Table 4. Soil N concentrations as a function of sampling depth and time for all plots that received no preplant N, 1992.

Site[1]	Sampling Time[2]	NO_3-N 0-1'	NO_3-N 1-2'	NO_3-N 2-3'	NH_4-N 0-1'	NH_4-N 1-2'	NH_4-N 2-3'	Hydrolyzable-N[3] 0-1'	Hydrolyzable-N[3] 1-2'	Hydrolyzable-N[3] 2-3'
		ppm N								
Outwash										
Sherburne	Preplant	1.2	1.1	0.8	3.3	3.0	2.6	28.0	14.0	4.9
	1-2 leaf	3.1	0.9	3.8	1.9	1.5	1.6	28.3	11.1	3.7
	6-12" tall	5.1	2.0	2.2	3.7	3.2	3.5	35.5	18.0	9.6
Dakota-1	Preplant	3.4	4.5	2.0	2.6	2.3	2.2	40.9	16.4	4.7
	1-2 leaf	4.5	3.9	3.9	3.8	2.3	2.3	41.1	17.3	5.8
	6-12" tall	6.9	5.5	4.2	2.5	2.0	1.6	51.0	24.0	9.3
Loess										
Dodge	Preplant	2.2	2.4	1.1	4.1	4.5	2.2	47.1	18.3	8.3
	1-2 leaf	7.2	4.9	3.1	5.4	4.1	3.1	43.2	22.6	12.4
	6-12" tall	8.6	6.5	6.1	4.6	3.8	3.6	43.0	21.6	13.7
Goodhue	Preplant	4.7	2.6	2.2	47.8	31.6	16.6	134.1	70.6	35.8
	1-2 leaf	12.3	5.2	4.0	5.3	3.1	2.9	52.8	29.9	16.3
	6-12" tall	14.4	14.8	3.9	6.5	4.5	3.0	60.1	31.8	14.6
Olmsted-1	Preplant	3.0	2.1	2.0	5.4	3.2	2.9	51.5	29.5	16.0
	1-2 leaf	5.7	3.3	2.7	4.7	2.7	2.4	63.6	33.3	16.9
	6-12" tall	9.8	5.9	4.4	5.0	3.1	2.4	48.1	28.1	16.8
Olmsted-2	Preplant	3.4	1.9	1.9	5.5	3.0	3.4	45.2	20.9	12.4
	1-2 leaf	10.1	4.3	4.0	5.9	3.2	2.9	51.2	27.9	21.6
	6-12" tall	17.4	6.2	4.7	5.1	3.0	3.1	51.3	24.5	17.0
Dakota-2	Preplant	5.3	7.4	6.5	4.5	3.1	3.0	58.5	20.2	8.4
	1-2 leaf	6.5	11.4	12.6	4.5	3.3	3.2	54.6	24.6	12.8
	6-12" tall	11.0	9.4	9.8	3.8	2.8	2.4	63.1	32.3	12.7
Wabasha	Preplant	3.4	2.8	3.9	3.4	3.0	3.0	48.7	18.1	11.6
	1-2 leaf	8.5	3.0	3.1	3.3	2.6	2.9	39.2	14.3	9.8
	6-12" tall	13.4	4.7	3.4	3.7	2.6	3.1	38.7	15.7	10.5
Till										
Waseca-1	Preplant	3.2	3.0	3.9	4.9	2.6	2.8	66.1	11.2	7.0
	1-2 leaf	8.7	4.8	4.0	5.3	2.5	2.4	77.2	19.5	12.0
	6-12" tall	6.5	3.8	4.0	5.0	1.6	1.5	73.3	15.6	10.0
Waseca-2	Preplant	5.4	2.4	1.5	6.6	3.6	3.6	65.1	14.7	5.7
	1-2 leaf	11.9	5.5	3.5	9.2	3.7	2.6	76.7	29.3	15.6
	6-12" tall	11.1	6.1	5.0	6.7	2.6	1.5	73.8	25.4	15.4
Blue Earth	Preplant	2.8	2.2	3.1	5.1	3.2	2.8	70.2	21.3	6.8
	1-2 leaf	7.9	3.5	3.4	6.6	2.3	1.9	65.9	29.0	13.6
	6-12" tall	8.8	3.8	3.5	4.3	1.4	0.9	60.9	25.3	8.2
Stevens	Preplant	10.5	5.7	1.5	6.5	2.6	2.2	57.2	16.9	8.3
	1-2 leaf	15.1	4.8	2.1	4.2	3.0	2.5	46.6	14.7	7.0
	6-12" tall	20.4	5.4	1.9	2.5	2.4	1.9	44.3	14.7	6.0
Chisago	Preplant	4.7	3.2	1.8	3.3	3.6	4.4	34.5	10.0	8.7
	1-2 leaf	14.9	3.8	3.9	3.0	2.8	3.3	34.0	12.6	9.0
	6-12" tall	15.0	6.5	5.2	6.2	5.8	5.5	46.8	17.5	15.1
Carver	Preplant	4.4	4.3	4.0	4.3	2.6	3.0	53.0	24.3	18.5
	1-2 leaf	5.9	6.2	4.9	4.6	4.6	4.0	59.0	30.6	24.3
	6-12" tall	7.7	6.2	5.7	7.0	3.4	3.9	58.2	29.3	23.3

[1] Sites are also categorized by soil's parent material.
[2] Sampling times were preplant, and at the 1-2 leaf and 6-12" tall growth stages.
[3] Includes ammonium-N.

Table 5. Effect of depth and time of sampling on correlation of N form and grain yield for all plots at 54 sites that received no N, 1989-92.

Time	Depth	NO_3-N	NH_4-N	Hyd-N
	- ft -	- - - - - - - - -	r[1/] - - - - - - - - -	
Preplant	0-2	0.52	-0.01[NS]	0.24
Preplant	0-3	0.52	-0.01[NS]	0.24
1-2 Leaf	0-1	0.49	0.31	0.38
1-2 Leaf	0-2	0.54	0.32	0.40
6-12" Tall	0-1	0.48	0.25	0.37
6-12" Tall	0-2	0.46	0.28	0.41

[1/] All coefficients are statistically significant at the 10% probability level except those designated with NS.

Table 6. The effect of sampling time, sampling depth, and N form on linear-plateau models with relative grain yields as the dependent variable from 49 sites (excluding where alfalfa was the previous crop), 1989-1992.

Sampling				Critical	Error
Time[1/]	Depth	N Form	R^2	Value	Rate
	-ft-			lb N/acre	-%-
PP	0-2	**NO_3-N**	0.49	127	22
PP	0-2	**NH_4-N**	NF[3/]	--	--
PP	0-2	**Hydrol-N[2/]**	0.12	210	54
PP	**0-1**	NO_3-N	0.36	78	22
PP	**0-2**	NO_3-N	0.49	127	22
PP	**0-3**	NO_3-N	0.49	174	20
V4	**0-1**	NO_3-N	0.41	51	31
V4	**0-2**	NO_3-N	0.44	160	20
PP	0-2	NO_3-N	0.49	127	22
V1	0-2	NO_3-N	0.57	160	26
V4	0-2	NO_3-N	0.44	160	20

[1/] Abbreviations for sampling time are: PP, preplant; V1, 1-2 leaf corn; V4, 6-12 in. corn.
[2/] Phosphate-borate extractable hydrolyzable N.
[3/] The data did not statistically fit a model.

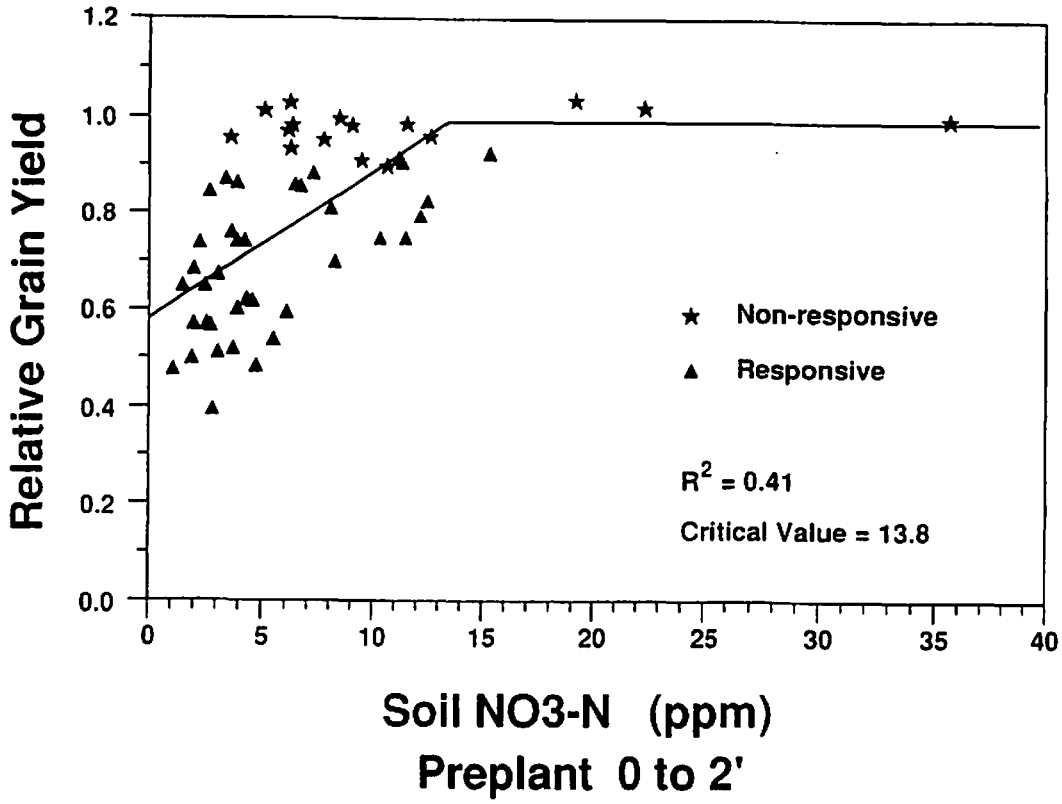

Figure 1. Relationship between soil NO_3-N and relative grain yield for all 1989-92 locations showing those sites that responded to fertilizer N.

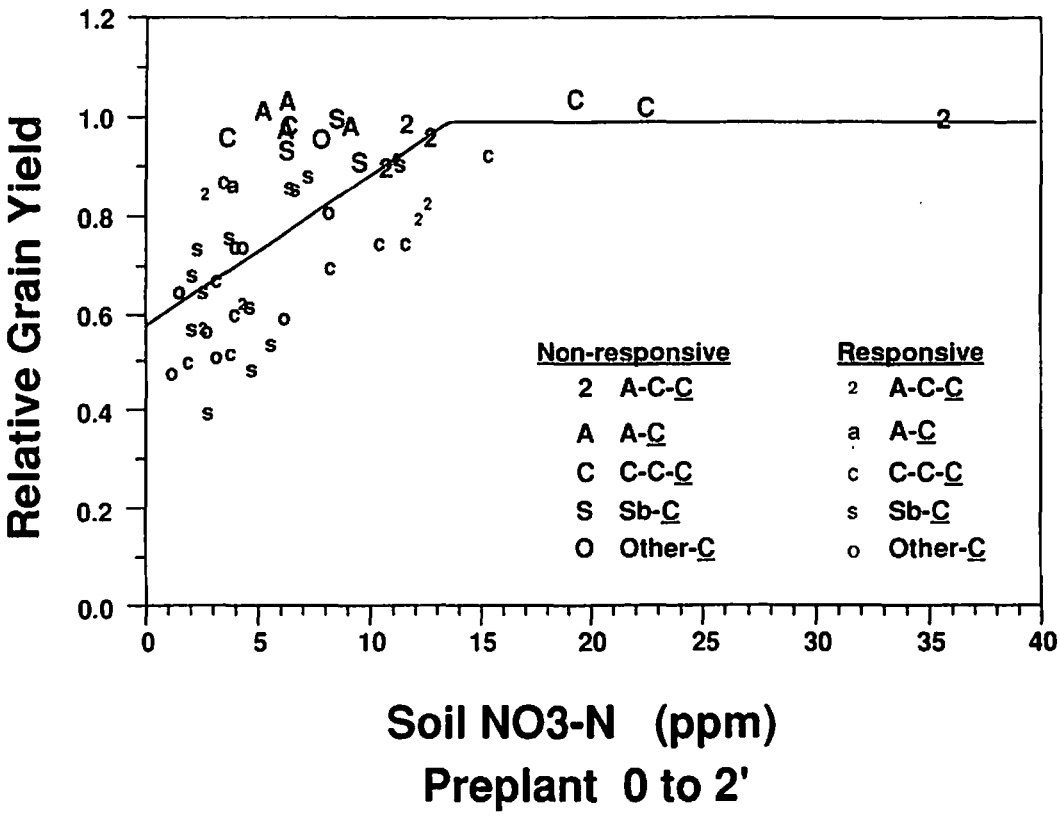

Figure 2. Relationship between soil NO_3-N and relative grain yield for all 1989-92 locations showing the previous crop at each site.

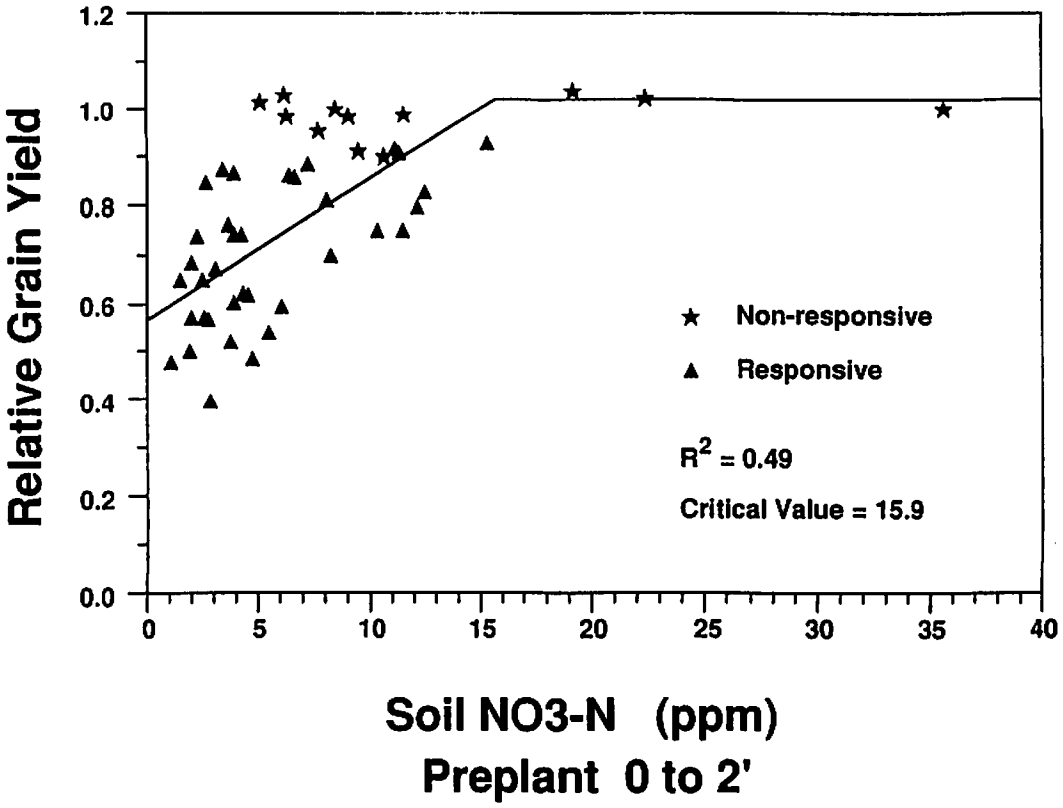

Figure 3. Relationship between soil NO_3-N and relative grain yield for those 1989-92 sites where alfalfa was <u>not</u> part of the crop history.

IMPROVING FERTILIZER RECOMMENDATIONS FOR PRODUCTION OF EDIBLE BEANS IN MINNESOTA

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

ABSTRACT: There was a need to review and evaluate current fertilizer recommendations used for edible bean production. Therefore, trials were conducted to evaluate the response of this crop to rates of N and P_2O for fine-textured soils as well as potash and sulfur for sandy soils. Response to fertilizer N was related to residual NO_3-N in the soil. When carryover was low, fertilizer N produced substantial increases in the yield of both red kidney and navy beans. There was no response when residual NO_3-N was high (approximately 100 lb./acre). Response to phosphate fertilization was related to the soil test value for P. No response was recorded when the soil test was in excess of 20 ppm P. Substantial increases in production were recorded when the soil test for P was low (6 ppm). The application of both potash and sulfur had no effect on yield when red kidney beans were grown on irrigated sandy soils. This study will be continued in 1993.

Agricultural statistics continue to show that dry edible bean production is a major component of the farm economy of both North Dakota and Minnesota. As with other crops, profitability hinges on producing high yields with the most efficient use of inputs. Effective and efficient use of fertilizer has a direct impact on edible bean production.

In recent years, the wise use of nitrogen fertilizers has been a major concern in the production of most agronomic crops. Effective use of nitrogen fertilizer has a direct impact on both farm profitability and environmental quality. Current nitrogen fertilizer recommendations for edible bean production on fine-textured soils are based on yield goals and a measure of residual or carryover nitrate-nitrogen (NO_3-N). For production on sandy soils, recommendations for use of fertilizer nitrogen are based on a yield goal and the previous crop. These recommendations, however, have evolved from a limited amount of research data collected from Minnesota and North Dakota.

Effective use of phosphate fertilizer is also a concern for edible bean production throughout Western Minnesota. Yet, there have been few trials to document the importance of phosphate in a fertilizer program.

Questions about fertilizer use are not always limited to nitrogen and phosphate. Very little is known about the need for potassium and sulfur when this crop is grown on sandy soils. Current fertilizer suggestions for the use of these two nutrients are based on very limited information collected when average yields were lower. The rates of these two nutrients needed for optimum production must be determined when modern production practices are used.

Recognizing the need for new information with respect to fertilizer recommendations, this research project is designed to meet 3 objectives. These are:

1. To improve nitrogen fertilizer recommendations for edible bean production. For much of the production area, this means improving fertilizer recommendations by adjusting for residual or carryover NO_3-N. Where production occurs on sandy soils, improvement of nitrogen recommendations means that more emphasis should be placed on nitrogen credits from previous legume crops used in the rotation.

