calculated as grain dry matter multiplied by grain N concentration and represents N uptake into grain rather than whole plant N uptake.

Analysis of variance was performed on overall means of N treatments and on means of N treatments by soil series using SAS. Grain yield, N uptake and responses to N-Serve were kriged using simple kriging to generate maps showing spatial trends at each level of N fertilizer. Kriging is one of the more reliable methods for estimating unmeasured points between measured points within a field area.

---

[1] The assistance and financial support of the Minnesota Agricultural Experiment Station, USDA-CSRS, Dow Elanco, Soil Teq Inc., and DMI is gratefully acknowledged.

[2] Professor, and Assistant Scientist, Dept. of Soil Science; Soil Scientist and Scientist, Southwest Experiment Station; Associate Professor, Assistant Scientist, Jr. Scientist, Jr. Scientist and Post-Doctoral Research Associate, Dept. of Soil Science, respectively.

Results

The overall means for corn grain yield and grain N uptake are presented in Table 1. Due to a wet spring, cool wet summer and flooding of some of the plot area, yield and N uptake were very low (0 to 90 bu acre^{-1} and 0 to 60 lb acre^{-1}, respectively) . The only difference detected between N treatments was significantly lower yield and N uptake on the check plot.

Analysis of variance indicated that variation due to soil series was as significant as that due to N treatment. Within each treatment Glencoe soil series had the lowest yield (Table 2). This soil has the poorest drainage of the soils in this plot area (Fig 1a) and is found in the lower elevation areas of the field (Fig 1b). Within each soil series the control produced significantly lower yields than the other treatments on all but two soils. On the Glencoe and Seaforth series no differences were detected between N treatments.

Both grain yields and N-Serve responses were highest in the areas of the field with higher elevation (Fig 2a,b,c,d). However, some of the higher elevation areas with relatively high grain yields had negative N-Serve responses (Fig 2c,d). Spatial variation in grain N uptake (nitrogen removal) followed a pattern similar to that of grain yield (Fig 3a,b,c). N-Serve effects on grain N uptake (nitrogen removal) were less clearly spatially clustered (Fig 4a,b) than were N-Serve effects on grain yield.

Discussion and Conclusions

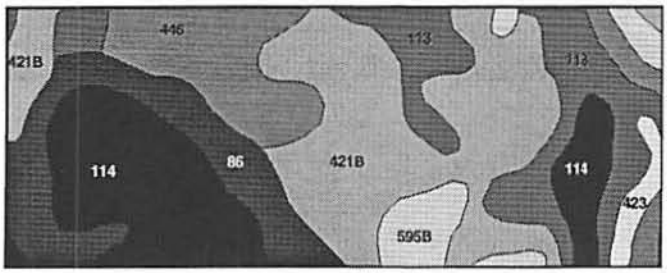
The observation of spatially contiguous clusters of positive and negative N-Serve responses indicates potential for site specific management. At the high rate of N fertilizer, approximately one quarter of the field area had a positive yield benefit from N-Serve, and the area with a negative yield effect was about equally as large. Further work will focus on predicting the areas likely to show positive responses.

Table 1. Corn grain yield and grain N uptake averaged over the whole field for each N treatment.

N-Rate lb acre^{-1}	N-Serve	# of obs	Grain Yield bu acre^{-1}	Grain N Uptake lb acre^{-1}	
0	without	144	31.6±20.1	18.9±11.7	a
60	without	144	53.4±28.0	33.9±17.8	b
60	with	144	54.8±28.2	33.9±17.2	b
120	without	144	54.4±29.6	35.0±18.7	b
120	with	144	54.3±30.5	34.7±19.1	b

Table 2. Corn grain yield treatment means arranged by soil series.

Trt #	Soil	# of obs	N Rate lb acre^{-1}	N-Serve	Grain Yield bu acre^{-1}		
1	Canisteo	20	0	without	25.9 ± 14.0	a	
2	Canisteo	15	60	without	39.5 ± 24.1		b
3	Canisteo	17	60	with	47.4 ± 23.6		b
4	Canisteo	21	120	without	51.0 ± 22.7		b
5	Canisteo	17	120	with	43.9 ± 27.2		b
1	Glencoe	5	0	without	4.4 ± 11.0	a	
2	Glencoe	5	60	without	5.9 ± 10.5	a	
3	Glencoe	6	60	with	8.0 ± 14.6	a	
4	Glencoe	4	120	without	3.9 ± 8.7	a	
5	Glencoe	5	120	with	5.7 ± 12.9	a	
1	Normania	15	0	without	33.7 ± 13.0	a	
2	Normania	22	60	without	64.8 ± 8.3		b
3	Normania	21	60	with	67.6 ± 10.0		b
4	Normania	17	120	without	68.6 ± 10.1		b
5	Normania	15	120	with	67.3 ± 9.5		b
1	Seaforth	2	0	without	33.3	a	
2	Seaforth	1	60	without	38.1	a	
3	Seaforth	2	60	with	49.8	a	
4	Seaforth	1	120	without	44.8	a	
5	Seaforth	2	120	with	45.2	a	
1	Swanlake	10	0	without	43.0 ± 10.1	a	
2	Swanlake	6	60	without	64.7 ± 3.1		b
3	Swanlake	8	60	with	69.6 ± 5.9		b
4	Swanlake	7	120	without	66.8 ± 7.2		b
5	Swanlake	6	120	with	69.1 ± 3.2		b
1	Ves	43	0	without	47.3 ± 11.7	a	
2	Ves	47	60	without	72.1 ± 8.6		b
3	Ves	46	60	with	72.9 ± 8.5		b
4	Ves	48	120	without	74.7 ± 7.1		b
5	Ves	50	120	with	75.6 ± 7.1		b
1	Webster	22	0	without	39.1 ± 11.9	a	
2	Webster	25	60	without	65.3 ± 19.7		b
3	Webster	21	60	with	65.8 ± 19.2		b
4	Webster	20	120	without	66.9 ± 18.3		b
5	Webster	21	120	with	70.0 ± 16.3		b

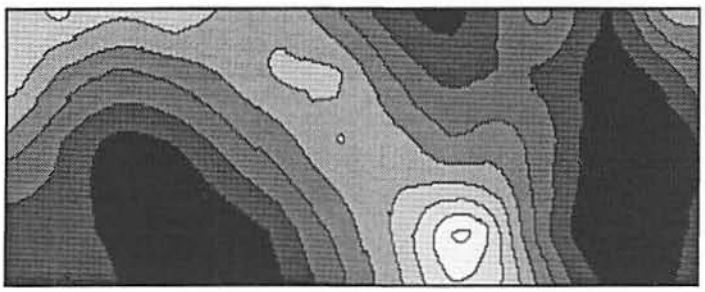


← N →

N-Serve Study Soil Map LEGEND

Symbol	Name	Drainage Class
114	Glencoe	Very Poorly Drained
86	Canisteo	Poorly Drained
113	Webster	Poorly Drained
446	Normania	Moderately Well Drained
421B	Ves	Well Drained
595B	Swanlake	Well Drained
423	Seaforth	Moderately Well Drained