2. To determine the rate of phosphate needed when the crop is grown on fine textured soils and relate the rate needed to soil test values for P.

3. To determine the response of edible beans grown on sandy soils to the application of potash and sulfur.

Experimental Procedure:

For this study, trials were conducted in farmers' fields in Renville, Yellow Medicine, and Cass Counties as well as the Irrigation Center at Staples. The details for the conduct of each trial are discussed separately.

[1/] Extension Soil Scientist, Assistant Scientist, Junior Scientist, and Plot Coordinator, University of Minnesota and Staples Irrigation Center, Respectively.

Nitrogen Trials

Three locations were used. Two were in Renville County and one was located in Yellow Medicine County. Initial plans called for a nitrogen trial to be conducted at the Irrigation Center. However, a substantial error in fertilizer application prevented the collection of useful data at this site.

Soil samples were collected from each location prior to fertilizer application. Soil was collected from depths of 0-6, 6-12, 12-24, and 24-36 inches. Routine soil testing procedures were used and the results are summarized in Table 1.

Five rates of nitrogen (30, 60, 90, 120, 150 lb. N/acre) were broadcast and incorporated before planting. The N was supplied as 46-0-0. An appropriate control (0 N applied) was also used. Each N rate was replicated 4 times in a randomized block arrangement of treatments. All plots received a uniform application of phosphate supplied as 0-46-0. The nitrogen and phosphate fertilizers were incorporated with a field cultivator prior to planting.

Table 1. Relevant soil test values for the experimental sites where the nitrogen and phosphate trials were conducted.

Soil Test Property	Depth	Location: Renville(W)	Renville(M)	Yellow Medicine
	in.			
pH	0-6	7.2	7.4	7.7
P (Bray), ppm	0-6	26.0	24.7	6.0
K, ppm	0-6	170	178	132
NO_3-N, lb./acre	0-6	5.7	10.9	9.4
	6-12	6.7	18.7	4.1
	12-24	9.5	37.5	9.1
	24-36	12.9	32.4	9.5
	Total:	34.8	99.5	32.1

Red kidney beans were planted at one Renville County site. Navy beans were planted at the second Renville County site and the Yellow Medicine County site. Appropriate planting rates, herbicides, etc. were used at all sites.

Whole plant samples were collected in late August for a determination of total dry matter production. These plants were dried, weighed, ground and analyzed for N to determine the total amount of N absorbed by the crop. Yields were measured in early to mid-September and are reported on a basis of 18% moisture.

Phosphate Trials

These studies were conducted in the fields used for the nitrogen trials and were placed immediately adjacent to the nitrogen trials. The results of the soil samples for the nitrogen trials are also appropriate for the phosphate trials.

Three rates of phosphate (23, 46, 69 lb. P_2O_5/acre) were broadcast and incorporated before planting. An appropriate control (No applied phosphate) was also used. The treatments were replicated four times and arranged in a randomized complete block design. All plots received a broadcast application of 120 lb. N/acre supplied as 46-0-0. The phosphate and nitrogen fertilizers were incorporated with a field cultivator before planting.

The cultural practices used during the growing season and the sampling and harvesting techniques were identical to those used for the nitrogen trials.

Potash and Sulfur Trials

These trials were conducted on irrigated sandy soils at two locations in north-central Minnesota. Soil samples (0-6 inches) were collected from each site prior to fertilizer application. The results of the analysis of these samples are summarized in Table 2.

Table 2. Relevant soil test values for the experimental sites where the potash and sulfur trials were conducted.

Soil Test Property	Depth	Location: Irrigation Center	Location: Cass Co.
	in.		
pH	0-6	7.1	5.6
P (Bray), ppm	0-6	32	67
K, ppm	0-6	70	139
SO_4-S, ppm	0-6	2.6	1.7

Four rates of K_2O (60, 120, 180, 240 lb./acre) were combined with a control treatment (no K_2O applied) for the potash trial. The source of K_2O was 0-0-60. The treatments were replicated four times and were arranged in a randomized complete block design. Adequate rates of sulfur and phosphate were applied to all plots. The potash, sulfur and phosphate fertilizers were incorporated with a field cultivator prior to planting.

The sulfur trials were conducted immediately adjacent to the potash trials. Three rates of sulfur (10, 20, 30 lb. S/acre) were used with an appropriate control. The treatments were replicated four times and arranged in a randomized complete block design. Granular gypsum was used as the sulfur source.

Both trials received 120 lb. N/acre supplied as 46-0-0. A split application of N was used. The initial application was made approximately 2 weeks after emergence. The remainder was applied 2 weeks later. All nitrogen was incorporated with irrigation water.

Appropriate cultural practices for the production of red kidney beans were used at both sites. The sampling and harvesting techniques were identical to those described for the nitrogen trial.

Results and Discussion:

Nitrogen Trial

In 1992, N fertilization increased total dry matter production and edible bean yield at 2 of the 3 sites (Table 3). In both situations, the overall yields continued to increase as the rate of applied N increased. The response to fertilizer N appeared to be related to the amount of residual or carryover NO_3-N measured to a depth of 3 feet. At the Renville (W) location, where red kidney beans were grown, the residual NO_3-N was 34.8 lb./acre. The residual NO_3-N at the Yellow Medicine County site, where navy beans were grown, was 32 lb./acre. The residual of 99.5 lb. NO_3-N/acre at the Renville (M) site appeared to be adequate for good yields of navy beans.

Table 3. The effect of rate of applied N on total dry matter yield and bean yield.

N	Location: Renville (W)		Renville (M)		Yellow Medicine	
Applied	D.M. Yield	Bean Yield	D.M. Yield	Bean Yield	D.M. Yield	Bean Yield
lb./acre	ton/A	lb./A	ton/A	lb./A	ton/A	lb./A
0	2.03	2279	2.18	3260	1.36	1878
30	2.60	2706	2.10	3059	1.40	1771
60	2.56	2732	2.47	3322	1.70	2212
90	2.65	2758	2.44	3503	1.75	2144
120	2.76	3120	2.38	3327	1.73	2504
150	2.99	3079	2.38	3430	1.81	2428

The concentration of N in the whole plant tissue at maturity was not significantly affected by rate of applied N at all sites (Table 4). Total N uptake was computed from the dry matter yields and the N concentration data. The rate of N applied affected N uptake at the two Renville County sites (Table 4).

Table 4. The effect of rate of applied N on the N concentration in whole plant at maturity and N uptake.

N Applied	Location: Renville (W) N Conc.	Renville (W) N Uptake	Renville (M) N Conc.	Renville (M) N Uptake	Yellow Medicine N Conc.	Yellow Medicine N Uptake
lb./acre	%	lb./A	%	lb./A	%	lb./A
0	1.97	78.4	1.93	84.3	1.55	43.2
30	2.00	104.1	1.97	82.2	1.45	41.3
60	2.22	113.4	1.82	89.9	1.84	61.5
90	1.88	99.7	2.04	99.2	1.68	58.3
120	1.87	102.9	1.96	92.9	1.57	55.1
150	1.87	111.5	2.25	108.4	1.51	54.8

In general, N uptake increased as rate of applied N was increased. A rather high amount of variability may have masked the uptake response to rate of applied N at the Yellow Medicine County site. The effect of rate of applied N on N uptake is consistent with the effect on yield. This suggests that absorbed N is being used to produce more dry matter and subsequently higher bean yields.

The impact of the residual NO_3-N on response to fertilizer N is important. The N recommendations in the future will be adjusted for the amount of residual NO_3-N measured to some appropriate depth.

Phosphate Trials

The response to phosphate fertilization was related to the soil test values for P (Table 5). In Yellow Medicine County (soil test P = 6.0 ppm), yield of navy beans increased as rate of applied phosphate increased. Total dry matter production at this site, however, was not significantly affected by phosphate fertilization. This absence of a significant effect is probably due to a large amount of variability in the data.

Table 5. The effect of rate of applied phosphate on total dry matter yield and bean yield.

P_2O_5 Applied	Location: Renville (W) D.M. Yield	Renville (W) Bean Yield	Renville (M) D.M. Yield	Renville (M) Bean Yield	Yellow Medicine D.M. Yield	Yellow Medicine Bean Yield
lb./acre	ton/A	lb./A	ton/A	lb./A	ton/A	lb./A
0	2.56	2685	1.99	2950	1.75	1841
23	2.84	2816	2.18	2893	1.85	2002
46	2.88	2956	1.98	3025	1.63	2194
69	2.90	2712	2.01	3034	1.84	2262

By contrast, use of phosphate did not increase the yield of navy beans at the Renville (M) site or the yield of red kidney beans at the Renville (W) site. The soil test value for P at both sites was in excess of 20 ppm indicating a relatively high level of available P in the soil.

The P concentration in the whole plant tissue at maturity was not significantly affected by phosphate fertilization at all sites (Table 6). As a result, there was no significant effect of phosphate fertilization on P uptake.

Table 6. The effect of rate of applied phosphate on the P concentration of whole plant at maturity and P uptake.

P_2O_5 Applied	Renville (W) P Conc.	Renville (W) P Uptake	Renville (M) P Conc.	Renville (M) P Uptake	Yellow Medicine P Conc.	Yellow Medicine P Uptake
lb./acre	%	lb./A	%	lb./A	%	lb./A
0	.295	15.0	.243	9.6	.146	5.1
23	.319	18.1	.263	11.2	.163	6.0
46	.336	19.4	.253	10.5	.171	5.5
69	.319	18.5	.280	11.0	.160	6.0

Potash Trials

The potash trials were conducted with red kidney beans. At both sites, the rate of applied K_2O had no significant effect on total dry matter yield, bean yield, and K uptake (Table 7). Potassium uptake was in the range of 100-120 lb./acre. The sandy soils were apparently able to supply the amount of K needed for optimum yield.

Table 7. The effect of rate of applied potash on yield and potassium uptake by red kidney beans.

K_2O Applied	Irrigation Center D.M Yield	Irrigation Center Bean Yield	Irrigation Center K Conc	Irrigation Center K Uptake	Cass Co. D.M. Yield	Cass Co. Bean Yield	Cass Co. K Conc	Cass Co. K Uptake
lb./acre	ton/A	lb./A	%	lb./A	ton/A	lb./A	%	lb./A
0	2.53	2552	2.38	120.6	2.49	2594	1.97	98.1
60	2.53	2383	2.12	106.8	2.44	2538	1.98	96.2
120	2.69	2449	2.25	120.5	2.28	2477	2.16	97.7
180	2.48	2389	2.43	119.7	2.33	2361	2.27	105.5
240	2.61	2384	2.59	134.4	2.30	2612	2.24	103.3

The K concentration in the whole plant tissue at maturity did increase with rate of applied K_2O. This increase was not related to yield and is an example of luxury consumption of K by crops.

Sulfur Trials

The application of S had no significant effect on both total dry matter production and bean yield at each site (Table 8). Even though the soils were sandy, the soil apparently was able to supply adequate S for optimum yield of the edible bean crop.

Table 8. The effect of rate of applied sulfur on dry matter yield and bean yield.

S Applied	Irrigation Center D.M. Yield	Irrigation Center Bean Yield	Cass Co. D.M. Yield	Cass Co. Bean Yield
lb./A	ton/A	lb./A	ton/A	lb.A
0	2.41	2309	2.22	2482
10	2.36	2433	2.37	2456
20	2.33	2649	2.22	2544
30	2.30	2366	2.22	2468

Plant samples collected at maturity will be analyzed for S, but results were not available at the time of preparation of this report.

NORTHERN CORNBELT SAND PLAINS MANAGEMENT SYSTEMS EVALUATION AREA, PRINCETON, MN[1]

J.A. Lamb, J.L. Anderson, R.H. Dowdy, G.N. Delin
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Abstract The Management Systems Evaluation Area (MSEA) site was established at Princeton, MN with the primary objective to evaluate the impact of an irrigated agricultural management system on ground water in a surficial sand and gravel aquifer.

Corn-soybean rotation, potato-sweet corn rotation, and continuous corn cropping systems are being evaluated. Preliminary results indicate that even in small areas crop yield and N uptake can vary and thus influence amount of chemicals that are moved to the ground water. Soil samples indicate herbicide concentrations decrease during the growing season and only moved to a maximum depth of 30 inches or less. Atrazine and metribuzin were not detectable in post harvest samples but alachlor was still present. At present the MSEA cropping systems have not influence herbicide concentrations in ground water. Potato and continuous corn production have increased nitrate + nitrite-N concentrations in the ground water.

The Management Systems Evaluation Area (MSEA) program was established as part of the Presidential initiative for water quality in 1990. Five MSEA programs were initiated in 1990 in the states of Nebraska, Ohio, Missouri, Iowa, and Minnesota. This is a multiagency project involving USDA-CSRS, USDA-ARS, USGS, EPA, USDA-ES, and USDA-SCS. The Minnesota MSEA (Northern Cornbelt Sand Plain MSEA) has established four research sites located near Arena, WI (Univ. of Wisconsin); Princeton, MN (Univ. of Minnesota); Aurora, SD (South Dakota State Univ.); and Oaks, ND (North Dakota State Univ.). This report will be for the primary site located near Princeton, MN. The specific objectives for the Minnesota MSEA are the following: 1) investigate the impacts of ridge-tillage practices in a corn and soybean cropping system on the rate of transport of atrazine, alachlor, and metribuzin in unsaturated and saturated zones, 2) determine the effects of nitrogen fertilizer management, 3) characterize water flow and relate these characteristics to transport and storage of agricultural chemicals, and 4) determine the relationship between ground water recharge and agricultural-chemical loading of ground water.

Materials and Methods:

Crop Production

The Northern Cornbelt Sand Plains (MSEA) Minnesota site was established in 1991. The 160 acre site is located three miles southwest of Princeton, MN. The major soil identified at the site by the soil survey is Zimmerman loamy fine sand (mixed, nonacid, frigid, Alfic Udipsamment). Three irrigated cropping systems are being studied i.) ridge-tillage corn-soybean rotation, ii.) full width tillage continuous corn, and iii.) full width tillage potato-sweet corn rotation. Each crop in the rotation is grown each year on cropping areas ranging in size from 4.4 to 6.6 acres. A 95 day relative maturity corn adapted for the region was planted at a rate of 34000 seed A^{-1} in late April of early May. Soybean and sweet corn were planted the second week of May at rates of 60 lb soybean seeds A^{-1} and 24000 sweet corn seeds A^{-1}. Early table market red potatoes were planted the first and second week of April. Nitrogen fertilizer was split applied to all crops except soybean at rates and times listed in Table 1. A 20 lb A^{-1} nitrogen credit for legumes (soybeans) was used in 1992 for rotation corn. During 1991 the crops were not irrigated but 25 inches of precipitation occurred during the growing season. In 1992, the check book method was used to schedule amounts and time of irrigation. Soil applied herbicides were applied at broadcast rate of 1.5 lb a.i. A^{-1} atrazine and 2.0 lb a.i. A^{-1} alachlor (Lasso) to continuous corn, rotation corn, and sweet corn. The atrazine and alachlor were applied

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[1] This report contains information from the first two years of a five year study and should be consider preliminary. The funding source is from the Presidential Initiative for Water Quality.

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broadcast to continuous corn and in a 10 inch band over the row at planting to the sweet corn and rotation corn. Soybeans had alachlor and metribuzin (Sencor) applied in a band at the broadcast rates of 2.0 lb a.i. A^{-1} and 0.5 lb a.i. A^{-1}, respectively. Metribuzin and metolachlor (Dual) were applied to potato broadcast after planting and before emergence at rates of 0.5 lb a.i. A^{-1} and 1.0 lb a.i. A^{-1}, respectively. Dry matter and yields were determined from 64 and 60, 50 X 60 ft cells in 1991 and 1992, respectively, in each of the cropping areas at harvest. Nitrogen concentrations were determined on the grain and dry matter and total N uptakes were calculated.

Table 1. Urea nitrogen applications made in 1991 and 1992 at Minnesota MSEA.

Crop	Application time	N applied	
		1991	1992
		-------- kg N A^{-1} --------	
Rotation Corn	Starter	20	20
Rotation Corn	V6	50	70*
Rotation Corn	V8	70	50
Continuous Corn	Starter	20	20
Continuous Corn	V6	50	70*
Continuous Corn	V8	70	60
Sweet Corn	Starter	20	20
Sweet Corn	V6	50	70*
Sweet Corn	V8	70	60
Potato	Starter	100	60
Potato	Cultivation	50	0
Potato	Hilling	50	70

* Nitrapyrin sprayed on urea as it was applied at rate of 0.5 lb A^{-1} a.i..

Soil Herbicide Movement

Each cropping area was soil sampled six times during the cropping season. The times are before herbicide application, immediately after application, two weeks after application, five weeks after application, eleven weeks after application, and post-corn harvest. Samples to a depth of three feet are obtained in noncontaminated sleeves and divided in six inch increments from the crop row and between crop rows. The samples were analyzed at the National Soil Tilth Lab, Ames Iowa for atrazine, alachlor, and metribuzin.

Ground Water Characterization

Water samples were taken from a series of multiport wells to determine the effect of agricultural farming system on ground water quality. These samples are taken four time a year; April, June, August, and October-November. The initial characterization of the research site was done April 1991 from sampling wells established on the perimeter of the site. By June 1991, the multiport wells were installed with one at the upgradient to ground water flow position of each cropping area, middle of cropping area, and down gradient of cropping area. This allows for monitoring of atrazine, alachlor, metribuzin, metolachlor, and nitrate + nitrite-N that is moving in under the cropping area, under the cropping area, and moving out under the cropping area.

Results and Discussion

Crop Production

Crop Yields

Corn grain yields in both 1991 and 1992 exhibited considerable variability across the small cropping areas, 4.4 A, Table 2. Continuous corn yields ranged from 91 to 163 bu A^{-1} in 1991 and 100 to 148 bu A^{-1} in 1992. Standard deviation for continuous corn decreased from 16 bu A^{-1} in 1991 to 11 bu A^{-1} in 1992 and is also reflected by the coefficient of variation (C.V.) Table 2. This decrease in variability is attributed to irrigation. Even though there was sufficient precipitation during 1991 growing season, some locations in the continuous corn cropping area were water stressed in June. Within cropping area, location of continuous corn grain yield variation for the two growing seasons were similar, but the range in grain yields in 1992 was smaller. Rotation corn was grown on cropping area D in 1991 and cropping area B in 1992. The standard deviation increased from 10 bu A^{-1} (C.V.= 6.4%) to 13 bu A^{-1} (C.V.=9.0%) Table 2. Areas B and D are spatially different in elevation relief and soil type. With only one year of data for each crop interpretation is difficult when comparing soybean grain yield variability in area B and D with corresponding corn grain variability, there was less in area B. Yield variability increased in cropping area D in 1992 (Table 2). This increase was the result of two early season frosts (June 1 and 21) which reduced soybean grain yields at lower elevations. Variability decreased from 1991 to 1922 for potatoes and sweet corn as indicated by lower C.V.s in 1992, Table 3.

Table 2. Statistical analyses of corn and soybean yields for 1991 and 1992.

Year	Crop	Cropping area	Mean	Minimum	Maximum	Std. Dev.	C.V.
			--------- bu A^{-1} ---------				%
1991	Soybean	B	33	22	39	3	10.8
1992	Corn	B	139	113	163	13	9.0
1991	Corn	D	147	124	177	10	6.4
1992	Soybean	D	25	18	34	4	14.6
1991	Corn	E	136	91	163	16	11.3
1992	Corn	E	126	100	148	11	8.3

Table 3. Statistical analyses of potato and sweet corn yields for 1991 and 1992.

Year	Crop	Cropping area	Mean	Minimum	Maximum	Std. Dev.	C.V.
			---------- Tons A^{-1} ----------				%
1991	Potato	A	9.4	6.2	13.1	1.3	13.9
1992	Sweet Corn	A	7.9	6.3	9.8	0.8	10.2
1991	Sweet Corn	C	5.8	4.1	7.4	0.7	12.2
1992	Potato	C	12.0	8.1	15.3	1.4	11.3

N Uptake

At this time data are only available for rotation corn (D) and continuous corn (E) Tables 4 and 5. Total plant dry matter, total N uptake at maturity, and grain yield were significantly correlated to each other, Table 6.

Table 4. Statistical analyses for total N uptake by corn in 1991.

Year	Crop	Cropping	Mean	Minimum	Maximum	Std. Dev.	C.V.
		area	---------- lb A^{-1} ----------				%
1991	Corn	D	125	107	146	8.6	6.9
1991	Corn	E	122	93	148	12.1	9.9

Table 5. Statistical analyses for total dry matter of corn in 1991.

Year	Crop	Cropping	Mean	Minimum	Maximum	Std. Dev.	C.V.
		area	---------- ton A^{-1} ----------				%
1991	Corn	D	6.6	5.6	7.4	0.4	6.1
1991	Corn	E	6.5	4.7	8.1	0.7	10.3

Table 6. Correlations and statistical probabilities for rotation and continuous corn grain yield, total dry matter, and total N uptake in 1991.

Cropping System	Correlation	r	Significance
Rotation Corn	Yield vs Total N Uptake	0.77	0.01
Rotation Corn	Yield vs Total Dry Matter	0.80	0.01
Rotation Corn	Total N Uptake vs Total Dry Matter	0.76	0.01
Continuous Corn	Yield vs Total N Uptake	0.83	0.01
Continuous Corn	Yield vs Total Dry Matter	0.84	0.01
Continuous Corn	Total N Uptake vs Total Dry Matter	0.79	0.01

Preliminary Results

Yield and N uptake variability exists in the cropping areas. This variability is exhibited by C.V.s of up to 15 % across an area as small as 4.4 A. Total dry matter, total N uptake, and grain yield for corn are highly correlated which means they vary similarly over the landscape. If constant rates of N fertilizer are applied and there is lower plant utilization of applied N there is a greater chance of excess N leaching to the ground water than if rates are varied according to yields found at different location in the cropping areas. Additional large field studies should be undertaken to confirm these results.

Soil Herbicide Results

Atrazine

At this time only the 1991 soil herbicide data is available. Where soil herbicides were band applied (soybean (area B), sweet corn (area C), and rotation corn (area D)) no chemicals were detected in between crop row soil samples. Soil atrazine concentrations in the continuous corn were greater in the row than between the row. Surface 0 to 6 inch depth concentrations after application were 537 ppb in the row and 128 ppb between row. Concentrations decreased to 16 ppb in the row and 10 ppb between the row from application time (5/15/91) to post harvest (11/26/91). The deepest depth that atrazine was detected was 24 to 30 inches eleven weeks after application in the row. Rotation corn soil atrazine concentration were similar to the continuous corn in row samples. No atrazine was detected between the row at any time in 1991. The deepest depth of detection was 12 to 18 inches at the eleven week sampling date. The row soil atrazine concentration in the sweet corn cropping area was greatest directly after application (714 ppb) and decreased to 12 ppb by post harvest. Again no atrazine was detected between the row.

Alachlor (Lasso)

Alachlor was applied to soybeans (area B), sweet corn (area C), rotation corn (area D), and continuous corn (area E) in 1991. The broadcast rate was 2.0 lb a.i. A^{-1}. Soybean, sweet corn, and rotation corn application were banded. No alachlor was detected in soil samples taken between the rows. In the row for the crops receiving banded application, alachlor did not move deeper than 30 inches. There were small amounts in the 0 to 6 inch depth (26 to 53 ppb) in the post harvest sample in the soybean and rotation corn cropping areas. Approximately 4 ppb was left in the 1991 sweet corn cropping area. Alachlor was detected in the row and between the in the continuous corn cropping area. The concentrations decreased with time but similar to soybean and rotation in the row. At post harvest there was still alachlor present in the 6 to 12 inch depth sample (9 ppb). Between row alachlor concentration were considerably lower than in the row. This is similar to what was reported for atrazine concentrations. Alachlor concentrations between the row decreased to 8.3 ppb in the 0 to 6 inch depth at post harvest. In both locations alachlor was not detected below 30 inches.

Metribuzin (Sencor)

Metribuzin was broadcast applied to potatoes in 1991. The concentration in the row and between were similar. Directly after application the concentration in the 0 to 6 inch depth increased to 115 ppb. Metribuzin was only detected in the 0 to 6 inch depth and was not detected by five weeks after application. The same trends occurred in the row of soybeans. The concentration after application in the 0 to 6 inch depth was less, 70 ppb. There were no detections in samples taken between the rows.

Preliminary Results

The use of banded application kept the herbicide only in the row. Atrazine, alachlor, and metribuzin concentration decreased to small detectable amounts during the growing season even in the surface soil. The deepest depth where herbicide was detected was 30 inches.

Ground Water

Initial Ground Water Characterization

Initial ground water samples were taken during April 1991. Fourteen wells were sampled between April 3 and April 18, 1991 around the perimeter of the research area. No detections of alachlor, metolachlor, or metribuzin were found, Table 7. Atrazine and nitrate + nitrite-N were detected. The median value for atrazine was below the reporting limit of 0.08 ppb. Nitrate + nitrite-N ranged from less than the reporting limit to 19.9 ppm with a median for the initial 14 well samples of 7.0 ppm.

Table 7. Contaminants measured in ground water at Princeton, MN sampled April 3 and April 18, 1991.

Contaminant	Number of water samples	Range	Median	Number of Detections
		----- ppb -----		
Atrazine	14	<0.08 - 0.17	<0.08	2
Alachlor	14	<0.08	<0.08	0
Metolachlor	14	<0.08	<0.08	0
Metribuzin	14	<0.08	<0.08	0
		----- ppm -----		
Nitrate + nitrite-N	14	<0.5 - 19.9	7.0	17

Effect of Cropping Systems

As of August 1992, cropping systems have not effected atrazine, alachlor, metolachlor, or metribuzin in the ground water. Table 8 indicates that nitrogen fertilizer use for potato production in 1991 has caused an elevation of nitrate + nitrite-N in the ground water. The N application was greater than recommended because of a problem in starter attachment calibration. The mid-plot well data indicates an elevation of nitrate + nitrite-N when compared to the upgradient values at the water table. The 1991 soybean, rotation corn, and sweet corn cropping areas had not been influenced by N fertilizer application. In 1992 a trend towards an elevated nitrate + nitrite-N concentrations under the continuous corn has been noted. Again the continuous corn received twice as much N fertilizer as the rotation corn.

Table 8. Water table nitrate + nitrite-N as effected by potato and continuous corn cropping systems.

Crop	Well	6/91	9/91	12/91	4/92	6/92	9/92
1991		ppm					
Potato	Upgradient	15	13	11	18	19	15
	Mid-plot	16	14	25	34	29	30
	Downgradient	13	11	47	19	30	29
Continuous corn	Upgradient	9	10	13	1	11	10
	Mid-plot	18	14	18	16	20	27
	Downgradient	6	10	8	15	13	17

Preliminary Conclusions

As of fall 1992, herbicide concentrations in the ground water have not been influenced by the MSEA cropping systems established in 1991. Fertilizer N use in the potato-sweet corn and continuous corn cropping systems have elevated nitrate + nitrite-N concentration in the ground water. The amount of N fertilizer applied is important in reducing the potential to contaminate ground water.

THE ANOKA SAND PLAIN WATER QUALITY DEMONSTRATION PROJECT: A SUMMARY OF RESULTS FROM NITROGEN MANAGEMENT DEMONSTRATIONS IN CORN AND POTATOES[1]

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Abstract

This report summarizes the results of project-sponsored on-farm demonstrations of best management practices (BMP's) for corn and potato nitrogen applications. Field-length replicated strips were used to evaluate the effects of conventional practices and BMP's on crop yields and other parameters. Corn demonstrations were generally successful in illustrating the validity of using University N recommendations and legume and manure N credits. However, poor growing conditions in 1992 may have had adverse effects on corn yields and organic N mineralization, making it difficult to accurately assess the size of the N credits. Potato yields increased with nitrogen rate in one of two demonstrations, but not significantly. A petiole sap nitrate test was evaluated and appeared to be useful in monitoring potato plant N status during the growing season. Petiole sap nitrate-N levels were generally well correlated with potato yields.

Introduction

The Anoka Sand Plain Water Quality Demonstration Project is one of sixteen demonstration projects nationwide, begun in 1990 as part of the USDA Water Quality Program. It is in its fourth of five years. The overall goal of the project is to encourage voluntary adoption of best management practices that will reduce the potential for contamination of the sensitive Anoka Sand Plain aquifer from agricultural non-point sources. The project works directly with forty cooperating farmers in seven counties and a wide variety of practices are demonstrated in the areas of nutrient, manure, pest and irrigation management. A large effort is maintained in the area of N management for corn and potatoes, as these crops require large N inputs. The demonstrations described below focused on the use of legume and manure N credits, University of Minnesota N recommendations and nitrification inhibitors for corn, and N management and plant N monitoring for potatoes. It is anticipated that the results from this project will be used to encourage the adoption of these practices by farmers in other regions with similar soils, crops and climatic conditions.

CORN NITROGEN MANAGEMENT DEMONSTRATIONS

Procedures

With the exception of Demonstration No. 1, conducted in 1991, all demonstrations described here took place in 1992. The best management practices of using split and sidedressed N applications are already in wide use by corn producers in the Anoka Sand Plain, so demonstrations focused on comparing the farmer's usual N rates to those recommended by the University of Minnesota or which included legume and manure N credits. In general, treatments consisted of varying sidedress N rates replicated two to four times in each field to evaluate differences in estimated total N supply. This approach was also used to evaluate the effects of the nitrification inhibitor N-Serve on corn yields. All demonstration fields were irrigated.

In all cases, non-treatment cultural practices for corn were identical between plot areas and will be included in more complete summaries of the project's 1990, 1991 and 1992 demonstrations. Other pertinent practices, including those affecting treatment results, are described in the individual demonstration discussions. Soil samples were taken to a depth of six inches in the spring prior to planting for routine analysis of pH, organic matter, P and K content. Preplant, pre-sidedress and post-harvest soil samples were taken from a 0-24" depth and analyzed for NO_3-N content. However, this nitrogen is not credited to corn N supply in these soils due to the high potential

[1]Support for this project is provided by the Minnesota Extension Service, the Soil Conservation Service, the Agricultural Stabilization and Conservation Service, the Anoka Sand Plain Association of Soil and Water Conservation Districts, and the cooperating farmers. Their support is greatly appreciated.

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for leaching. Manure was analyzed for N, P_2O_5 and K_2O content and nutrient availabilities determined with current University of Minnesota recommendations. Application rates were calculated with spreader calibrations or based on storage and application tank capacities.

All corn producers utilized starter fertilizer applied in a band two inches below and two inches to the side of the seed at planting. Sidedressed N applications to corn were banded six inches from the row about four to six weeks after emergence. Ear leaf samples were taken from at least one treatment in each demonstration at about 50% silking. Twenty leaves from just below and opposite the ear were gathered from each of two rows and analyzed for N content. Yields were measured by weighing the grain harvested with a field combine or by hand from randomly chosen representative areas of the treatment strips or plots. Combined corn plots were usually four to six rows wide and varied in length, but were approximately 1/10 of an acre or more in area. Hand-harvested corn was picked from twenty foot lengths of two adjacent rows in each replicate. Grain moisture content was determined gravimetrically and yields are expressed on a 15.5% moisture basis. Grain yield standard deviations are included with the demonstration results.

Results and Discussion

Demonstrations of Recommended N Rates and Nitrification Inhibitors

Soils and crop nutrient information is shown in Table 1 and results in Table 2.

Table 1. Soils and crop nutrient information for N rate and N-Serve demonstrations.

Demonstration number	1	2	3
County	Sherburne	Sherburne	Sherburne
Soils Information			
Soil type	Hubbard sandy loam	Hubbard loamy sand	Hubbard loamy sand
Subgroup	Udic haploboroll	Udorthentic haploboroll	Udorthentic haploboroll
Family	Sandy, mixed	Sandy, mixed	Sandy, mixed
pH	6.4	6.4	6.4
Organic matter	2.9 %	1.8 %	2.0 %
Phosphorus	28 ppm	34 ppm	48 ppm
Potassium	104 ppm	144 ppm	149 ppm
Sulfate-S	NA	1 ppm	1 ppm
Nitrate-N			
Preplant	NA	14 lb/A	16 lb/A
Presidedress	58 lb/A	36 lb/A	40 ppm
Post-harvest	21 lb/A	NA	NA
Crop Nutrient Information			
Corn yield goal	180 bu/A	200 bu/A	200 bu/A
Recommended N rate	220 lb/A	220 lb/A	220 lb/A
Previous legume crop			Soybeans, 65 bu/A
N credit			40 lb/A
Starter fertilizer			
Form[1]	Dry (13-6-23-12)	Dry	Dry
Units applied[2]	26-12-46-24	28-40-24-15	28-40-24-15
Sidedressed fert.			
Form	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)
Applied N rate			
Normal	170 lb/A	180 lb/A	180 lb/A
Demo. plots	140, 180 or 220 lb/A	140, 150, 190, 220 or 230 lb/A	140, 150, 190, 220 or 230 lb/A
Topdressed fert.			
Form		Potash (0-0-60)	Potash (0-0-60)
Units applied		90 lb/A K_2O	90 lb/A K_2O
Fertigation			
Form		Liquid (28-0-0)	Liquid (28-0-0)
Applied N rate		10 lb/A	10 lb/A
Irrigation water			
N concentration	9.6 ppm	24.8 ppm	24.8 ppm
Applied N rate	NA	45 lb/A	45 lb/A

[1] Percent $N-P_2O_5-K_2O-S$ [2] Lb/A $N-P_2O_5-K_2O-S$

The nitrification inhibitor N-Serve was applied to the indicated treatments (Table 2) at a rate of 1 pt/A at the same time as N sidedressing. Corn yields in Demonstration No. 1 were unaffected by differences in total N supply or the presence or absence of N-Serve. Ear leaf N concentrations indicate that actual N supply may have increased with N rate, although all reflected an adequate N supply.[3] The University of Minnesota recommendation for yields in this range is 200 lb N/A, yet yields of about 168 bu/A were obtained with a minimum of 166 lb N/A. This may have been due to better than average growing conditions in 1991.

Demonstration Nos. 2 and 3 were on adjacent areas of one field, where corn followed corn on one half of the field (Demo. No. 2) and soybeans on the other half (Demo. No. 3). A comparison should not be made between these two areas, however, because a longer season variety was used on the half following corn. This resulted in lower yields than the other variety (following soybeans), due to the short, cool growing season of 1992. In both cases, however, a maximum yield was obtained with a rate close to the University recommendation (in Demo. No. 2, this included an N credit from the previous soybean crop). All but the middle sidedressed N rate received N-Serve, and so it is difficult to determine whether these yields would have been obtained at these rates in its absence. Since both producers in these demonstrations already sidedress the majority of their corn N, a nitrification inhibitor would be expected to provide little benefit in their programs.

Table 2. Results from N rate and N-Serve demonstrations.

Demo. No.	Replications	N-Serve	Sidedress N Rate	Total N Supply	Grain Yield	Std. Dev.[1]	Grain Moisture	Ear Leaf
			lb/A	lb/A	bu/A		%	% N
1	3	With	140	166	167.7	3.5	15.0	3.00
	3	Without	140	166	167.3	3.8		3.08
	3	"	180	206	169.0	2.0		3.14
	3	"	220	246	168.2	2.7		3.29
2	2	With	140	218	162.6	3.3	23.7	3.27
	2	"	150	228	157.8	1.1	25.1	3.03
	2	Without	190	268	158.2	1.3	25.2	3.03
	2	With	220	298	157.1	1.3	25.5	3.03
	2	"	230	308	162.0	2.3	23.3	3.18
3	3	With	100	218	179.9	3.8	21.4	3.25
	3	"	110	228	178.8	2.4	21.8	3.36
	2	Without	150	268	183.3	2.6	20.9	3.28
	3	With	180	298	188.6	10.8	21.0	3.26
	3	"	290	308	181.2	2.5	21.4	3.51

[1] Standard deviation for grain yield

[3] Ear leaf N concentrations of 2.75% or more are generally accepted as indicating the presence of sufficient N supply to optimize corn yields.