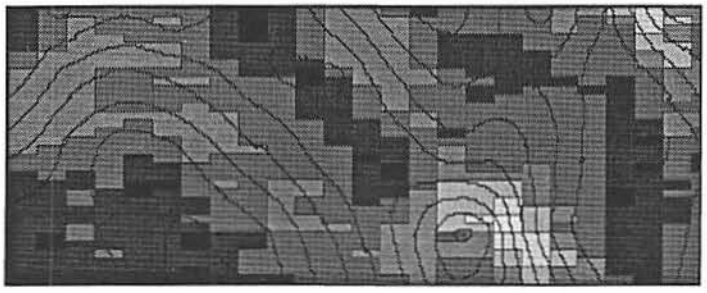
Figure 1a. Soil survey map of study area.



0 1 2 3 4 5 6 7 8 9

Relative Elevation LEGEND (ft.)

Figure 1b. Digital Elevation Model (DEM) illustrating relative topographic variations across the study area.



0 1 2 3 4 5

Average Slope Class by Harvest Sample Area (%)

Figure 1c. Slope class map. Average slope (%) was calculated for each 51x15' harvest sample area. Slope was derived from the DEM for the site (Fig 1b).

Figure 1. N-Serve Response Study. The experiment was conducted on a 13.7 acre field at the U of MN Southwest Experiment Station. Soils in the plot area (Fig 1a) varied from very poorly drained concave landscape positions to well drained sloping soils (Fig 1c). Relative elevation ranged from 0 to > 9 feet (Fig 1b). The experimental design included six blocks and five treatments. Treatment (1): control strip receiving no nitrogen application; (2): transects receiving 60 lb N acre^{-1} without N-Serve; (3): transects receiving 60 lb N acre^{-1} with N-Serve; (4): transects receiving 120 lb N acre^{-1} without N-Serve; (5): transects receiving 120 lb N acre^{-1} with N-Serve. Treatment strips were paired by N-rate within each block. Harvest samples were collected at 51 foot intervals accross each transect. N-Serve response was approximated for both grain yields and nitrogen removal by adjacent N-rate pairs. A centroid coordinate was determined for each sample pair and the parameters were kriged to illustrate spatial variability of N-Serve effects at different landscape positions and soil conditions.

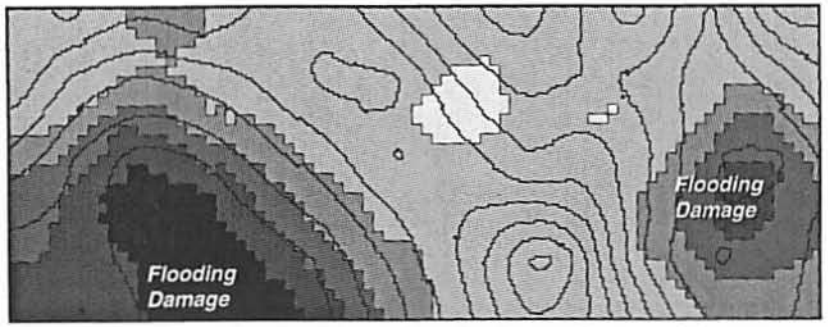


Figure 2a. Kriged estimates of corn grain yields (bu acre^{-1}) across plot area; N-Rate = 60 lb N acre^{-1} (treatment 3).

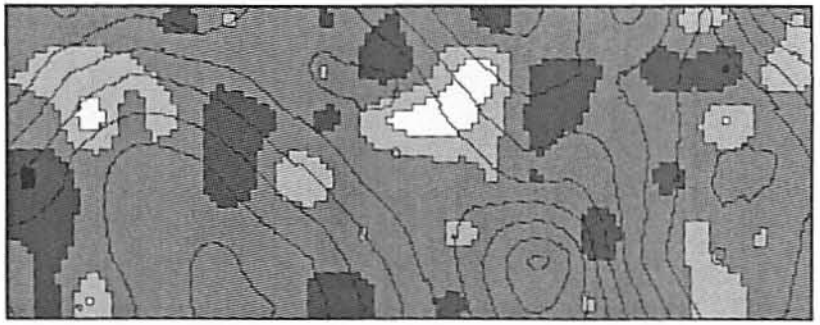


Figure 2c. Kriged estimates of N-Serve response (bu acre^{-1}) across plot area; N-Rate = 60 lb N acre^{-1} (treatment 3 minus treatment 2).

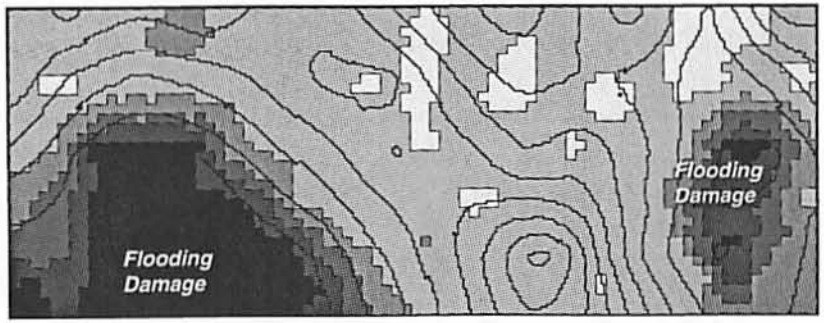


Figure 2b. Kriged estimates of corn grain yields (bu acre^{-1}) across plot area; N-Rate = 120 lb N acre^{-1} (treatment 5).

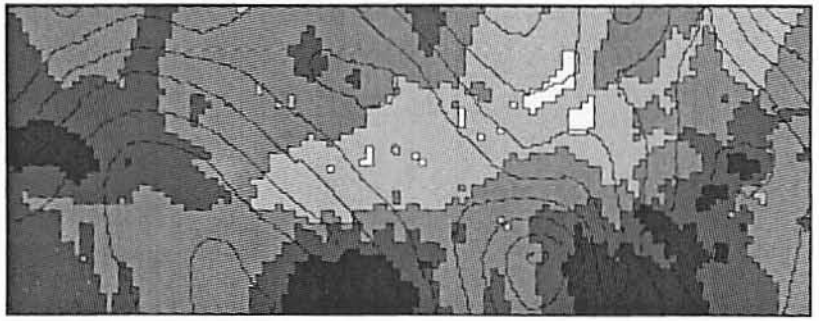


Figure 2d. Kriged estimates of N-Serve response (bu acre^{-1}) across plot area; N-Rate = 120 lb N acre^{-1} (treatment 5 minus treatment 4).