Demonstration of Alfalfa N Credits with Different Tillage Systems

Soils and crop nutrient information is summarized in Table 3. The producer in this demonstration incorporated an alfalfa stand of unknown plant density in the spring of 1992, using a moldboard plow on one half of the field and a chisel plow on the other half. Each tillage operation was followed by discing. With a yield goal of 120 bu/A, University of Minnesota 1992 recommendations called for no additional N applied following a good stand of alfalfa (150 lb/A N credit) or 75 lb N/A following a poor stand (75 lb/A N credit). In the results of a five-year study on an irrigated sandy soil in Staples, Minnesota,[4] higher intensity tillage resulted in higher yields of first year corn after alfalfa when no additional fertilizer N was supplied. Applied N made up the yield difference between tillage systems in the first year but not in subsequent years.

Table 3. Soils and crop nutrient information for alfalfa N credit demonstration.

Demonstration number	4		
County	Mille Lacs		
Soils Information		**Crop Nutrient Information**	
Soil type	Sartell fine sand	Corn yield goal	120 bu/A
Subgroup	Typic Udipsamment	Recommended N rate	150 lb/A
Family	Frigid	Legume crop	Alfalfa
pH	6.9	Plants/ft^2	NA
Organic matter	1.6%	N Credit	75-150 lb/A
Phosphorus	49 ppm	Starter fertilizer	
Potassium	161 ppm	Form[1]	Dry (20-20-7-6)
Sulfate-S	1 ppm	Units applied[2]	32-32-11-10
Nitrate-N		Sidedressed fertilizer	
Preplant	26 lb/A	Form	Anhyd. NH_3 (82-0-0)
Presidedress	84 lb/A	Applied N Rate	
Post-harvest	12 lb/A	Normal	80 lb/A
		Demo. plots	0, 40 or 80 lb/A
		Irrigation water	
		N concentration	0.7 ppm
		Applied N Rate	Negligible

[1] Percent $N-P_2O_5-K_2O-S$ [2] Lb/A $N-P_2O_5-K_2O$

Table 4. Results from alfalfa N credit demonstration.

Replications	Sidedress N Rate	Total N Supply[1]	Grain Yield	Std. Dev.[2]	Grain Moisture	Ear Leaf N	Grain N	Grain N Uptake
	lb/A	lb/A	bu/A		%	%	%	lb/A
Moldboard								
4	0	182	105.4	11.0	27.7	1.93	1.26	62.4
4	40	222	116.1	8.1	27.9	(not	1.40	76.4
4	80	262	123.0	7.4	28.0	done)	1.34	77.5
Chisel								
4	0	182	100.0	18.2	27.2	1.76	1.26	59.2
4	40	222	104.4	12.4	27.5	(not	1.25	61.3
4	80	262	103.9	8.4	27.4	done)	1.27	62.0

[1] Assumes 150 lb/A N credit from alfalfa [2] Standard deviation for grain yield

In this demonstration, similar yields (Table 4) were obtained in the two tillage systems when no additional fertilizer N was applied, and these yields indicate that the alfalfa supplied the effects

[4] Moncrief, J.F., M.J. Wiens, N. Krause, and B.J. Johnson. 1992. Tillage effects on N available to irrigated corn from alfalfa: A five-year summary. p. 96-99. In Field Research in Soil Science. Univ. of Minnesota Misc. Publ. 75-1992.

of at least 90 lb N/A in both tillage systems (this equals University recommendations of 120 lb N/A for 100 bu/A corn minus 30 lb N/A in the starter). It is not likely that the alfalfa N supply was much greater than this, as corn yields in the moldboard area increased with sidedressed N rate. Alfalfa N mineralization, as well as corn yields in general, were most likely limited by cool conditions throughout the 1992 growing season. Chisel-plowed corn did not respond to additional N. Factors such as cooler soil temperatures and much higher weed pressure than in the moldboard-plowed area had additionaly adverse effects on yields. Both ear leaf and grain N concentration indicated that neither system supplied sufficient N to maximize corn yields in this particular year.[5] This demonstration will be repeated in 1993 to estimate second year alfalfa N credits from the two tillage systems.

Demonstrations of Pulse Legume N Credits

Table 5 lists soils and crop nutrient information for these demonstrations. The University of Minnesota corn N recommendations in 1992 allowed a 40 lb/A N credit for soybeans, but no credit was given for edible beans, a legume crop grown in this area in rotation with potatoes and corn. The 1993 soybean N credit is still 40 lb/A, but this year a 20 lb/A N credit is suggested for edible beans.

Table 5. Soils and crop nutrient information for pulse legume N credit demonstrations.

Demonstration number	5	6	7
County	Stearns	Mille Lacs	Sherburne
Soils Information			
Soil type	Estherville sandy loam	Sartell fine sand	Pierz sandy loam
Subgroup	Typic hapludoll	Typic udipsamment	Udic argiboroll
Family	Sandy, mixed, mesic	Frigid	Coarse, loamy, mixed
pH	6.6	6.7	6.7
Organic matter	3.3 %	1.2 %	1.8 %
Phosphorus	25 ppm	38 ppm	39 ppm
Potassium	147 ppm	97 ppm	158 ppm
Sulfate-S	3 ppm	1 ppm	1 ppm
Nitrate-N			
Preplant	36 lb/A	20 lb/A	6 lb/A
Presidedress	88 lb/A	30 lb/A	40 lb/A
Post-harvest	32 lb/A	20 lb/A	NA
Crop Nutrient Information			
Corn yield goal	150 bu/A	170 bu/A	150 bu/A
Recommended N rate	180 lb/A	220 lb/A	180 lb/A
Previous legume crop	Navy beans	Soybeans	Soybeans
N credit	Unknown	40 lb/A	40 lb/A
Starter fertilizer	Liquid	Dry	Dry
Form[1]	9-18-9 + 0-0-30	NA	16-11-15-12
Units applied[2]	5-10-12	35-30-35-10	21-15-20-16
Sidedressed fertilizer			
Form	Anhyd. NH_3 (0-0-82)	NH_4NO_3 (28-0-0)	Anhyd. NH_3 (82-0-0)
Applied N rate			
Normal	120 lb/A	50 lb/A	136 lb/A
Demo. plots	120, 150 or 180 lb/A	0, 50 or 100 lb/A	0, 100, 140 or 180 lb/A
Fertigation			
Form		NH_4NO_3 (28-0-0)	
Applied N rate		87 lb/A	
Irrigation water			
N concentration	4.7 ppm	NA	NA
Applied N rate	Negligible	NA	NA

[1] Percent $N-P_2O_5-K_2O-S$ [2] Lb/A $N-P_2O_5-K_2O-S$

[5] Grain N concentrations of 1.4 to 1.6% usually indicate adequate corn N supply.

Results of these demonstrations are shown in Table 6. In Demonstration No. 5 (corn after navy beans), corn yields of 130 to 140 bu/A were obtained with as little as 125 lb/A fertilizer N (the University recommended 150 to 180 lb N/A for these yields). This indicates that an edible bean N credit of at least 20 lb/A is realistic.

Corn yields in Demonstration No. 6 (following soybeans) did increase with N supply, although these differences may not be significant. The ear leaf and grain N concentrations of the corn with 0 lb/A sidedressed N indicated inadequate N supply. It is possible that the cool conditions of 1992 resulted in less soybean N mineralization than in a more normal year. However, a large amount of the total N supply was topdressed through the irrigation system, and some of this N may have been applied beyond the period of maximum corn N uptake (application dates between July 17 and August 4). This premise is supported by the fact that the highest N rate (262 lb/A, including soybean N credit) resulted in a yield of only 143 bu/A, though weather could also have been a factor. In this situation, it is difficult to judge the size of the legume N credit.

Yields in Demonstration No. 7 were likely limited by soil moisture rather than N supply, as late season rainfall was below normal and less than three inches of irrigation water was applied. No conclusion may be made regarding the soybean N credit since the 100 lb/A sidedress N rate (121 lb/A total N supply without the credit) should have been adequate to produce yields of 107 to 114 bu/A, and ear leaf N concentrations of 2.7% or greater seem to confirm this.

Table 6. Results of pulse legume N credit demonstrations.

Demo. No.	Reps.	Sidedress N Rate	Total N Supply	Grain Yield	Std. Dev.[1]	Grain Moisture	Ear Leaf N	Grain N	Grain N Uptake
		lb/A	lb/A	bu/A		%	%	%	lb/A
5	3	120	125	141.3	2.0	28.1	3.25	(not	(not
	3	150	155	140.1	5.8	30.5	(not	done)	done)
	3	180	185	129.3	8.2	32.2	done)		
6	3	0	162	126.6	4.2	25.2	1.78	1.27	75.6
	3	50	212	136.1	3.7	28.7	2.44	1.41	90.2
	3	100	262	143.2	6.0	27.5	3.01	1.45	97.6
7	3	0	61	52.8	7.5	27.9	2.41		
	3	100	161	107.4	3.6	27.1	2.70	(not	(not
	3	140	201	113.8	4.4	27.5	2.75	done)	done)
	3	180	241	114.5	10.4	27.9	2.71		

[1] Standard deviation for grain yield

Demonstrations of Combined Manure and Pulse Legume N Credits

Table 7. Soils and crop nutrient information for manure N credit demonstrations.

Demonstration number	8	9	10
County	Stearns	Stearns	Wright
Soils Information			
Soil type	Estherville sandy loam	Estherville sandy loam	Hubbard loamy sand
Subgroup	Typic hapludoll	Typic hapludoll	Udorthentic haploboroll
Family	Sandy, mixed, mesic	Sandy, mixed, mesic	Sandy, mixed
pH	6.6	6.3	7.0
Organic matter	3.3 %	2.5 %	1.0 %
Phosphorus	25 ppm	52 ppm	61 ppm
Potassium	147 ppm	134 ppm	108 ppm
Sulfate-S	3 ppm	4 ppm	1 ppm
Nitrate-N			
Preplant	36 lb/A	32 lb/A	14 lb/A
Presidedress	88 lb/A	36 lb/A	68 lb/A
Post-harvest	32 lb/A	28 lb/A	21 lb/A

--- Continued ---

--- Table 7 continued ---

Demonstration No.	8	9	10
Crop Nutrient Information			
Corn yield goal	150 bu/A	160 bu/A	160 bu/A
Recommended N rate	180 lb/A	200 lb/A	200 lb/A
Manure type	Dairy, liquid	Swine, solid	Dairy, solid
Application rate	3 Mgal/A	6 T/A	17.4 T/A
Application method	Broadcast	Broadcast	Broadcast
Incorporation	Within 4 days	Within 4 days	None (daily haul)
Analysis[1]	48-19-33	16-10-12	13-8-20
Availability[2]	17-70-75	30-80-85	20-80-85
Nutrient credits[3]	25-40-75	29-48-61	46-117-293
Previous legume crop	Navy beans	Soybeans	Soybeans
N credit	Unknown	40 lb/A	40 lb/A
Starter fertilizer			
Form[2]	Liquid (9-18-9 and 0-0-30)	Dry (14-16-13-11)	Dry (20-16-9-8)
Units applied[3]	5-10-12	19-22-18-15	20-16-9-8
Sidedressed fertilizer			
Form	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)	Anhyd. NH_3 (82-0-0)
Applied N rate			
Normal	120 lb/A	100 lb/A	120 lb/A
Demo. plots	90, 120 or 150 lb/A	100 or 140 lb/A	0, 30, 60, 90 or 120 lb/A
Irrigation water			
N concentration	4.7 ppm	<0.5 ppm	NA
Applied N rate	Negligible	Negligible	NA

[1] Lb/T (solid) or lb/Mgal (liquid) $N-P_2O_5-K_2O$ (as-is basis) [2] Percent $N-P_2O_5-K_2O-(S)$ [3] Lb/A $N-P_2O_5-K_2O-(S)$

Three demonstrations were conducted on soybean or edible bean fields to which manure had been applied prior to corn planting (Table 7, above). These fields had probably also been manured prior to project involvement, and soil P and K levels were high to very high. Very little P or K was therefore required or used in the starter fertilizers. A conservative estimate of manure nutrient availability was used in Demonstration No. 8 since the cooperator was unsure of the presence of these nutrient credits. A corn yield of 127 bu/A (Table 8, below) was achieved with an estimated total N supply of 120 lb/A (including 25 lb/A from the manure only). The beans and/or the manure appear to have contributed up to 30 lb N/A more than was credited, as yields of this size normally require about 150 lb N/A. Additional fertilizer N did not increase yields, which may have been limited by weather or other factors.

Table 8. Results of combined manure and pulse legume N credit demonstrations.

Demo. No.	Repli-cations	Sidedress N Rate	Total N Supply	Grain Yield	Std. Dev.[1]	Grain Moisture	Ear Leaf N
		lb/A	lb/A	bu/A		%	%
8	3	90	120	126.8	10.7	28.8	(not
	3	120	150	124.5	8.8	29.1	done)
	3	150	180	127.9	1.7	27.4	
9	3	100	188	144.2	1.2	20.2	3.09
	2	140	228	152.0	0.1	19.3	(not done)
10	1	0	106	102.8	---	24.4	1.92
	3	30	136	138.3	3.6	22.5	2.40
	3	60	166	130.5	4.0	22.6	2.50
	3	90	196	132.2	3.8	22.9	2.51
	3	120	226	141.3	8.0	22.5	2.34

[1] Standard deviation for grain yield

Corn yields did increase with sidedressed N rate in Demonstration No. 9, but this difference may not be significant as ear leaf N at the lower rate was more than adequate. The manure and soybean N credit estimates were probably accurate since the yield at the lower N rate (144 bu/A) was about what would be expected with the total N supplied (188 lb/A). The nitrification inhibitor N-Serve was applied to this field at the rate of 1 pt/A, but its effects cannot be evaluated without a control treatment. Other non-manured demonstration plots have not shown yield improvements with the use of N-Serve.

The results seem inconclusive in the demonstration of daily haul manure and soybean N credits (No. 10). Yields at the lower N rates do reflect the estimated N supplies, but ear leaf N at all rates indicates lower than optimum supply. Again, yields at the upper N rates were probably limited by weather conditions. It is likely that the manure contributed nitrogen to the corn, but it is difficult to accurately assess the size of a credit from daily haul manure as bedding content may be high, applications are difficult to spread evenly and it is almost never incorporated in a timely manner.

Demonstration of Poultry Manure N Credits

This demonstration was conducted for a broiler operation with a high level of manure production but limited acreage on which to spread it. As a consequence, soil P and K levels were very high (Table 9). Poultry manure also has a higher N content than other livestock manures. Manure application, combined with starter N and a normal sidedressed N application of 190 lb/A, resulted in this field receiving approximately 360 lb N/A in 1992.

Table 9. Soils and crop nutrient information for poultry manure N credit demonstration.

Demonstration number	11	**Crop Nutrient Information**	
County	Sherburne	Manure type	Poultry, solid
		Application rate	7 T/A
Soils Information		Application method	Broadcast
Soil type	Hubbard sandy loam	Incorporation	Within 12 hours
Subgroup	Typic haploboroll	Analysis[2]	74-59-30
Family	Sandy, mixed	Availability[3]	30-80-85
pH	6.2	Nutrient credits[4]	155-330-179
Organic matter	2.3 %	Starter fertilizer	
Phosphorus	100+ ppm[1]	Form[3]	Dry (12-12-12-12)
Potassium	149 ppm	Units applied[4]	18-18-18-18
Sulfate-S	1 ppm	Sidedressed fertilizer	
Nitrate-N		Form	Anhyd. NH_3 (82-0-0)
Preplant	28 lb/A	Applied N rate	
Presidedress	252 lb/A	Normal	190 lb/A
Post-harvest	65 lb/A	Demo. plots	0, 140 or 190 lb/A
		Irrigation water	
		N concentration	6 ppm
		Applied N rate	Negligible

[1] Soil P content was greater than analysis limit of 100 ppm
[2] Lb/T (solid) or lb/Mgal (liquid) $N-P_2O_5-K_2O$
[3] Percent $N-P_2O_5-K_2O-(S)$
[4] Lb/A $N-P_2O_5-K_2O-(S)$

Table 10. Results of poultry manure N credit demonstration.

Replications	Sidedress N Rate	Total N Supply	Grain Yield	Std.Dev.[1]	Grain Moisture	Ear Leaf N
	lb/A	lb/A	bu/A		%	%
4	0	173	146.3	13.2	23.2	(not
5	140	313	165.1	8.5	22.3	done)
5	190	363	166.2	4.9	22.7	

[1] Standard deviation for grain yield

With a yield goal of 185 bu/A and manure N supply of about 155 lb/A, only 50 to 70 lb/A of additional N should have been needed. An average yield of 146 bu/A was achieved with just the manure and starter N, indicating the accuracy of the N credit estimation (Table 10, above). Sidedressing an extra 140 lb N/A resulted in only a 20 bu/A yield increase, but without incremented N treatments below this level, it cannot be determined at what total N rate yields would have been maximized. It was obvious however that the poultry manure provided a very large and very real N credit.

POTATO N MANAGEMENT AND PETIOLE N MONITORING DEMONSTRATIONS

Procedures

Demonstration No. 12 was conducted with the help of Carl Rosen, Extension Soil Scientist at the University of Minnesota, and focused mainly on evaluating the use of petiole sap nitrate testing with the Cardy Nitrate meter[6] to monitor potato plant N status and predict in-season N needs. Demonstration No. 13 was conducted separately by the project but with the same goals and methods. Nitrogen rate treatments consisted of different total rates and time-of-application splits based on normal field operations, University of Minnesota recommendations and either reduced starter N (Demo. No. 12) or reduced N at hilling (Demo. No. 13). Each treatment was replicated three times. Nitrogen application amounts for both demonstrations are shown in Table 11. All nitrogen applied up to hilling was ammonium nitrate (34-0-0) in Demonstration No. 12 and a low pressure liquid ammonium nitrate + ammonia solution (38-0-0) in Demonstration No. 13. All post-hilling N applications were as 28-0-0 (UAN) through the irrigation systems.

Table 11. Nitrogen application amounts for potato N management demonstrations.

Demo. No.	Treatment	Nitrogen Applications: Planting	Emergence	Hilling	Post-Hill	Total N Applied
		lb/A				lb/A
12	1. Univ. of MN rec.	32	50	80	51	213
	2. Reduced starter	32	80	50	51	213
	3. Grower treatment	64	80	50	51	245
13	1. Univ. of MN rec.	25	95	95	NA	215[1]
	2. Reduced hilling	25	95	120	NA	240
	3. Grower treatment	25	95	140	NA	260

[1] Does not include post-hilling N applications for Demo. No. 13.

The potato variety in each demonstration was Russett Burbank. Both demonstration fields were irrigated to provide adequate water supplies. Non-treatment cultural practices consisted of the producer's customary planting, hilling, pesticide application, vinekill and harvest practices, and were the same between the N management treatments. Soil samples for NO_3-N analysis were taken as with the corn demonstrations. Potato petiole samples from the most recently matured leaf were collected every 7-10 days starting on 6/3/92. Thirty petioles were collected in three areas within each treatment (total of 90 petioles per treatment). For each area, 15 petioles were crushed with a Hach press[7] for sap analysis. Sap nitrate was determined using the Cardy nitrate meter. For Demonstration No. 12 only, the remaining 15 petioles were dried for conventional petiole nitrate analysis. Potatoes were hand-dug from thirty foot lengths of three rows per replicate and separated into quality and size grades before weighing. Potato yields are expressed on an as-is basis.

Results and Discussion

The N treatments tested in Demonstration No. 12 had little effect on potato yields (Table 12, below). Rainfall during the 1992 growing season was very timely with only one leaching event occurring in July. Had more leaching rains occurred earlier in the season, the University recommendations treatment (more N at hilling than at emergence) may have been more beneficial. The results of this demonstration clearly suggest that high amounts of starter nitrogen are not needed

[6] Spectrum Technologies, Inc., 12010 S. Aero Dr., Plainfield, IL 60544

[7] Hach Co., P.O. Box 389, Loveland, CO 80539.

for optimum potato yields, provided that nitrogen is available at later stages of growth.

Table 12. Yield results of potato N management demonstrations.

Demo. No.	Treatment	Total N	< 3 oz.	3-12 oz.	> 12 oz.	Culls	Total
		lb/A	cwt/A				lb/A
12	1 (U of M)	213	35	432	58	54	579
	2 (Red. St.)	213	37	404	84	44	570
	3 (Grower)	245	38	423	53	49	563
13	1 (U of M)	215[1]	59	292	41	77	469
	2 (Red. Hil.)	240	57	339	30	113	539
	3 (Grower)	260	68	361	34	84	547

[1] Does not include post-hilling N applications for Demo. No. 13.

Petiole nitrate-N values for Demonstration 12 are shown in Table 13. Sap nitrate-N correlated well with conventional petiole analysis, suggesting that the sap test is a useful indicator of plant N status. Petiole nitrate-N generally followed rate of nitrogen applied, with the grower N treatment having highest petiole nitrate-N levels. However, for all treatments, these levels were on the low side throughout the growing season compared to established sufficiency ranges.[8] Additional treatments would be needed to determine whether higher N rates than those used in this demonstration would have increased yields. At least in this year, good yields were achieved with petiole nitrate-N levels lower than those suggested for sufficiency ranges. Additional research is still required to determine the practicality of using the sap test.

Table 13. Petiole nitrate-N values for Demonstration 12.

Date	6/3	6/10	6/17	6/24	7/1	7/8
	ppm NO_3-N					
Petiole sap[1]						
Trmt. 1	837	1000	1050	733	577	560
2	947	920	1027	743	423	320
3	973	1027	1200	1053	927	970
Petiole tissue[2]						
Trmt. 1	20764	21252	21749	13138	8039	3766
2	22991	19302	20308	12242	5235	2440
3	23560	21285	23445	19452	15991	12307

Date	7/15	7/22	8/5	8/12	8/19
	ppm NO_3-N				
Petiole sap[1]					
Trmt. 1	417	557	563	596	297
2	520	223	490	360	300
3	697	457	860	616	453
Petiole tissue[2]					
Trmt. 1	3951	1375	2808	4303	2610
2	2709	1388	3204	2252	707
3	6685	2409	5289	6332	1783

[1] Critical range for petiole sap NO_3-N: 6/15-7/1, 1200-1500 ppm
7/1-7/15, 800-1100 ppm
7/15-8/15, 400- 700 ppm

[2] Critical range for petiole tissue NO_3-N: 6/15-7/1, 17000-22000 ppm
7/1-7/15, 11000-15000 ppm
7/15-8/15, 6000-15000 ppm

[8] The critical ranges for petiole nitrate-N are those levels which have been found to correlate with optimum potato yields.

Potato yields in Demonstration 13 did increase with N rate (Table 12), mainly due to increases in yields in the 3-12 oz. size grade. However, these differences were not statistically significant, possibly due to large variability between individual replication yields (statistical analysis not shown). Petiole sap nitrate-N values (Table 14) for the grower N treatment tended to fall within the indicated sufficiency ranges, while those of the other two treatments fell below these levels. This is in contrast to the previous demonstration, where hilling N applications were smaller and petiole nitrate-N levels were below the critical values in all treatments.

Table 14. Petiole nitrate-N values for Demonstration No. 13.

Date		6/3	6/10	6/17	6/24	7/1	7/8
		ppm NO_3-N					
Trmt.	1	(not	937	1037	1167	1366	767
	2	done)	1007	1167	1233	1333	833
	3	860	980	1233	1233	1466	913
Date		7/15	7/22	7/29	8/6	8/13	8/20
		ppm NO_3-N					
Trmt.	1	1016	723	426	426	210	337
	2	953	727	563	280	343	213
	3	1233	930	736	540	303	320

Critical range for petiole sap NO_3-N: 6/15-7/1, 1200-1500 ppm
7/1-7/15, 800-1100 ppm
7/15-8/15, 400- 700 ppm

NITROGEN SPECIFIC MANAGEMENT BY SOIL CONDITION[1]

J.A. Vetsch, G.L. Malzer, P.C. Robert, and D.R. Huggins[2]

Abstract: Recent advances in technology has brought about considerable interest in developing the methodology for making variable N (site-specific) rate applications within a field. The objectives of this study were to evaluate yield variability within production fields, determine yield response to applied fertilizer N and differential N loss as influenced by soil conditions. This report contains results from the second year of a research project originated in 1991 to evaluate site-specific application of anhydrous ammonia to corn. Preliminary analysis by soil map unit shows considerable yield variability in segmented harvest areas between and within map units at both sites. Economic analysis of variable rate application suggests potential improvement over conventional application.

Introduction: Nitrogen specific management by soil condition (NSMSC) has evolved from recent advances in geographic information system technology and renowned interest in improving best management practices for nitrogen. Nitrogen specific recommendations, based on yield goal and soil conditions of production fields, are stored on a computer as digitized maps. The applicator's computer reads the digitized map and applies the specific N rate. Implementation of NSMSC may increase yields by better evaluating yield potentials of fields, increase profits by lowering inputs and improve water quality by identifying areas of potential N loss. This paper contains data from the second year of study to evaluate NSMSC. Anhydrous ammonia was applied in strips across production corn fields and the response to fertilizer was measured on a 'field scale'. The objectives of this study were to evaluate the variability in yield potentials within production fields, determine yield response to applied fertilizer N and differential N loss as influenced by soil conditions and ascertain what measurable soil conditions are best suited for making site specific N recommendations.

Materials and Methods: Experimental sites for 1992 were chosen at the Southwest Experiment Station, Lamberton (dryland) and the Malcolm and Steve Olson Farm, Becker (irrigated) of 19 and 29 acres respectively. The sites selected represented soil variability common to the respective areas. Experimental measurements for both sites include: an improved soil survey, grid soil sampling (analyzed for NO_3-N, NH_4-N, total N, carbon, mineralizable N and soil water), corn grain yield, grain moisture and N accumulation in grain. Soil sample grid size was 90 by 50 feet and 140 by 50 feet, samples were taken to a depth of 4 and 3 feet at Lamberton and Becker, respectively. Soil samples were separated into one foot increments for analysis. A summary of the sites soil characteristics are presented in Tables 1 and 2.

Table 1. Soil data for Nitrogen Specific Management by Soil Condition Lamberton 1992.

Soil Series	Symb	Acre	Text	Slope	T.C.	NO_3-N	Subgroup
				%	%	lbs/A	
Canisteo	86	4.9	cl	0-2	2.3	23	Mollic Haplaquoll
Delft-Web*	884	0.6	cl	0-2	2.2	38	Typic Haplaquoll
Normania	446	6.2	l	0-2	1.9	21	Aquic Haplustoll
Ves B	421B	2.0	l	2-6	1.6	23	Udic Haplustoll
Ves-Swan**	954C2	0.7	l	6-12	0.9	19	Entic Hapludoll
Seaforth	423	2.8	l	0-2	2.0	30	Auqic Calciustoll
Ves-E-S***	999B2	1.7	l/s	2-6	1.1	12	Hapludoll/Udorthent

Symb Soil series symbol
Text Soil texture
T.C. Total Carbon (values for one foot depth)
NO_3-N Residual Nitrate (values for zero to two foot depth)
* Delft Webster Complex
** Ves Swanlake Complex
*** Ves Esterville Storden Complex

[1] The assistance and financial support of the Minnesota Agricultural Experiment Station, USDA-CSRS, Dow Elanco and Soil Teq Inc. is greatfully acknowledged.
[2] Graduate assistant, Professor and Assistant Professor, Department of Soil Science, and Soil Scientist, Southwest Experiment Station, respectively.

Table 2. Soil data for Nitrogen Specific Management by Soil Condition Becker 1992.

Soil Series	Symb.	Acres	Text.	Slope	T.C.	NO_3-N	Subgroup
				%	%	lbs/A	
Hubbard A	7A	8.5	ls	0-2	1.0	8.4	Udorthentic Haploboroll
Hubbard B	7B	6.1	ls	2-6	0.7	8.4	Udorthentic Haploboroll
Hubbard C	7C	1.1	ls	6-12	0.8	6.3	Udorthentic Haploboroll
Mosford A	768A	13.6	sl	0-2	1.0	8.9	Udic Haploboroll

T.C. Total Carbon (values for one foot depth)
NO_3-N Residual Nitrate (values for one foot depth)

Lamberton: Pioneer 3615, was planted on May 4, 1992 on 30 inch row spacing. Weed control was accomplished by using Lasso at 3.0 lbs/A and Bladex at 1.5 lbs/A on May 5 and cultivation on June 4. Twelve treatments consisting of eight constant N rates (60, 90, 120, 150 and 180 lbs N/A) and (60, 90 and 120 with N-Serve, N-Serve applied at 1 qt/A), two variable N rates (soil and residual nitrate) and two checks (zero N) were applied sidedress as anhydrous ammonia on May 15 (emergence) in 15 foot strips (6 rows) across the field in a split plot randomized complete block design with 4 blocks. Rates for the variable rate by soil (VSoil) treatment were determined by existing extension recommendations and the soil map units crop equivalency rating (CER). Rates for the variable by residual nitrate (VNO_3N) were determined by the grid soil samples and the nitrogen credit equation. The previous crop was soybeans in a corn-soybean rotation.

Becker: Pioneer 3751 was planted on May 1 at a desired plant population of 31,000 on 38 inch row spacing. Starter fertilizer was applied as a side banded application of 240 lbs/A of a 12-9-30 plus sulfur and zinc. Weed control was accomplished with a tank mix of Prowl at 2 pts/A and Attrex at 1.75 lbs/A, rotary hoe and cultivation. Eleven treatments consisting of eight constant N rates paired with N-serve (90, 120, 150 and 180 lbs N/A, N-Serve applied at 0.6 qt/A), one variable rate (VSoil), and two checks (zero N) were applied sidedress as anhydrous ammonia on June 12 in 25 foot strips (8 rows) across the field in a split plot randomized complete block design with 3 blocks. Rates for the variable by soil treatment were calculated using existing recommendations and the soils CER. The previous crop was corn on a corn-corn-soybean rotation.

Results and Discussion Lamberton: (Note: This is a presentation of preliminary results, the author reserves the right to change results and conclusions.) Grain yields on check plots ranged from 28 to 154 bu/A. Variability in grain yield from the check areas was high on all soils with standard deviations ranging from 14 to 24 bu/A. This suggests that soil map unit may not be the only parameter needed to describe soil variability. The yield averages for treatments by soil map unit are presented in Table 3. All soil map units responded to fertilizer N, but generally soil map units did not respond equally. This implies differential N response to fertilizer N between soil map units. Early indications show no statistically significant yield response to N-serve by map unit, however, pairwise comparisons of 40 ft harvest segments showed large positive and negative responses in various locations of the field.

Table 3. Grain yield averages and (Standard Deviations) by soil map units for Nitrogen Specific Management by Soil Condition, Lamberton 1991.

NRate	999B2	954C2	421B	446	423	86	884
lbs/A				bu/A			
60NI	86 (27)	71 (07)	125 (12)	114 (25)	116 (26)	119 (18)	121 (04)
90NI	105 (12)	74 (12)	117 (14)	122 (18)	128 (18)	122 (12)	112 (07)
120NI	104 (21)	65 (16)	130 (09)	113 (20)	113 (22)	127 (19)	113 (NA)
0	75 (24)	54 (21)	88 (14)	88 (20)	84 (19)	79 (10)	95 (19)
60	89 (23)	89 (NA)	112 (18)	112 (23)	117 (24)	117 (16)	125 (01)
90	108 (11)	50 (19)	126 (11)	123 (20)	136 (15)	124 (17)	125 (06)
120	109 (22)	92 (15)	133 (06)	120 (19)	114 (27)	129 (19)	127 (NA)
150	128 (08)	94 (10)	135 (09)	136 (09)	115 (28)	132 (14)	126 (09)
180	129 (07)	73 (32)	128 (12)	131 (11)	119 (29)	131 (13)	106 (14)
VSNI	128 (06)	93 (13)	127 (10)	132 (10)	124 (18)	122 (10)	123 (10)
VNO_3N	99 (18)	NA (NA)	127 (17)	117 (24)	131 (22)	129 (18)	NA (NA)

NI Nitrification inhibitor (N-Serve)
NA No data or not applicable
VSNI Variable by soil treatment (N-Serve applied to Canisteo soil only)

Table 4 presents the economics for variable rate application by soil map unit at Lamberton. Two commonly used statistical models (Linear Plateau and Quadratic) were used to quantify yield response to the constant rate strips. The economic optimum N rates (EOR) for each map unit were calculated using these models. The nitrogen fertilizer return (NFR) was calculated with model predicted yields, $2.00 per bu corn, $0.13 per lb N, and N rates based on the fertilizer strategy (Conv, 150 lbs N/A for all soils; VSoil, 150 lbs N/A on map units 999B2 and 421B and 120 lbs N/A on all other map units; EOR, N rates based on economic optimum N rates. Variable rate application, VSoil, performed as well or better than conventional application on all soils except 954C2 and 446. On these soils yields were slightly reduced by lower than economic optimum rates. The NFR EOR shows that significant improvement over conventional application can be obtained.

Table 4. Economic optimum N rate (EOR) and nitrogen fertilizer return (NFR) by soil map unit for Lamberton 1992.

Statistical Model		999B2	954C2	421B	446	423	86	884
Linear Plateau								
EOR	(lbs N/A)	173	144	106	145	66	97	48
NFR Conv	($/A)	78	33	64	62	54	78	26
NFR VSoil	($/A)	78	28	64	52	58	82	30
NFR EOR	($/A)	90	34	70	62	65	85	39
Quadratic								
EOR	(lbs N/A)	NA	NA	143	160	104	134	92
NFR Conv	($/A)	NA	NA	69	62	52	85	27
NFR VSoil	($/A)	NA	NA	69	59	63	86	40
NFR EOR	($/A)	NA	NA	71	62	64	86	44

NA Model doesn't fit data

Results and Discussion Becker: Grain yields varied from 73 to 146 bu/A on check strips with considerable variability in all soil map units and standard deviations ranging from 10 to 15 bu/A. Table 5 displays yield averages for each treatment by soil map unit. Early indications show no statistically (α=0.1) significant yield response to N-serve by map unit, however, a 4.7 bu/A response was observed on soil 7A. Also, pairwise comparisons of 50 ft harvest segments showed significant positive and negative responses in various locations of the field.

Table 5. Grain yield averages and (Standard Deviation) by soil map unit for Nitrogen Specific Management by Soil Condition, Becker 1992.

NRate lbs/A	7A	7B	7C	768A
	bu/A			
90NI	140 (11)	136 (20)	141 (08)	141 (09)
120NI	153 (11)	151 (11)	131 (05)	146 (13)
150NI	144 (08)	150 (11)	146 (02)	142 (13)
180NI	150 (12)	154 (12)	170 (NA)	151 (11)
0	105 (12)	106 (15)	99 (10)	105 (14)
90	129 (12)	141 (18)	144 (03)	144 (14)
120	142 (11)	143 (09)	140 (03)	135 (10)
150	148 (13)	143 (11)	145 (03)	140 (15)
180	140 (13)	156 (10)	138 (04)	144 (09)
VS	147 (08)	149 (13)	146 (02)	142 (13)

NI Nitrification inhibitor (N-Serve)
NA No data or not applicable
VS Variable by soil treatment

The economics for variable rate application at Becker (Table 6) were calculated with the same models and parameters as Lamberton except the conventional application rate was 180 lbs N/A and the variable rates by soil were 150 lbs N/A for 768A and 120 lbs N/A for 7A, 7B and 7C. The variable rate treatment was effective on two of the soils (768A and 7A), but did not supply adequate N on the others (7B and 7C). Conclusions for the NFR EOR at Lamberton apply to the Becker site as well.

Table 6. Economic optimum N rate (EOR) and nitrogen fertilizer return (NFR) by soil map unit for Becker 1992.