Corn Grain Yield (bu acre^{-1}) LEGEND

< 5 | 5 - 20 | 20 - 40 | 40 - 60 | 60 - 80 | 80 - 100

N-Serve Response (bu acre^{-1}) LEGEND

< -15 | -15 - -5 | -5 - +5 | +5 - +15 | > +15

Figure 2. Spatial models of corn grain yields using two different nitrogen application rates (Figs 2a and 2b) and variable N-Serve responses at different landscape positions (Figs 2c and 2d). Contour lines represent one foot increments of the digital elevation model (DEM) from the study area (Fig 1b). Flooding damage occurred within closed, concave landscape positions (Glencoe soils; Fig 1a).

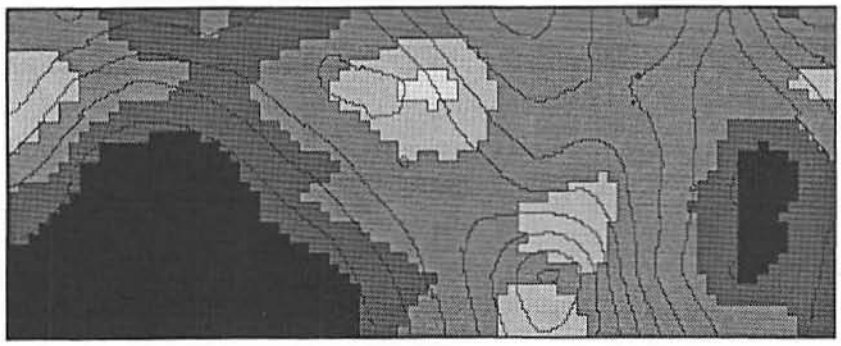


Figure 3a. Nitrogen Removal (lb N acre^{-1}; N-Rate = 0 lb N acre^{-1})

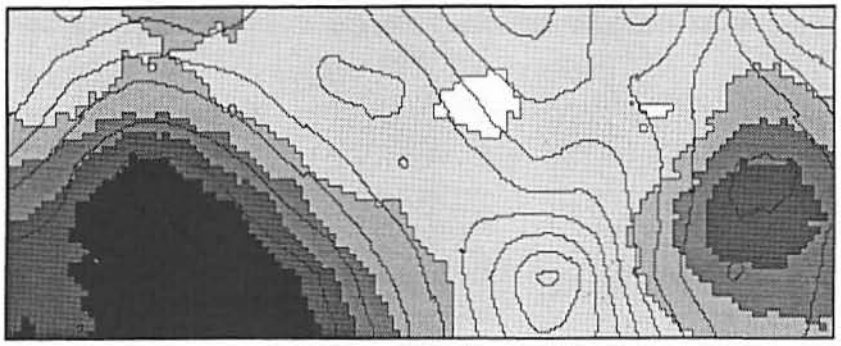


Figure 3b. Nitrogen Removal (lb N acre^{-1}; N-Rate = 60 lb N acre^{-1})

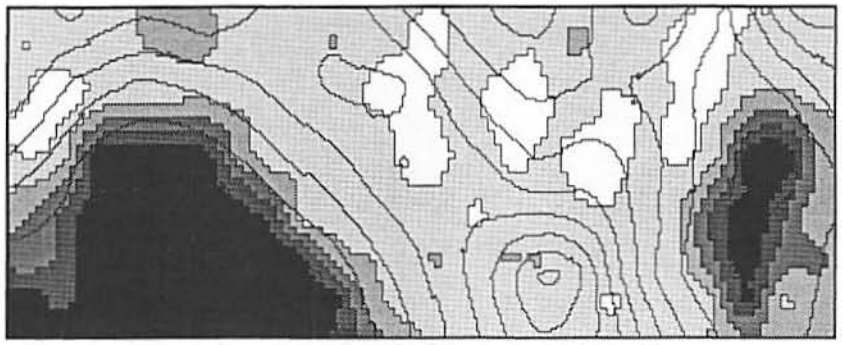


Figure 3c. Nitrogen Removal (lb N acre^{-1}; N-Rate = 120 lb N acre^{-1})

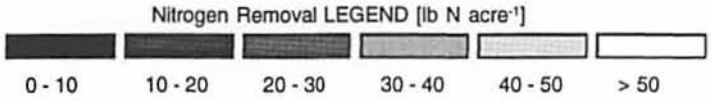


Figure 3. Spatial variations of nitrogen removal at three nitrogen application rates.

Figure 4a. N-Serve effect on nitrogen removal (N-Rate = 60 lb N acre^{-1})

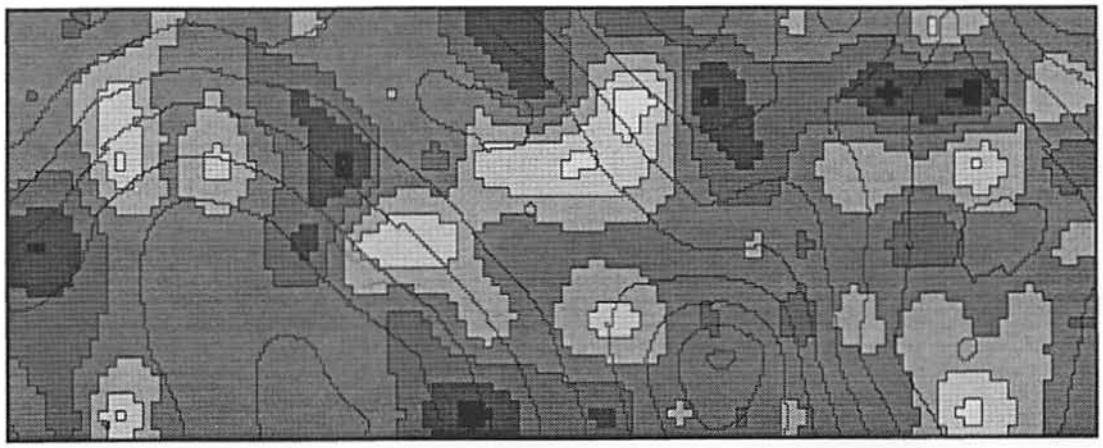


Figure 4b. N-Serve effect on nitrogen removal (N-Rate = 120 lb N acre^{-1})

N-Removal Difference LEGEND [lb N acre^{-1}]

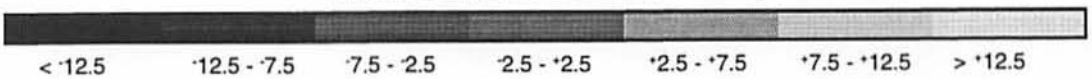


Figure 4. Spatial variations of N-Serve effects on N-removal. Adjacent paired harvest samples were used to calculate differences in nitrogen uptake for each nitrogen application rate. A centroid coordinate (x, y) was calculated for each sample pair and the resulting N-removal differences kriged to illustrate the spatial variability.