Statistical Model		7A	7B	7C	768A
Linear Plateau					
EOR	(lbs N/A)	120	162	141	93
NFR Conv	($/A)	59	70	63	53
NFR VSoil	($/A)	66	54	58	57
NFR EOR	($/A)	66	73	68	65
Quadratic					
EOR	(lbs N/A)	141	186	144	139
NFR Conv	($/A)	59	71	68	56
NFR VSoil	($/A)	62	62	70	60
NFR EOR	($/A)	64	71	72	61

PROFITABILITY OF VARIABLE NITROGEN APPLICATION, BUTTERFIELD, MN[1]

D.S. Long, P.C. Robert, and D. Fairchild[2]

An experiment was performed to study the profitability of variable applications of nitrogen (N) in a field. Mean net returns and production costs were compared with respect to a variable N application rate, a single conventional N application rate, and a zero N application rate. N rates were applied in strips across Clarion loams, Canisteo-Glencoe clay loams, and Clarion-Storden loams. Net return was computed for each treatment based on value of yield at $1.82 bu/ac minus production costs for grain drying, nitrogen fertilizer, soil sampling, fertilizer application, and soil mapping. Net return was maximum at 191 $/ac for variable application followed by 181 $/ac for conventional application and 163 $/ac for zero application. The analysis of variance was applied separately to the data of each soil mapping unit. Net returns for variable and conventional rates were significantly greater than that for the zero N rate. In Clarion soils, net return for the variable rate was significantly greater than that for the conventional application (192 $/ac vs. 174 $/ac). However, significant differences in net return were not detected between variable and conventional rates in Canisteo-Glencoe soils (182 $/ac vs. 171 $/ac) and Clarion-Storden soils (198 $/ac versus 197 $/ac).

Materials and Methods

A 360 X 1320 foot (10.9 acre) field near Butterfield, MN was divided into six 180 X 1320 foot blocks in 1992. Each block consisted of three 60 X 1320 foot strips that intercepted the following three soil map units: (1) Clarion loams, 1-4 % slopes, (2) Canisteo-Glencoe clay loams, and (3) Clarion-Storden loams, 3-6 % slopes, eroded. Each strip represented one of the following treatments: (1) a conventional application of 95 lbs N/ac stripped across all soils, (2) variable application of 135 lbs N/ac to Clarion soils, 50 lbs N/ac to Canisteo-Glencoe soils, and 95 lbs N/ac to Clarion-Storden soils, and (3) a check with zero-applied N. The field was planted to corn following application of the N treatments.

Net return was based on dollar value of corn yield ($1.82 per bushel) minus production costs for grain drying to 15.5 percent moisture, nitrogen fertilizer, soil sampling, fertilizer application, and mapping. Table 1 lists unit prices for each type of cost. Yield and net return were then tabulated for the conventional, variable, and zero N treatments. The analysis of variance was applied separately to the data of each soil map unit to test for significant differences in yield and net return at the 10 percent level of probability.

Results and Discussion

Table 2 presents the summary statistics for the gross return, production costs, and net return for the conventional, variable, and zero N treatments in the entire field. The ANOVA was not applied to the entire data set because the variable rate treatments were not balanced across all soils. Production costs included those for grain drying, soil sampling, nitrogen, custom fertilizer application, and soil mapping. Gross return was maximum at 284 $/ac for the variable N rate followed by 269 $/ac for the conventional N rate and 227 $/ac for the zero N rate. These differences in gross return were due to differences in mean yield which was 156 bu/ac for the variable N rate, 148 bu/ac for the conventional N rate, and 125 bu/ac for the zero N rate. Mean production costs were maximum at 93 $/ac for the variable N rate followed by 88 $/ac for the conventional N rate and 64 $/ac for the zero N rate. Evidently, the higher production costs for variable rate was offset by the higher gross return. Accordingly, mean net return was 191 $/ac for the variable rate followed by 181 $/ac for the conventional rate and 163 $/ac for the zero rate.

Table 3 shows the effect of zero, conventional, and variable N application on yield and net return for each soil map unit in the field. Mean yield and net return of the zero rate were significantly less than that of conventional and variable rates. Significant differences in mean yield and net return were not detected between conventional and variable rates in Canisteo-Glencoe soils and

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

[2] D.S. Long and P.C. Robert are Scientist and Associate Professor in the Soil Science Department at the University of Minnesota, St. Paul, 55108. D. Fairchild is president of Agri-information Services, Inc., White Bear Lake, MN, 55110.

Clarion-Storden soils. However, mean yield and net return were 163 bu/ac and 192 $/ac for the variable rate versus 146 bu/ac and 174 $/ac for the conventional rate and these differences were significant.

Mean values for gross return, production costs, and net return for Clarion soils are reported in Table 4. Production costs were 104 $/ac for the variable rate, 92 $/ac for the conventional rate, and 65 $/ac for the zero rate. The higher production costs of the variable rate resulted from the higher amount of applied N. However, the higher N rate lead to increased yield and gross return which offset the associated production costs. This resulted in a net return of 192 $/ac versus 174 $/ac for the conventional rate and 158 $/ac for the zero rate.

Mean values for gross return, production costs, and net return for Clarion-Glencoe soils and Clarion-Storden soils are reported in Tables 5 and 6. In the Canisteo-Glencoe soils, production costs were 88 $/ac for the variable rate, 90 $/ac for the conventional rate, and 70 $/ac for the zero rate. The lower nitrogen costs associated with the variable treatment were balanced by higher costs for sampling, fertilizing, and mapping. This lead to the production costs for variable and conventional N rates being about equal. In the Clarion-Storden soils, the production costs were 85 $/ac for the variable rate, 83 $/ac for the conventional rate, and 57 $/ac for the zero rate. The slightly higher production costs for the variable versus conventional N rates were again due to additional costs for sampling, fertilizing, and mapping. In all soils, the lower net return and production costs for the zero N rate obviously resulted from avoiding inputs for sampling, nitrogen, fertilizing, and mapping.

Table 1. Unit costs of production for conventional, variable, and zero (check) nitrogen applications.

N Application	Grain Drying	Sampling	N	Application	Mapping
	-$/%-	-$/ac-	-$/lb-	-$/ac-	-$/ac-
Convent.	0.03	0.75	0.125	4.00	0
Variable	0.03	0.75	0.125	5.00	0.50
Zero	0.03	0	0	0	0

Table 2. Entire field: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	----------$/ac----------			
	Conventional N Rate; 95 lb/ac			
Gross Return	269.16	23.97	211.12	320.32
Drying	-71.59	8.15	59.12	86.42
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	180.94	n/a	n/a	n/a
	Variable N Rates; 135, 95, and 50 lb/ac			
Gross Return	283.62	21.72	256.62	351.26
Drying	-72.78	9.36	56.57	98.36
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-11.67	4.47	6.25	16.88
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	190.92	n/a	n/a	n/a
	Zero N Rate; 0 lb/ac			
Gross Return	227.10	21.81	182.00	254.80
Drying	-63.96	8.57	47.52	79.86
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	163.14	n/a	n/a	n/a

Table 3. Effect of zero, conventional, and variable N rates application on corn yield and net return for each soil.

N Application	Mean Yield †	Mean Net Return	N
	--bu/ac--	--$/ac--	
	Clarion Soils		
Zero	122.7 A	158.04 A	6
Conventional	146.3 B	174.43 B	6
Variable	163.2 C	192.27 C	6
	Canisteo-Glencoe Complex		
Zero	125.3 A	158.25 A	6
Conventional	143.3 B	171.22 B	6
Variable	148.5 B	182.26 B	6
	Clarion-Storden Complex		
Zero	126.3 A	173.12 A	6
Conventional	154.0 B	197.14 B	6
Variable	155.8 B	198.24 B	6

† Means with the same letter are not significantly different at the 10 percent level of probability based on method of least square means.

Table 4. Clarion Soil: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	----------$/ac----------			
	Conventional N Rate, 95 lb/ac			
Gross Return	266.33	35.83	211.12	320.32
Drying	-75.26	10.02	59.12	86.42
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	174.44	n/a	n/a	n/a
	Variable N Rate, 135 lb/ac			
Gross Return	296.96	31.93	256.62	351.26
Drying	-79.57	10.65	68.12	98.36
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-16.88	n/a	n/a	n/a
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	192.26	n/a	n/a	n/a
	Zero N Rate: 0 lb/ac			
Gross Return	223.25	29.00	183.82	252.98
Drying	-65.22	7.13	55.76	72.36
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	158.03	n/a	n/a	n/a

Table 5. Canisteo-Glencoe soils: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	----------$/ac----------			
	Conventional N Rate, 95 lb/ac			
Gross Return	260.87	18.97	242.06	283.92
Drying	-73.02	6.94	62.72	81.50
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	171.22	n/a	n/a	n/a
	Variable N Rate, 50 lb/ac			
Gross Return	270.27	9.05	262.08	283.92
Drying	-73.51	6.15	68.51	83.05
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-6.25	n/a	n/a	n/a
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	182.26	n/a	n/a	n/a
	Zero N Rate, 0 lb/ac			
Gross Return	228.11	26.86	182.00	254.80
Drying	-69.85	8.51	56.12	79.86
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	158.26	n/a	n/a	n/a

Table 6. Clarion-Storden soils: gross return, production costs, and net return for conventional, variable, and zero N rate.

Costs	Mean	S.D.	Minimum	Maximum
	----------$/ac----------			
	Conventional N Rate, 95 lb/ac			
Gross Return	280.28	8.38	265.72	289.38
Drying	-66.51	5.29	62.46	76.90
Sampling	-0.75	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-4.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	197.14	n/a	n/a	n/a
	Variable N Rate, 95 lb/ac			
Gross Return	283.62	8.65	267.54	293.02
Drying	-65.25	4.73	56.57	70.54
Sampling	-2.25	n/a	n/a	n/a
Nitrogen	-11.88	n/a	n/a	n/a
Application	-5.50	n/a	n/a	n/a
Mapping	-0.50	n/a	n/a	n/a
Net Return	198.24	n/a	n/a	n/a
	Zero N Rate, 0 lb/ac			
Gross Return	229.93	5.10	222.04	234.78
Drying	-56.81	4.61	47.52	60.04
Sampling	0.00	n/a	n/a	n/a
Nitrogen	0.00	n/a	n/a	n/a
Application	0.00	n/a	n/a	n/a
Mapping	0.00	n/a	n/a	n/a
Net Return	173.12	n/a	n/a	n/a

MAPPING SENSOR MEASURED SOIL ORGANIC MATTER[1]

D.S. Long and P.C. Robert[2]

The soil monitoring and applicator regulator (SMART) system continuously measures soil red spectral reflectance to estimate organic matter directly. This system was investigated for potential in mapping soil organic matter in a field. For purpose of comparison, soil organic matter content also was measured by means of laboratory analysis of soil samples. Kriged maps made from SMART measured organic matter and from laboratory measured organic matter were similar in appearance. This suggested the potential usefulness of the SMART system for rapid survey of soil organic matter content.

Materials and Methods

A 730 X 2100 ft (35 acre) field near Clarkston, Minnesota was sampled for soil organic matter content. The soil monitoring and application regulator system (SMART) was used to estimate organic matter content along a series of six parallel transects that were oriented with the length of the field. Each transect was separated by 120 ft. The SMART system took approximately 50 samples along each transect thus yielding a sampling interval of about 42 ft.

Uncorrected readings (n=3) from the SMART sensor were calibrated to percent organic matter using an appropriate mathematical expression. This expression was found to be an exponential function of the form

$$y=ae^{bx} \tag{1}$$

where y is percent organic matter, a equals 0.00004, e is the exponential function, b is a constant equal to 2.54, and x is the SMART reading in volts. The conventional technique involved sampling soils in the 0-m to 0.15-m depth increment at points along each of the six transects. The separation distance between samples was 100 ft. The samples were analyzed for organic matter content in a laboratory using the Walkley-Black method.

Geostatistics were used to estimate values of organic matter to the nodes of a 7 X 12 estimation grid in a procedure known as kriging. Semivariograms using in kriging were based on a contiguous subset of the field where the data expressed no major trends and hence, was stationary. Estimated values of organic matter were generated to an 11 X 23 rectangular grid system having 22 separations in the x direction and 10 separations in the y direction. The x separation distance was 76.5 ft and the y separation distance was 99 ft.

Results and Discussion

SMART estimated organic matter ranged from a low of 1.3 % to a high of 4.5 %. Corresponding laboratory estimated organic matter ranged from a low of 2.2 % to a high of 8.0 %. Summary statistics reporting the mean, minimum, maximum, standard deviation, and coefficient of variation for each variable are given in Table 1.

Table 1. Summary statistics for SMART voltage, SMART calibrated percent organic matter content (OM_c), and laboratory measured percent organic matter content (OM_l).

Variable	Mean	Min.	Max.	S.D.	C.V.	N
Voltage	4.38	4.08	4.58	.108	2.47	271
OM_c	2.78	1.27	4.49	.728	2.62	271
OM_l	4.38	2.20	8.00	1.59	36.3	117

[1] Support for this project was provided by a grant from USDA-CSRS, and Tyler Inc., Benson, MN, 56215.

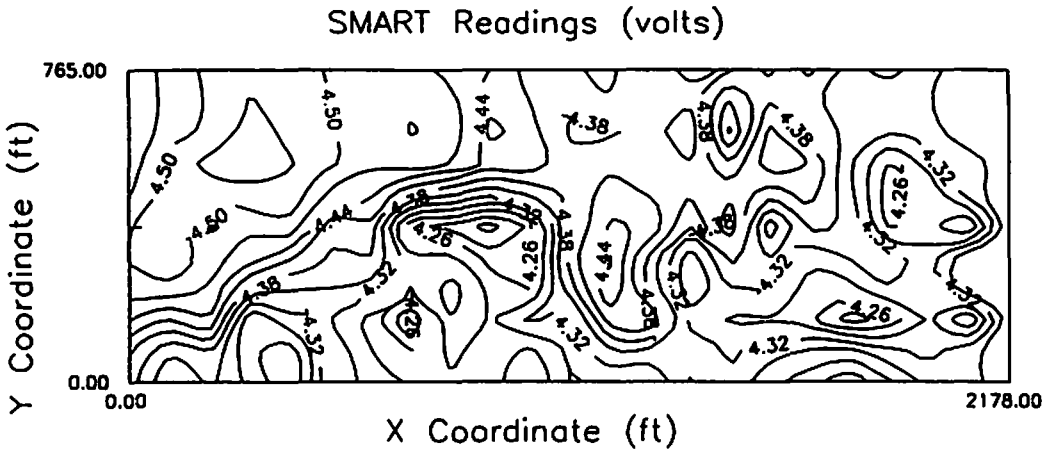
[2] D.S. Long and P.C. Robert are Scientist and Associate Professor in the Soil Science Department at the University of Minnesota, St. Paul, MN, 55108.

As indicated in Table 1, the minimum and maximum values of SMART and laboratory derived organic matter differed in magnitude. The lack of a sufficient number of observations to develop the calibration curve was a reason for this inconsistency. To properly develop this calibration, users of the SMART system should include a larger sample number from a diversity of soil conditions in a field.

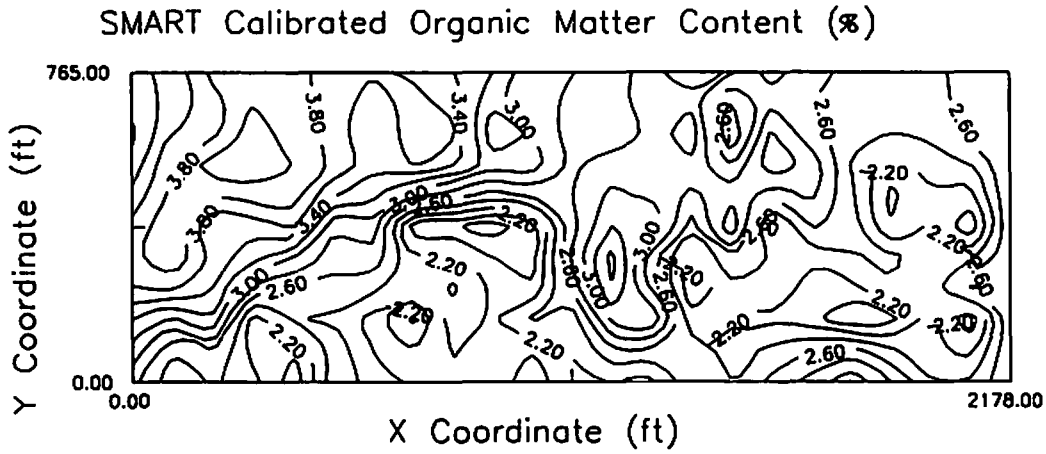
Maps of kriged organic matter content are illustrated in Figures 1, 2, and 3. In general, the maps formed from SMART and laboratory measurements were similar in appearance. High and low areas of organic matter content were consistent from map to map. Areas of low and high organic matter were detected by both techniques and correspond with well drained soils in sloping terrain and poorly drained soils in depressions, respectively. This correlation suggests that the SMART system is a potentially useful technique for rapid survey of soil organic matter content in fields.

The correlation between SMART and laboratory measured organic matter content was 0.35. This weak correlation may be attributed to pairs of SMART and laboratory measurements that were not sampled from joint field locations. Instead only data were available that were located within approximately 10 ft of one another. Furthermore, the accuracy of the SMART sample locations is unknown and hence, sampling error may exist in measured observations of this variable. These problems suggest that this correlation should be interpreted with caution and that a future correlation should be based on jointly located pairs of samples.

(a)



(b)



(c)

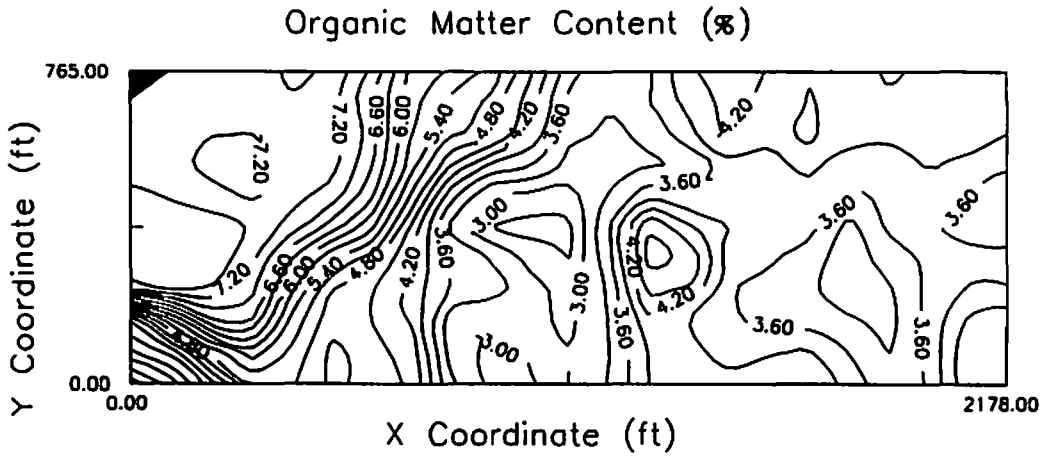


Figure 1. Maps of (a) kriged SMART voltage, (b) kriged SMART calibrated organic matter, and (c) kriged laboratory measured organic matter.

PERFORMANCE OF A VARIABLE TILLAGE IMPLEMENT[1]

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

A study to determine the performance of a variable tillage implement (VTI) was initiated in corn and soybean residues in 1992. By controlling blade depth and angle, the implement was designed to vary the amount of crop residue incorporated in soil. For purpose of comparison, this study included the following conventional tillage systems: no-till, field cultivation, and moldboard. Soybean residue cover left after tillage was about 6 percent despite different blade angle and depth settings of the variable rate implement. Field cultivation left 17 percent residue cover versus the variable rate implement at zero blade settings which left 9 percent. Corn residue cover left after tillage ranged from 46 percent at zero blade settings to 22 percent at maximum blade settings of 30 degree angle and 10 inch depth. These results suggest that better performance is obtained when the implement is used in corn residue versus soybean residue.

Materials and Methods

A variable tillage implement (VTI), a prototype built by DMI Inc., was tested in corn and soybean residues at the Southwest Experiment Station, Lamberton, MN in 1992. The residues were from crops that were harvested in fall 1991. Each residue type constituted a separate randomized complete block experiment. Testing will continue in 1993.

The experiment for soybean residue included the following tillage treatments: four different rates of the VTI unit, field cultivation, and no-till (Table 1). These treatments in turn subdivided three replicated mainplots of poorly drained Webster soils (Typic Haplaquolls) and well drained Ves soils (Udic Haplustolls). The tillage treatments were applied in early spring.

The experiment for corn residue included subunits of chopped and unchopped residue treatments that were stripped across three replicated mainplots of poorly drained Webster soils and well drained Ves soils. The residue was chopped in fall 1991. Each subunit was divided into the following tillage treatments: five different VTI rates, moldboard plow, and no-till (Table 1). Tillage treatments were applied in early spring.

Ultra-large scale (1:13) vertical photographs were taken to record the residue cover in each plot before and after tillage. A 35 mm camera was mounted to a frame such that 1 m^2 of the ground surface was photographed from overhead. Each plot was subsampled four times in separate places. The film type used was KODAK Kodachrome Gold.

The percentage of cover was determined from the photographs using image processing techniques. The photographs were electronically scanned at a resolution of 100 pixels per square inch. Then an image processing system was used to analyze the tonal contrast between soil and residue features. Dark toned soil features were separated from light toned residue features in a procedure termed density slicing. Some photographs were carefully retouched to enhance poor contrast in areas of dry, light colored soils. A binary image resulted that consisted of black residue features (pixel value = 0) and white soil features (pixel value = 255). The steps in computing the percentage of residue cover for each image were twofold: (1) computing a mean pixel value by summing the pixel values and dividing by the total number of pixels, and (2) dividing the mean pixel value by 255 followed by subtraction from unity and multiplication by 100. Percent residue cover left after tillage was calculated by dividing the difference between residue cover before and after tillage by the residue cover before tillage then multiplying this ratio by 100. The resulting data were then statistically analyzed with the analysis of variance (ANOVA).

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

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

Results and Discussion

Soybean Residue Cover. The residue cover before tillage in early spring was about 44 ± 18 percent in all plots. Table 2 presents the summary statistics for percent soybean residue cover left after tillage. In general, the results show that soybean residue cover was maximum for no-till, followed by field cultivation and the VTI method. To satisfy the equal variances assumption in ANOVA, the no-till treatment was dropped from the analysis and the log-transform function was applied [Y = log(X)]. This transform also produced normality for the data of each tillage treatment according to the Shapiro-Wilk test statistic at the 5 percent level of probability.

Table 3 presents the ANOVA for percent soybean residue left after tillage. The F statistic is significant for tillage treatments and hence, the null hypothesis of equal treatment means was rejected. Though the F value is significant for soil the effect of this treatment was difficult to interpret because the experiment was limited to only one field. Meanwhile, the soil-by-tillage interaction was insignificant.

Table 4 shows the effect of tillage treatments on percent soybean residue cover as measured across all soils. Residue cover was highest at 17 percent for field cultivation and this was significantly greater than that for all VTI treatments. Residue cover was second highest at 9 percent for the VTI treatment having zero blade settings and this was significantly greater than all other VTI treatments. There were no significant differences among the VTI treatments with respect to a blade angles greater than 15 degrees and blade depth greater than 2 inches. These results indicate that changing blade angle and depth beyond zero has little effect on incorporated levels of soybean residue.

Corn Residue Cover. The residue cover before tillage in early spring was about 67 ± 15 percent in all plots. Table 5 presents the summary statistics for percent corn residue cover left after tillage. In general, the results show that corn residue cover was maximum for no-till, followed by the VTI method and moldboard. To satisfy the equal variances assumption in ANOVA, the no-till treatment was dropped from the analysis and the log-transform function was applied [Y = log(X)]. This transform also produced normality for the data of each tillage treatment according to the Wilk-Shapiro test statistic at the 5 percent level of probability.

Table 6 presents the ANOVA for percent corn residue left after tillage. The F statistic was significant for tillage treatments and hence, the null hypothesis of equal treatment means was rejected. The soil-by-tillage interaction was significant, however, this interaction became insignificant when the moldboard treatment was excluded from the ANOVA.

Table 7 shows the effect of the tillage treatments on percent corn residue cover as measured across all soils. All VTI treatments incorporated significantly less residue than the moldboard method. The results show that residue cover left after tillage with the VTI implement decreases with increasing blade angle and blade depth. Residue cover was highest at 46 percent for the VTI method with zero blade settings and decreased to 22 percent with blade angle of 30 degrees and blade depth of 4 inches. There may have been little practical difference between moldboard and maximum VTI blade settings (16.5 versus 21.8 percent). The results indicate that changing the blade angle and depth with the VTI implement does effect levels of incorporated corn residue.

Table 1. Tillage treatments in soybean and corn residues.

Soybean Residue	Corn Residue
1 No-till	1 No-till
2 Field Cultivation	2 Moldboard
3 VTI 0 deg. 0 in.	3 VTI 0 deg. 0 in.
4 VTI 15 deg. 5 in.	4 VTI 15 deg. 5 in.
5 VTI 15 deg. 10 in.	5 VTI 15 deg. 10 in.
6 VTI 30 deg. 5 in.	6 VTI 30 deg. 5 in.
	7 VTI 30 deg. 10 in.

Table 2. Descriptive statistics for percent soybean residue cover left after tillage relative to measurements from all soils.

Treatment	Mean	Variance	Max.	Min.	N
	----------%----------				
Fld. Cult.	17.4	88.4	40.1	6.7	40
No-till	72.0	4658.0	450.9	22.5	40
VTI 0 0	8.9	17.8	18.4	1.1	40
VTI 15 5	6.6	10.1	15.3	1.1	40
VTI 15 10	5.1	5.4	11.3	1.3	40
VTI 30 5	5.6	10.7	14.7	0.7	40

Table 3. Analysis of variance for percent soybean residue cover.

Source of Variation	Sum of Squares	F Statistic	P Value
Soil	3.005	12.94	.0004
Replications	1.661	.415	.1331
Tillage	21.18	22.8	.0001
Samples	7.619	10.93	.0001
Soil*Tillage	1.937	2.08	.0846

Table 4. Effect of tillage treatments on percent soybean residue cover.

Treatment	Residue Left After Tillage †	Standard Deviation	N
	----------%----------		
Fld. Cult.	17.4 A	9.4	40
VTI 0 0	8.9 B	4.2	40
VTI 15 5	6.6 C	3.2	40
VTI 15 10	5.1 C	2.3	40
VTI 30 5	5.6 C	3.3	40

† Means with the same letter are not significantly different at the 5 percent level of probability.

Table 5. Descriptive statistics for corn residue cover left after tillage expressed in percent relative to measurements from all soils and residue treatments.

Treatment	Mean	S.D.	Min.	Max.	N
	----------%	----------			
No Till	102.3	22.9	49.2	160.2	36
Moldboard	16.5	11.4	4.0	46.7	36
VTI 0 0	45.5	25.8	14.4	145.6	36
VTI 15 5	32.7	18.6	10.5	98.2	36
VTI 15 10	40.1	23.6	14.2	137.8	36
VTI 30 5	28.8	15.4	10.0	71.7	36
VTI 30 10	21.8	11.1	5.7	59.5	36

Table 6. Analysis of variance for percent corn residue cover left after tillage.

Source of Variation	df	Sum of Squares	F Statistic	P Value
Soil	1	0.649	2.72	0.10
Replications	2	2.93	1.46	0.0026
Residue	1	0.235	0.99	0.32
Tillage	5	30.42	25.5	0.0001
Soil*Residue	1	0.740	3.10	0.080
Soil*Tillage	5	5.52	4.63	0.0005
Samples	2	0.882	1.85	0.16

Table 7. Effect of tillage treatments on percent corn residue cover.

Treatment	Residue Left After Tillage †	Standard Deviation	N
	----------%	----------	
VTI 0 0	45.5 A	25.8	36
VTI 15 10	40.1 AB	23.6	36
VTI 15 5	32.7 BC	18.6	36
VTI 30 5	28.8 CD	15.4	36
VTI 30 10	21.8 D	11.1	36
Moldboard	16.5 E	11.4	36

† Means with the same letter are not significantly different at the 5 percent level of probability.

LAND SPREADING OF YARD WASTE

Carl Rosen, Thomas Halbach, Jean Molina, Dave Birong, Jennifer Weiszel

ABSTRACT: A field experiment at the Sand Plain Research Farm in Becker, Minn. was conducted to determine the effects of applying yard waste applications (primarily tree leaves) on corn production and soil nitrate movement. The yard waste was applied in the fall of 1991. Treatments included four rates of yard waste (0, 20, 40, and 80 T/A) with either 0 fertilizer N applied, 200 lbs N/A during the 1992 growing season, or 66 lbs N/A applied with the yard waste plus 200 lbs N/A applied during the growing season. Yard waste application initially inhibited growth and depressed tissue nitrogen composition of developing corn plants. The inhibitory effect diminished when fertilizer N was applied. These results suggest that soil N was immobilized for 5-6 weeks after planting. By harvest, corn grain yield increased with increasing yard waste application when no fertilizer N was applied, presumably due to release of nitrogen and possibly other nutrients from the yard waste. When N was added during the growing season, with or without fall applied N, the effect of yard waste on grain yield was generally not significant. Maturity, as measured by % moisture in the grain, was delayed with yard waste application. Yard waste application tended to decrease nitrate leaching during the first year after application. Highest nitrate-N concentrations in soil water at the three foot depth were recorded when N was applied in the fall with or without yard waste. During the first year after yard waste application, acceptable yields were obtained at all rates of applied yard waste combined with 200 lb N/A without significant nitrate losses.

Until recently, yard wastes (tree leaves and grass clippings) accounted for 15-20% of the bulk in landfills. In 1990 (metro counties) and in 1992 (greater Minnesota), regulations were passed that prohibited yard wastes from being put in landfills. Because of this legislation, alternatives to landfilling yard waste need immediate attention. Some options for using or recycling the yard waste include: 1) backyard composting and application of the compost to gardens; 2) municipal composting followed by land application of the compost; and 3) direct land application of noncomposted yard waste. While backyard composting is a desirable way to handle yard waste, not all homeowners desire to compost their own yard waste. Several problems with municipal yard waste composting include finding an acceptable site, controlling nutrient runoff, and controlling odors. Direct land application of noncomposted yard waste may be more efficient than composting and does not have the same problems associated with composting. Land application of yard waste may require an adjustment of nitrogen requirements, because of its generally low available nitrogen content. In addition, the effects on nitrogen use and crop production in general need to be ascertained. Therefore, the objectives of this study were to: 1) Determine the effects of direct application and incorporation of noncomposted yard waste (primarily tree leaves), with and without fertilizer nitrogen, on productivity of irrigated field corn, and 2) Characterize nitrogen release from the leaves during the growing in terms of availability for crop needs and movement through the soil profile.

PROCEDURES

The experiment was conducted at the Sand Plain Research Farm in Becker, MN on a Hubbard loamy sand soil. Initial soil chemical characteristics include (0-6"): organic matter, 1.7%; pH (1:1 soil:water), 6.8; Bray P, 26 ppm; K (NH_4OAc), 61 ppm. Extractable (KCl) nitrate-N and ammonium-N in the top 3 feet were 30 lbs/A and 4 lbs/A, respectively. The previous crop was rye. Yard waste was collected in October 1991 and applied to 15' x 35' plots with a front end loader on October 31, 1991. The yard waste primarily consisted of tree leaves, although some garden plants and grass clippings were also present. Subsamples of yard waste applied to each plot were collected for chemical analysis. The following 12 treatments were tested: 0, 20, 40, 80 dry tons/A yard waste (no added N); these same treatments with 200 lb N/A applied during 1992; these same treatments with 66 lb N/A applied in the fall of 1991 plus 200 lb N/A applied during 1992. The fertilizer N source used in all cases was urea. An average of 30% moisture was assumed for application of all yard waste treatments. The experimental design was a randomized complete block with 4 replications. The leaves were incorporated with a rototiller after application (fall 1991) and the whole field was moldboard plowed one week prior to planting in 1992. In addition, 235 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated prior to planting. Pioneer hybrid 3751 (100 day maturity) was planted on April 28, 1992 at a population of 30,700 seeds/A (2.5 ft. between rows). At planting, 185 lbs/A 0-14-42 was banded 2 inches to

[1]Funding for this project was provided by the Legislative Commission for Minnesota Resources
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the side and two inches below the seed. On May 27, 100 lbs N/A was sidedressed with a hand pushed Gandy fertilizer applicator and cultivated in. Additional N at a rate of 50 lbs/A per application was applied with the Gandy applicator on June 17 and June 22 and irrigated in with 0.5 inch of water. Irrigation was used to supplement rainfall (Figure 1).

Soil samples at the 0-8 inch depth were collected from each plot before planting. After harvest, soil samples were collected from 0-6, 6-12, 12-24 and 24-36 inch depths. Soil nitrate and ammonium were determined on 2 N KCl extracts.

Suction tubes with ceramic cups were installed at a depth of 3 feet in two replications of each treatment. Suction tubes at the 6 foot depth were installed in two reps for the control and 40 T/A yard waste plus 266 lbs of N treatments. Water samples were collected every two weeks through the growing season and analyzed for nitrate. On one set of water samples (September 11), a more extensive elemental analysis was performed using an ICP spectrophotometer.

Whole plant samples (4 per plot) were collected at the three leaf stage (May 26) before fertilizer N was applied in 1992. Whole plant samples (4 per plot) at the 8-12 leaf stage were collected on June 26 after all fertilizer N was applied. Ear leaf samples at 50% silking were collected on July 28. Two, 20 foot rows were harvested for grain and stover yield from each plot on October 10. Subsamples of stover and grain plus cob were taken for moisture determinations, shelling percentages, and nitrogen analyses. Plant tissue samples were dried and then ground through a 30 mesh screen. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

RESULTS

Yard Waste Elemental Composition: The yard waste had an acid pH (Table 1). The average moisture content was 30% with a range of 18.6 - 48.1%. The outer part of the pile tended to be drier than the inner part. The C/N ratio averaged 37.8%, which is on the low side for leaves, but is in a range that should initially immobilize N. The yard waste contained 21.2 lbs N/dry ton, 3.2 lbs P/dry ton (7.4 lbs P_2O_5), and 14.4 lbs K/dry ton (17.3 lbs K_2O). The yard waste contained significant quantities of Ca, Mg and S. Trace elements were also present in the yard waste, but were not at levels considered to be detrimental to the environment.

Corn Growth and Yield: Initial growth of corn was significantly inhibited as leaf application rate increased (Table 2). Application of N tended to minimize the negative effect of yard waste application on initial corn growth. Greatest growth at the 8-12 leaf stage occurred when N was applied in the Fall and during the growing season. Yard waste application rate up to 40 T/A tended to increase final stand count. At the 80 T/A rate, stand count declined. Stand count also increased with increasing fertilizer N rate. At harvest, increasing yard waste rates increased grain yield when no N was applied, indicating a significant release of N from the yard waste. However, when N was added during the growing season with or without fall applied N, the effect of yard waste on grain yield was generally not significant. There was a slight decrease in grain yield at the highest yard waste rate and when fall N plus 200 lb N/A was applied. Stover yield increased with increasing yard waste application and fertilizer N rate. Yard waste and low fertilizer N tended to delay maturity as measured by higher kernel moisture percentage.

Tissue Nitrogen Concentrations: Nitrogen concentrations in whole plants sampled at the 3 leaf stage decreased as yard waste application increased (Table 3). These results indicate that early in the season N was immobilized by the yard waste. Fall applied N significantly increased N concentrations in the plant. By the 8-12 leaf stage, yard waste application was beginning to have a positive effect on N concentrations in the plant, while the effect of fall application of N began to diminish. Ear leaf N increased with increasing yard waste application when no fertilizer N was applied, but was not affected by yard waste when fertilizer N was applied. Application of fertilizer N increased N concentrations in the ear leaf. Cob N concentrations were not affected by yard waste application and were not consistently affected by fertilizer N application. Stover N concentrations tended to increase with increasing yard waste application, primarily when no fertilizer N was applied. Application of fertilizer N also increased N concentrations in the stover. Kernel N increased with increasing application of yard waste and increasing fertilizer N application. As with other tissues, the effect of yard waste was most pronounced when fertilizer N was not applied.

Soil Nitrogen Content: Soil nitrogen increased with increasing yard waste application in the top 6 inches, but was not significantly affected by yard waste at the lower depths (Table 4). Soil nitrogen increased with increasing fertilizer N application, with the fall applied N treatment having the highest residual N in the top 3 feet. It is interesting to note, however, that the initial soil nitrate-N content of 30 lbs/A was higher than the soil nitrate-N content following any of the fertilizer N and/or yard waste treatments.