SITE SPECIFIC CROP MANAGEMENT: N-RESPONSE BY SOIL CONDITION AT HILDRETH SITE 1993[1]

G.L. Malzer, T.J. Graff, P.C. Robert, D.R. Huggins, D.J. Fuchs, W.H. Thompson, C.L. Gaalaas, and T.W. Bruulsema[2]

Abstract

Corn N responses vary spatially with site properties. This study was conducted to relate corn yield responses to soil factors varying spatially within a field. Six N fertilizer rates were applied in transects over the length of the field. Corn growth was severely delayed by cool, wet weather to the extent that maturity did not occur before the killing frost. Therefore yields were taken as silage. Silage yields at the critical N rate showed substantial spatially related variation. Maximum yields in much of the field area did not occur at the highest N rate.

Introduction

Corn responses to N fertilizer vary spatially with soil properties and landscape position. Variable rate application of nitrogen fertilizers is now possible because of recent advances in variable rate technologies (VRT), geographic information systems (GIS) and positioning technology. This study was conducted to examine the spatial variability of N response curves and their relationships to soil properties and landscape position. The goal was to ascertain which parameters are best suited for making site specific N recommendations.

Experimental Procedures

The field, previously cropped to soybean, was at the Southwest Experiment Station at Lamberton, MN. Six N fertilizer treatments, consisting of five constant N rates (0, 60, 90 120, and 150 lb acre^{-1}) and one variable N rate, were applied as anhydrous ammonia on May 21 in strips (transects) 15 feet wide and 1150 feet long (Fig 1c). The variable rate was determined by existing extension recommendations and the soil map unit equivalency rating. Treatments were arranged in a randomized complete block design with six blocks each containing 23 N response replicates. Corn (Pioneer 3563) was planted on May 22 and 25 (interrupted by rain) with 30 inch row spacing. Weed control was accomplished using Lasso plus Bladex (3 lb acre^{-1} and 2 lb acre^{-1}, respectively) on May 25.

A detailed soil survey was obtained on a scale of approximately 1:6,000. Soil samples were taken on May 21 from the control treatment strips at 100 foot intervals to a depth of two feet in one foot increments. Soils were analyzed for NO_3-N, NH_4-N, total N, total carbon, mineralizable N and soil water. Due to the cool wet summer and early frost, the corn did not reach maturity. Silage yields were determined on October 13 and 14 by harvesting one row in 50 foot increments down the entire strip with a mechanical silage harvester, producing 23 yield samples per strip.

Analysis of variance was performed on overall means of N treatments and on means of N treatments by soil series using SAS. Responses to N rates were fitted to linear-plateau models (Fig 5). The response models were calculated on a moving average basis for centroid points between adjacent replicates within transects. Silage yield, N uptake and response curve parameters were kriged using simple kriging to generate maps showing spatial trends. Kriging is one of the more reliable methods for estimating unmeasured points between measured points within a field area.

Results

Silage dry matter yield and N uptake were low but did respond to N fertilizer (Table 1). Silage yield and N uptake varied considerably among soil series, especially at the zero rate of N fertilizer (Table 2). Variability in percent dry matter was also high, likely resulting from wide variation among plants in maturity stage at the first killing frost. Maximum silage yields were fairly uniform across the field except in one of the three map units with Glencoe soil and low relative elevation (Fig 2a). However, silage yields at the critical N rate (i.e. model plateau yields) varied to a greater extent (Fig 2b). Variation in silage yield without N fertilizer was greater yet (Fig 2c). The model estimates of silage yield without N fertilizer (β_0; Fig 2d) agreed closely with the measured yields without N (Fig 2c) indicating validity of the fitted linear plateau models.

Nitrogen rates corresponding with maximum observed silage yields were less variable than critical N rates, and were spatially more contiguous (Fig 3a and 3b). This was unexpected, as the N rate at which maximum yield occurred was expected to be more affected by random error than the model estimated critical N rate. Nitrogen response rates (β_1) varied strongly across the field (Fig 4), ranging from zero to more than 180 pounds of silage dry matter per pound of N applied.

---

[1] The assistance and financial support of the Minnesota Agricultural Experiment Station, USDA-CSRS, Soil Teq Inc., and DMI is gratefully acknowledged.

[2] Professor, Assistant Scientist, and Associate Professor, Dept. of Soil Science, Soil Scientist and Scientist, Southwest Experiment Station; Assistant Scientist, Jr. Scientist and Post-Doctoral Research Associate, Dept. of Soil Science, respectively.

Discussion and Conclusions

Critical nitrogen rate can be treated as an approximation of the N rate above which no yield response is expected. The critical rate estimates had substantial spatially related variation (Fig 3b) that would warrant variable rate application of N fertilizer, if the critical N rates could be predicted in advance. Further analysis of the data will be performed to evaluate the possibility of such prediction.

The map of N rates that correspond with maximum silage yield shows that more than half of the field did not produce the highest yield at the highest N rate. Most of the field area produced the highest yield at the 80 to 120 lb acre^{-1} N rate. The practical interpretation is that adding extra N fertilizer to a given recommendation does not maximize yield and most certainly does not maximize profit.

Table 1. Corn silage yield responses to N fertilizer rates averaged over soil series. Means ± standard deviations.

N-Rate lb acre^{-1}	# of obs	%Dry Matter of Silage	N uptake lb acre^{-1}	Dry Matter Yield ton acre^{-1}
0	138	46 ±10	54 ±17	3.2 ±1.0
60	218	52 ±08	81 ±21	4.4 ±1.0
90	196	52 ±10	87 ±27	4.5 ±1.2
120	138	53 ±08	92 ±23	4.7 ±1.0
150	138	51 ±11	96 ±27	4.7 ±1.3

Table 2. Corn silage yield responses to N fertilizer rate by soil series. Means ± standard deviations.

Soil Map Unit	N Rate lb acre^{-1}	# of obs	Dry Matter % of Silage	N Uptake lb acre^{-1}	Silage Yield ton acre^{-1}
Glencoe	0	11	36 ± 13	42 ± 19	2.3 ± 1.2
Glencoe	60	15	41 ± 14	60 ± 31	3.2 ± 1.7
Glencoe	90	8	37 ± 16	52 ± 30	2.7 ± 1.5
Glencoe	120	11	48 ± 7	75 ± 20	4.0 ± 1.1
Glencoe	150	9	47 ± 6	87 ± 19	4.0 ± 1.0
Normania	0	17	45 ± 6	58 ± 17	3.1 ± 0.8
Normania	60	15	48 ± 5	73 ± 14	3.9 ± 0.6
Normania	90	39	52 ± 7	89 ± 19	4.5 ± 0.9
Normania	120	19	53 ± 6	93 ± 17	4.7 ± 0.6
Normania	150	22	55 ± 5	102 ± 21	5.2 ± 0.8
Swanlake	0	7	52 ± 5	53 ± 13	3.5 ± 0.8
Swanlake	60	12	58 ± 4	82 ± 20	4.7 ± 0.6
Swanlake	90	7	59 ± 4	85 ± 16	4.6 ± 0.5
Swanlake	120	7	59 ± 4	101 ± 26	5.2 ± 0.8
Swanlake	150	6	60 ± 5	109 ± 31	5.2 ± 0.5
Ves	0	59	49 ± 7	58 ± 15	3.6 ± 0.8
Ves	60	132	54 ± 6	86 ± 17	4.8 ± 0.7
Ves	90	54	56 ± 6	102 ± 20	5.2 ± 0.6
Ves	120	56	54 ± 6	97 ± 19	5.0 ± 0.6
Ves	150	58	53 ± 7	103 ± 19	5.0 ± 0.7
Webster	0	44	44 ± 12	50 ± 18	2.8 ± 1.0
Webster	60	44	49 ± 10	73 ± 24	4.0 ± 1.1
Webster	90	88	50 ± 12	82 ± 29	4.3 ± 1.4
Webster	120	45	52 ± 10	87 ± 28	4.5 ± 1.4
Webster	150	43	46 ± 16	83 ± 36	4.2 ± 1.8

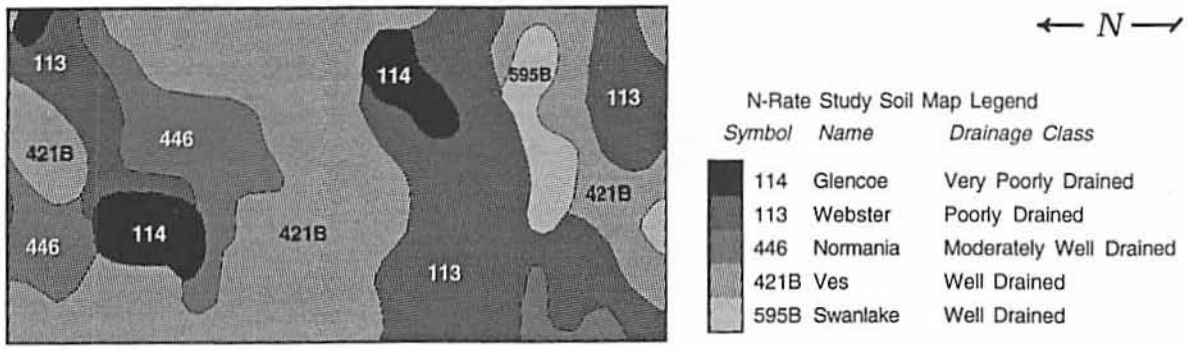


Figure 1a. Soil map of study area. The map is based on a detailed survey of the field plot; approximate scale = 1:6,000.

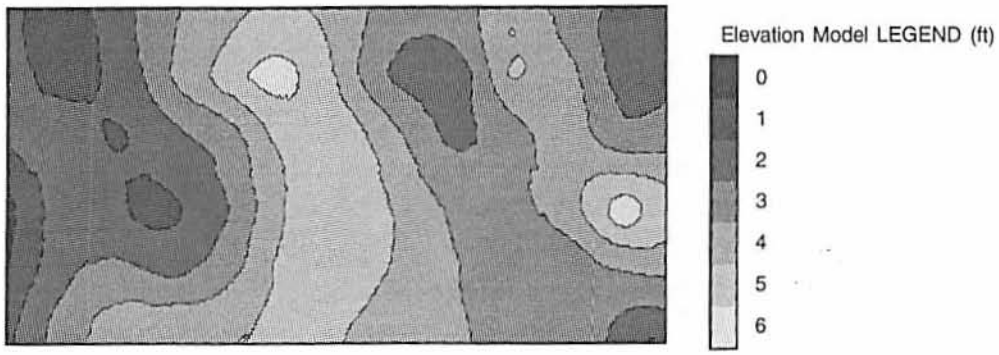


Figure 1b. Elevation model of study area. Elevation data was collected with a laser theadolite and kriged using simple kriging. The continuous elevation estimates were partitioned at one foot contour intervals.

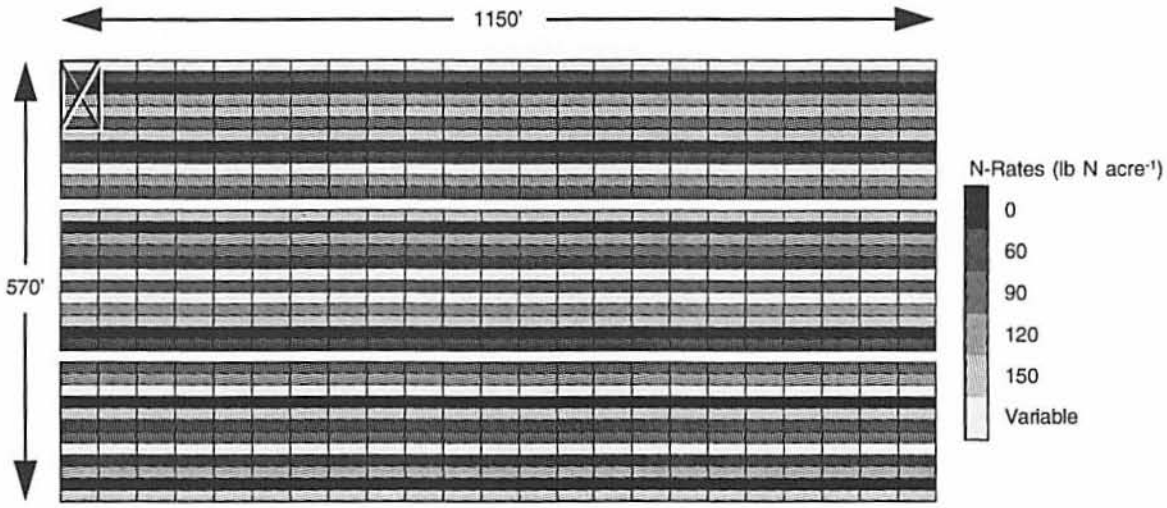


Figure 1c. Experimental design of nitrogen response landscape study. The field plot consisted of six blocks. A series of six transects (nitrogen rates) were randomized within each block. The small rectangles represent 826 (50') silage yield samples. The box with an "X" illustrates an "N-Response replicate".

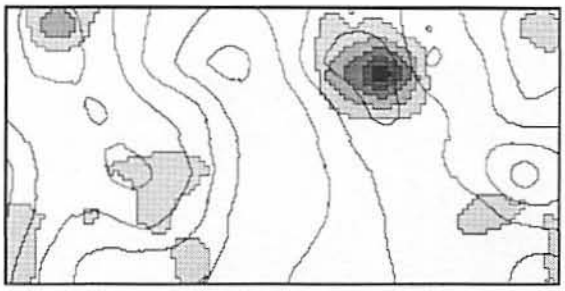


Figure 2a. Maximum silage yields. (kriged estimates from N-response replicates) [ton acre^{-1}].

Figure 2b. Silage yields at critical N-rate (*P*). (kriged estimates from moving averages of linear plateau N-response models by paired replicate) [ton acre^{-1}].

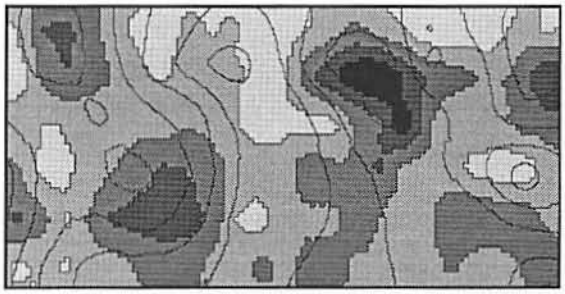


Figure 2c. Silage yields without applied nitrogen (kriged estimates from control treatment; N-rate = 0 lb N acre^{-1}).

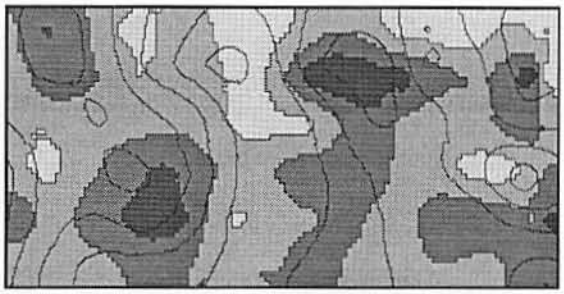


Figure 2d. Silage yield without N (kriged estimates from linear plateau model; β_0) [ton acre^{-1}].

Silage Yields LEGEND [ton acre^{-1}]

< 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | > 5

Figure 2. Comparison of spatial variations in silage yields. Simple kriging was used to interpolate silage yields across the plot area for each parameter. Fig 2a represents measured maximum yields by N-response replicate. Fig 2b indicates potential yields that would result from an optimum (critical) application of variable N-rates. Control treatment harvest data is presented in Fig 2c. Integrity of the linear plateau model estimates of potential silage yields without applications of nitrogen (β_0) is shown by close agreement of spatial patterns in Figs 2c and 2d. Black lines in each figure represent one foot contour intervals (Fig 1b).

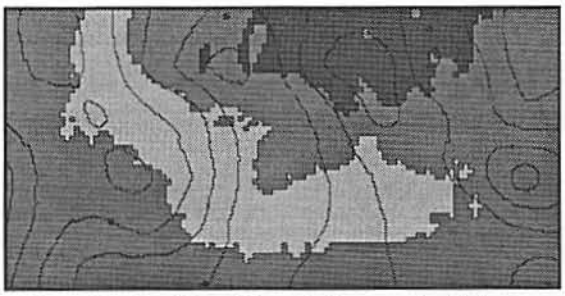


Figure 3a. Spatial variation of nitrogen rates that correspond with maximum silage yields (Fig 2a).

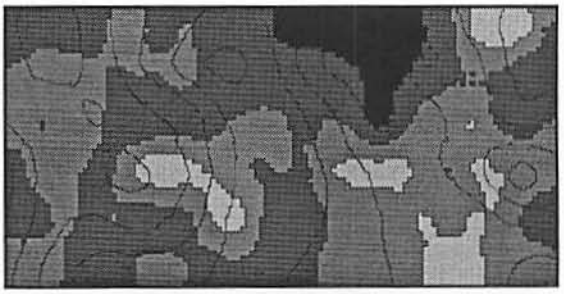


Figure 3b. Spatial variation of critical nitrogen rates (*C*) that correspond with silage yields (Fig 2b).

Nitrogen Application Rate LEGEND [lb N acre^{-1}]

0 - 40 | 40 - 80 | 80 - 120 | 120 - 150

Figure 3. Spatial variation of maximum (Fig 3a) and critical (Fig 3b) nitrogen application rates. The maximum nitrogen rates correspond with measured maximum silage yields (Fig 2a) from each N-response replicate (Fig 1c). The spatial variability map of critical nitrogen rates (Fig 3b) was generated by kriging the moving averages of linear plateau model estimates from paired adjacent N-response replicates. Black lines in each figure represent one foot contour intervals (Fig 1b).

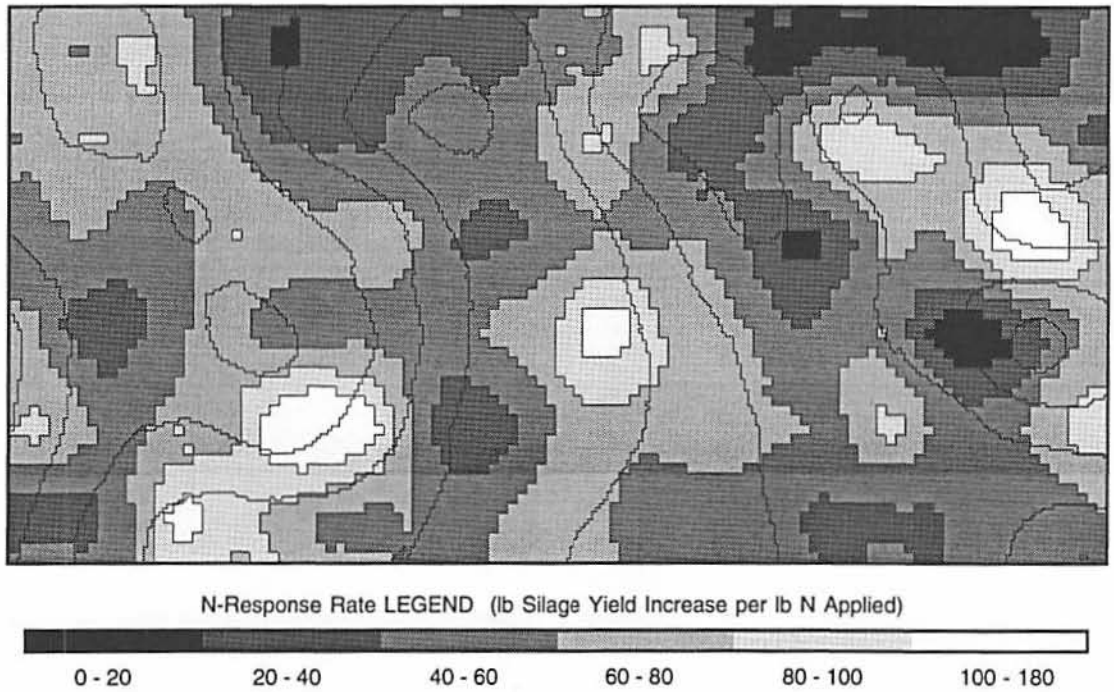


Figure 4. Spatial variability of nitrogen response rates (β_1). Response rates vary from 0 to > 180 (lb lb^{-1}) across the field.

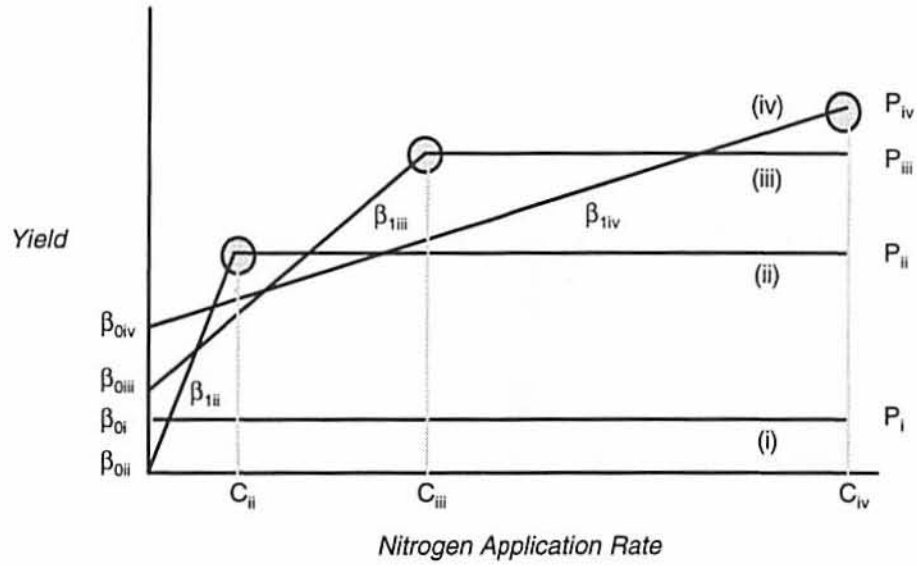


Figure 5. Four examples of nitrogen response rate functions. Linear plateau models are presented to describe four N-response scenarios (i, ii, iii and iv). where, β_0: yield without nitrogen applied [Fig 2d]; β_1: N-response rate [Fig 4]; *C:* Critical N-rate [Fig 3b]; and *P:* crop yield at critical N-rate [Fig 2b]. N-response scenario (i): no yield response to N applications; (ii): rapid N-response with low critical N-rate and moderate yield increase; (iii): moderate N-response with moderate critical N-rate and large yield increase; (iv): continuous yield increase with increasing N-rates.

EVALUATION OF A VARIABLE TILLAGE IMPLEMENT ON CORN AND SOYBEAN YIELDS[1]

D.J. Fuchs, D.R. Huggins, and P.C. Robert[2]

Abstract

A study to determine the performance of a variable tillage implement (VTI) was conducted in corn and soybean residues in 1992 and 1993. By controlling disc depth and angle, the implement was designed to vary the amount of crop residues incorporated in the soil. For purpose of comparison, this study included the following conventional tillage systems: no-tillage, fall no-tillage with spring secondary tillage, chisel plow, and moldboard plow. In 1992, the corn and soybean yields with VTI treatments were not significantly different than other tillage treatments for both soil types. In 1993, corn and soybean yields on the well drained Ves soil were significantly lower with no tillage as compared to the other tillage treatments. The VTI, for the two years evaluated, resulted in corn and soybean yields that were comparable to other treatments with tillage (moldboard plow, chisel plow, and spring cultivation).

Introduction

The objective of this study was to dynamically control the amount of residue left on the surface, according to soil type. A variable primary tillage implement (VTI), a prototype built by DMI Inc., was tested in corn and soybean residues at the Southwest Experiment Station, Lamberton, MN in 1992 and 1993. The VTI implement was a modified 12.5-wide DMI Tiger II®. The first and second gang of concave discs were 20-inch in diameter with 15-inch spacings. The front and rear gang were offset by 7.5 inches. The discs for the first gang were at a 15 degree angle. Modifications were made to the second gang, that allowed the disc angle to be changed, from 15 to 30 degrees. The angle of the second gang of discs and the depth of both sets of gangs were hydraulically and independently controlled from the tractor and changed "on the go" over the field. The two gangs of discs are followed by 5 shanks with 30-inch spacing. Each shank had a 10-inch wide "Tiger Point" tip. The depth of the shanks was also controlled from the tractor. The shanks were followed with smaller discs that helped level the soil.

Materials and Methods

1992

The study with soybean residue included the following tillage treatments: four different settings of the VTI unit, field cultivation, and no-tillage (Table 1). VTI shanks were set at a working depth of 10 to 12 inches for all VTI settings. The different settings were accomplished by changing the working depth and angle of the front gang of discs. The four different settings for the VTI unit were: 1) no disc action, 2) discs at 15 degree angle and 5 inch working depth, 3) discs at 15 degree angle and 10 inch working depth, 4) discs at 30 degree angle and 5 inch working depth. These treatments in turn divided three replicated mainplots of a poorly drained Webster clay loam (Typic Haplaquolls) and a well drained Ves loam (Udic Haplustolls). **The tillage treatments were applied in early spring.**

The study with corn residue included subunits of chopped and unchopped residue treatment that were stripped across three replicated mainplots of a poorly drained Webster clay loam and a well drained Ves loam. The residue was chopped in the fall of 1991. Each subunit was divided into the following tillage treatments: five different VTI settings, moldboard plow, and no-tillage (Table 1). **The tillage treatments were applied in early spring.**

1993

The study with soybean residue included tillage treatments of: two VTI settings, chisel plow, no-tillage in the fall with spring tillage using a field cultivator, and no-tillage (Table 3). The treatments were subdivided into 5 replicated mainplots of a poorly drained Webster clay loam and a well drained Ves loam.

The study with corn residue included subunits of chopped and unchopped residue treatments that were stripped across three replicated mainplots of poorly drained Webster clay loam and well drained Ves loam. The residue was chopped in the fall of 1992. Each subunit was divided into the following tillage treatments: three VTI settings, moldboard plow, and no-tillage (Table 3).

Additional management information may be found in Tables 2 and 4. Yield results are presented in Tables 5, 6, 7, and 8. For both years corn and soybean yields were collected in the fall, using an Almaco plot combine.

---

[1] Support for this project was provided by a grant from the USDA-CSRS, and Soil Teq Inc.

[2] D.J. Fuchs and D.R. Huggins are Scientist and Assistant Professor at the Southwest Experiment Station, Lamberton, MN 56152. P.C. Robert is Associate Professor at the Soil Science Department at the University of Minnesota, St. Paul, MN 55108.

Results

1992

The tillage treatments did not have a significant effect on the corn or soybean yields for either soil type (Table 5 and 6). Chopping the corn stalks in the fall before tillage did not significantly effect soybean yields.

1993

Soybean Residue. Tillage treatments had a significant effect on corn yields on well drained Ves loam, but not on Webster clay loam (Table 7). No-tillage was the lowest yielding treatment for both soil types, yielding 4.4 to 10.1 bu/ac less than the other tillage treatments on the well drained soil, and 1.9 to 9.1 bu/ac less than the other tillage treatments on the poorly drained soil (Table 7). There was no significant difference in yields between tillage treatments that disturbed the soil surface prior to planting (Table 7).

Corn Residue. No yields were collected on the poorly drained soil. The area was severely flooded several times, destroying the soybean crop. On the well drained area, the tillage treatment had a significant effect on soybean yield. No-tillage yields were 7.5 to 11.5 bu/ac less than the other tillage treatments (Table 8). There was not a significant difference in yields between the moldboard plow and the three VTI rates (Table 8). Chopping the corn stalks in the fall before tillage had no significant effect on soybean yields.

Table 1. 1992 Tillage treatments in corn and soybean residue.

Soybean Residue		Corn Residue	
Spring Primary Tillage	Spring Secondary Tillage	Spring Primary Tillage	Spring Secondary Tillage
No-tillage	none	No-tillage	none
No-tillage	1 pass with field cult.	Moldboard plow	2 passes with field cult.
VTI 0 deg. 0 in.	1 pass with field cult.	VTI 0 deg. 0 in.	2 passes with field cult.
VTI 15 deg. 5 in.	1 pass with field cult.	VTI 15 deg. 5 in.	2 passes with field cult.
VTI 15 deg. 10 in.	1 pass with field cult.	VTI 15 deg. 10 in.	2 passes with field cult.
VTI 30 deg. 5 in.	1 pass with field cult.	VTI 30 deg. 5 in.	2 passes with field cult.
		VTI 30 deg. 10 in.	2 passes with field cult.

Table 2. Management information for 1992.

Crop	Item	Type	Rate	Date
Corn	Fertilizer	Urea	150 lbs N/ac	4/13/92
	Herbicides	Lasso and Bladex (preemergent)	3.0 lbs ai /ac 1.5 lbs ai /ac	5/8/92
		Accent and Buctril and 28 % N	0.031 lbs ai/ac 0.25 lbs ai/ac 4 % v/v	6/5/92
	Planting	Pioneer 3615 JD 7000 15-ft 6-row	29,000 seeds/ac	5/6/92
	Row Cultivation		once	6/4/92
	Soil Test	P_2O_5 K_2O pH	17 ppm 131 ppm 3	Fall 1988
Soybean	Fertilizer	none		
	Herbicides	Poast Plus and COC	0.19 lbs ai/ac 1.3 % v/v	6/10/92
		Pinnacle and Surfactant and 28 % N	0.004 lbs ai/ac 0.125 % v/v 1.0 % v/v	6/11/92
	Planting	Hardin JD 750 10-ft notill drill	160,000 seeds/ac	5/7/92
	Row Cultivation		none	
	Soil Test	P_2O_5 K_2O pH	35 ppm 175 ppm 6.5	Fall 1990

Table 3. 1993 Tillage treatments in corn and soybean residue.

Soybean Residue		Corn Residue	
Fall Primary Tillage	Spring Secondary Tillage	Fall Primary Tillage	Spring Secondary Tillage
No-tillage	none	No-tillage	none
No-tillage	1 pass with field cult.	Moldboard plow	2 passes with field cult.
Chisel Plow	1 pass with field cult.	VTI 0 deg. 0 in.	2 passes with field cult.
VTI 0 deg. 0 in.	1 pass with field cult.	VTI 15 deg. 5 in.	2 passes with field cult.
VTI 30 deg. 10 in.	1 pass with field cult.	VTI 30 deg. 10 in.	2 passes with field cult.

Table 4. Management Information for 1993.

Crop	Item		Type	Rate	Date
Corn	Fertilizer		Urea	150 lbs N/ac	5/6/93
	Herbicides		Eradicane and Bladex	2.5 lbs ai /ac 1.5 lbs ai /ac	5/20/93
	Planting		JD 7000 6-row	29,000	5/21/93
	Row Cultivation			once	
	Soil Test:	Ves loam	P_2O_5 K_2O	22 ppm 105 ppm	Fall 1992
		Webster clay loam	pH P_2O_5 K_2O pH	6.0 68 ppm 269 ppm 7.3	Fall 1990
Soybean	Fertilizer		none		
	Herbicides		Roundup (spot spray) Lasso and Sencor and Ranger Poast Plus and Pursuit and Basagran and Surfactant and 28 % N	1.0 lbs ai /ac 3.0 lbs ai /ac 0.25 lbs ai /ac 0.5 lbs ai/ac 0.16 lbs ai/ac 0.031 lbs ai/ac 0.5 lbs ai/ac 0.013 % v/v 0.013 % v/v	5/26/93 5/28/93 7/21/93
	Planting		Hardin JD 750 10-ft notill drill	195,000 seeds/ac	5/26/93
	Row Cultivation			none	
	Soil Test		P_2O_5 K_2O pH	12.5 ppm 135 ppm 7.1	Fall 1988

Table 5. Corn yields by soil type and tillage treatment in 1992.

Tillage treatment	Well drained soil[1]		Poorly drained soil[2]		Average
	(bu/ac)	(std. dev.)	(bu/ac)	(std. dev.)	(bu/ac)
No-tillage	128.7	15.9	114.0	18.3	**121.4**
No-tillage (w/spr cult.)	124.1	13.4	119.9	7.7	**122.0**
VTI 0 deg. 0 in.	130.0	13.5	126.5	5.4	**128.3**
VTI 15 deg. 5 in.	133.2	15.5	129.5	9.3	**131.3**
VTI 15 deg. 10 in.	139.1	12.2	114.6	19.2	**126.8**
VTI 30 deg. 5 in.	144.0	8.0	131.7	4.3	**137.8**
Average	**133.2**		**122.7**		**127.9**

[1] No significant difference between tillage treatments.

[2] No significant difference between tillage treatments.