Soil Water Elemental Concentrations: Elemental concentrations in soil water sampled on September 11 are presented in Table 5. Al, B, Cd, Cr, Cu, Fe, Mo, Ni, and Pb were generally below detection limits of the ICP. Ca, K, Na, and S tended to increase with increasing yard waste application. P concentrations tended to increase with increasing yard waste when no fertilizer N was applied, but was not consistently affected when fertilizer N was applied. Except for soil water nitrate (see below), other elements determined in soil water were not affected by yard waste application or fertilizer N.

Soil Water Nitrate Concentrations: Concentrations of nitrate-N in soil water as affected by treatments are presented in Figures 2-13. Yard waste applications tended to decrease nitrate concentrations in soil water at the three foot depth when fertilizer N was not applied. The control treatment had the highest water nitrate-N concentrations with levels slightly above 10 ppm. When yard waste was applied nitrate-N concentrations were less than 10 ppm. Nitrate-N concentrations at the three foot depth, when fertilizer N was applied during the season, tended to be highest when 80 T/A yard waste was applied at mid-season. However, by the end of the season, the 0 yard waste treatment with fertilizer N had the highest nitrate concentrations. Nitrate-N concentrations in soil water were greatest when fertilizer N was applied in the fall. Highest concentrations at mid-season were recorded when 0 T/A leaves were applied. Yard waste application tended to decrease nitrate-N concentrations; however, compared to the other N treatments, fall applied N resulted in the highest losses at the end of the growing season. From these measurements, yard waste amendments appear to reduce nitrate-N losses during the first growing season after application.

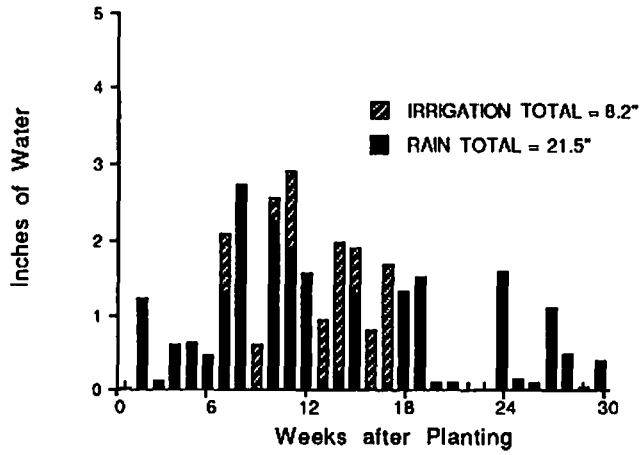

Figure 1. Rainfall and irrigation provided over the 1992 growing season.

Table 1. Elemental concentrations of original yard waste samples.

	Mean	Standard Deviation	Minimum	Maximum	lbs element/ dry ton
pH	4.9	0.2	4.4	5.5	
% moisture	29.7	7.7	18.6	48.6	
C to N ratio	37.9	3.2	29.6	42.6	
Macroelements (%)					
Carbon	39.76	3.49	33.56	45.95	795.2
Nitrogen	1.06	0.12	0.81	1.46	21.2
Phosphorus	0.16	0.02	0.12	0.20	3.2
Potassium	0.72	0.14	0.47	1.16	14.4
Calcium	2.33	0.25	1.75	2.75	46.6
Magnesium	0.37	0.04	0.27	0.49	7.4
Sulfur	0.19	0.02	0.15	0.22	3.8
Microelements (ppm)					
Aluminum	1052	464	254	1960	2.1
Boron	65	9	48	97	0.13
Cadmium	<0.52	0.35	<0.16	1.30	<0.10
Chromium	7.5	3.5	1.6	14.4	0.015
Copper	8.4	1.2	5.6	10.7	0.016
Iron	969	334	359	1755	1.9
Lead	<15.5	7.7	<2.2	39.6	<0.031
Manganese	249	40	177	399	0.50
Nickel	<6.5	3.3	<0.9	13.4	0.013
Sodium	105	23	60	163	0.21
Zinc	61	9	40	85	0.12

Table 2. Effect of leaf and nitrogen application on whole plant dry matter at the 8-12 leaf stage, final stand count, grain and stover yield, and kernel moisture.

Leaf rate	Nitrogen application	Whole plant dry matter (8-12 leaf)	Final stand count	Grain yield	Dry stover	Kernel moisture
-tons/A-	--lbs/A--	-grams/plant-	-plants/A-	-bu/A-	-tons/A-	- % -
0	0	16.0	26463	76	1.25	36
20	0	5.5	26789	99	1.37	39
40	0	8.8	28532	124	1.68	38
80	0	6.0	26681	130	1.86	36
0	200	21.8	27770	188	2.48	29
20	200	12.5	27334	185	3.06	34
40	200	9.3	27770	188	3.05	35
80	200	10.5	27770	182	3.17	35
0	66+200	29.3	27660	195	2.91	31
20	66+200	25.5	28859	203	3.01	30
40	66+200	15.0	28859	195	3.15	35
80	66+200	13.0	27661	176	2.95	34
Significance		**	NS	**	**	**
BLSD (5%)		9.3	--	20	0.50	3
Main effects						
	Leaf Rate					
	0	22.3	27298	153	2.22	32
	20	14.5	27661	162	2.48	34
	40	11.0	28387	169	2.63	36
	80	9.8	27370	162	2.66	35
	Significance	**	NS	NS	*	**
	BLSD (5%)	5.3	--	--	0.34	2
	Linear	**	NS	NS	**	**
	Quadratic	*	*	*	NS	**
	Nitrogen Application					
	0	9.0	27116	107	1.54	37
	200	13.5	27661	186	2.94	33
	66+200	20.8	28260	192	3.01	32
	Significance	**	*	**	**	**
	BLSD (5%)	4.3	892	10	0.24	2
Interaction						
	Leaf x Nitrogen	NS	NS	**	NS	*

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

Table 3. Effect of leaf and nitrogen application on percent nitrogen present at various growth stages and in various plant tissues.

Leaf rate	Nitrogen application	Whole plant 3 leaf stage	Whole plant 8-12 leaf stage	Ear leaf silking stage	Cob	Stover	Kernel
-tons/A-	--lbs/A--	% Nitrogen					
0	0	4.19	1.74	1.34	0.31	0.38	0.92
20	0	3.19	2.49	1.97	0.29	0.42	1.01
40	0	3.03	2.57	2.05	0.28	0.47	1.12
80	0	2.80	3.00	2.31	0.27	0.52	1.24
0	200	4.21	3.14	2.89	0.25	0.53	1.26
20	200	3.20	3.80	2.94	0.26	0.58	1.29
40	200	3.16	3.96	2.68	0.24	0.61	1.35
80	200	3.19	3.71	3.04	0.26	0.60	1.37
0	66+200	4.32	3.08	3.00	0.26	0.57	1.35
20	66+200	4.39	3.30	2.51	0.26	0.65	1.38
40	66+200	4.10	3.57	2.95	0.26	0.63	1.41
80	66+200	3.60	3.66	2.94	0.27	0.55	1.41
Significance		**	**	**	**	**	**
BLSD (5%)		0.72	0.40	0.76	0.03	0.12	0.09
Main effects							
Leaf Rate							
0		4.24	2.66	2.35	0.27	0.49	1.18
20		3.59	3.20	2.47	0.27	0.55	1.23
40		3.43	3.36	2.56	0.26	0.57	1.29
80		3.20	3.46	2.76	0.26	0.56	1.34
Significance		**	**	NS	NS	NS	**
BLSD (5%)		0.39	0.23	--	--	--	0.05
Linear		**	**	NS	NS	NS	**
Quadratic		*	**	NS	NS	NS	NS
Nitrogen Application							
0		3.30	2.45	1.92	0.29	0.45	1.07
200		3.44	3.65	2.89	0.25	0.58	1.32
66+200		4.10	3.40	2.84	0.26	0.60	1.39
Significance		**	**	**	**	**	**
BLSD (5%)		0.34	0.19	0.33	0.01	0.05	0.04
Interaction							
Leaf x Nitrogen		NS	NS	NS	NS	NS	*

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

Table 4. Effect of leaf and nitrogen application on soil nitrate-N (lbs/A) in the top three feet at the end of the growing season.

Leaf rate	Nitrogen application	sample depth (inches) 0 - 6	6 - 12	12 - 24	24 - 36	Total
-tons/A-	--lbs/A--	lbs nitrate-N/A				
0	0	0.78	0.74	0.75	0.72	2.98
20	0	1.24	0.99	0.94	0.64	3.81
40	0	1.90	1.54	1.47	0.67	5.58
80	0	2.96	2.53	1.36	1.12	7.97
0	200	2.35	2.34	1.67	0.74	7.09
20	200	4.22	3.78	2.24	1.22	11.46
40	200	5.30	4.10	2.63	1.25	13.28
80	200	6.34	3.76	2.10	0.79	12.99
0	66+200	2.73	3.29	1.54	1.18	8.74
20	66+200	7.98	9.50	6.82	3.14	27.44
40	66+200	7.96	6.69	2.93	1.42	18.99
80	66+200	9.20	5.10	3.31	2.19	19.80
Significance		**	**	**	**	**
BLSD (5%)		3.41	4.62	2.96	1.24	10.80
Main effects						
Leaf Rate						
0		1.95	2.12	1.32	0.88	6.27
20		4.48	4.76	3.33	1.67	14.23
40		5.05	4.11	2.34	1.11	12.61
80		6.17	3.80	2.26	1.37	13.59
Significance		**	NS	NS	NS	*
BLSD (5%)		1.94	--	--	--	6.57
Linear		**	NS	NS	NS	NS
Quadratic		NS	NS	NS	NS	NS
Nitrogen Application						
0		1.72	1.45	1.13	0.79	5.08
200		4.55	3.49	2.16	1.00	11.20
66+200		6.97	6.14	3.65	1.98	18.74
Significance		**	**	**	**	**
BLSD (5%)		1.57	1.93	1.28	0.54	4.78
Interaction						
Leaf x Nitrogen		NS	NS	NS	NS	NS

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

Table 5. Effect of leaf and nitrogen application on elemental composition of soil water collected at 3' from suction tubes - Sept. 11, 1992.

Leaf rate	Nitrogen application	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn
-tons/A-	--lbs/A--	ppm																
0	0	<0.18	<0.02	44	<0.006	<0.01	<0.03	<0.02	1.6	6	0.015	<0.01	6	<0.022	0.08	<0.09	33	0.11
20	0	<0.18	<0.03	55	<0.006	<0.01	0.06	<0.02	1.7	10	0.037	<0.01	38	0.028	0.08	<0.09	73	0.35
40	0	<0.18	0.17	111	<0.006	<0.01	<0.03	<0.02	1.6	13	0.052	<0.01	12	0.028	0.10	<0.09	97	0.15
80	0	<0.18	0.07	123	<0.006	<0.01	<0.03	0.03	3.8	14	0.017	<0.01	47	<0.024	0.21	<0.09	117	0.09
0	200	<0.18	<0.02	66	<0.006	<0.01	<0.03	<0.02	1.9	12	0.029	<0.01	12	<0.026	0.17	<0.09	58	0.17
20	200	<0.18	0.28	62	<0.006	<0.01	<0.03	<0.02	0.9	5	0.035	<0.01	17	<0.027	0.10	<0.09	45	0.20
40	200	<0.18	<0.02	81	<0.006	<0.01	<0.04	<0.02	1.6	8	0.027	<0.01	22	<0.023	0.08	<0.09	55	0.10
80	200	<0.18	<0.27	94	<0.006	<0.01	<0.05	<0.02	1.7	16	0.035	<0.01	27	<0.029	0.12	<0.09	83	0.13
0	66+200	<0.18	<0.15	89	<0.006	<0.01	<0.03	<0.02	2.7	10	0.036	<0.01	18	<0.029	0.07	<0.09	73	0.26
20	66+200	<0.18	<0.03	78	<0.006	<0.01	<0.03	<0.02	4.0	12	0.038	<0.01	24	<0.026	0.08	<0.09	67	0.19
40	66+200	<0.18	<0.04	67	<0.006	<0.01	<0.03	0.03	3.5	14	0.036	<0.01	22	<0.030	0.11	<0.09	65	0.19
80	66+200	<0.18	0.04	106	<0.006	<0.01	<0.03	0.04	8.3	20	0.096	<0.01	19	0.035	0.10	<0.09	86	0.25
Significance		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	0.08	--	--	--
Main effects																		
Leaf Rate																		
0		<0.18	<0.06	66	<0.006	<0.01	<0.03	<0.02	2.1	9	0.027	<0.01	12	<0.025	0.11	<0.09	55	0.18
20		<0.18	<0.13	67	<0.006	<0.01	<0.03	<0.02	2.3	9	0.036	<0.01	24	<0.027	0.09	<0.09	60	0.23
40		<0.18	<0.08	86	<0.006	<0.01	<0.03	<0.02	2.2	12	0.038	<0.01	19	<0.027	0.10	<0.09	72	0.15
80		<0.18	<0.13	108	<0.006	<0.01	<0.04	<0.03	4.6	16	0.049	<0.01	31	<0.029	0.14	<0.09	96	0.16
Significance		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	*	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	0.04	--	28	--
Linear		--	--	*	--	--	--	--	NS	*	NS	--	*	--	*	--	**	NS
Quadratic		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	NS	NS
Nitrogen Application																		
0		<0.18	<0.08	87	<0.006	<0.01	<0.03	<0.02	2.2	11	0.029	<0.01	24	<0.025	0.12	<0.09	81	0.15
200		<0.18	<0.15	76	<0.006	<0.01	<0.03	<0.02	1.5	10	0.031	<0.01	20	<0.026	0.12	<0.09	60	0.15
66+200		<0.18	<0.06	85	<0.006	<0.01	<0.03	<0.02	4.7	14	0.051	<0.01	21	<0.030	0.09	<0.09	73	0.22
Significance		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	NS	--	NS	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Interaction																		
Leaf x Nitrogen		--	--	NS	--	--	--	--	NS	NS	NS	--	NS	--	*	--	NS	NS

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

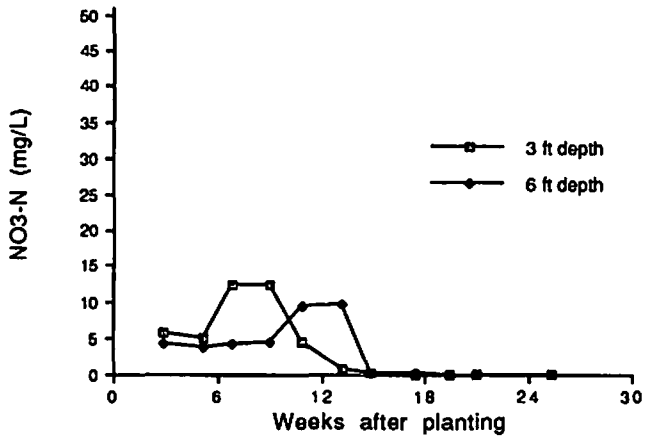

Figure 2. Nitrate-N concentration in soil water at 3 and 6 ft. depths over the 1992 growing season. Treatment 1: no leaves, no nitrogen applied.

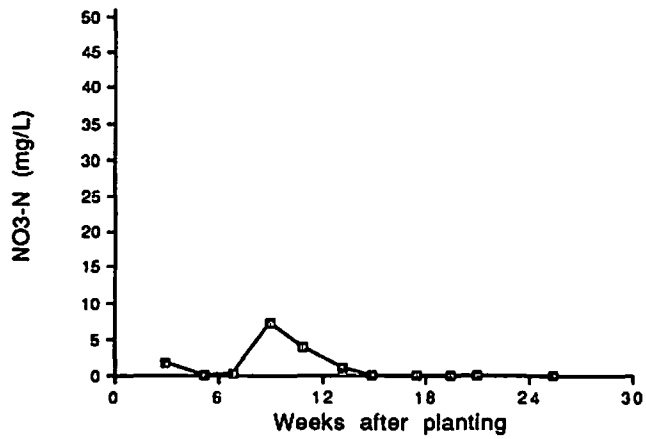

Figure 3. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 2: 20 tons/A leaves, no nitrogen applied.

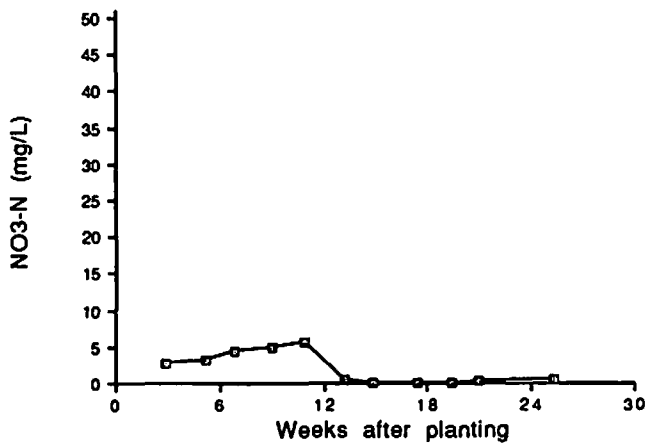

Figure 4. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 3: 40 tons/A leaves, no nitrogen applied.

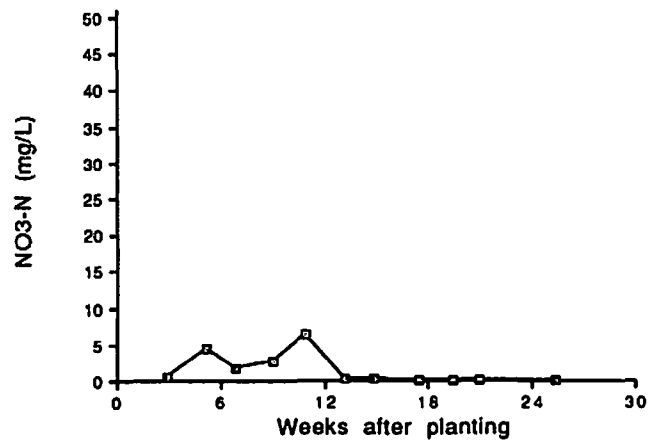

Figure 5. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 4: 80 tons/A leaves, no nitrogen applied.

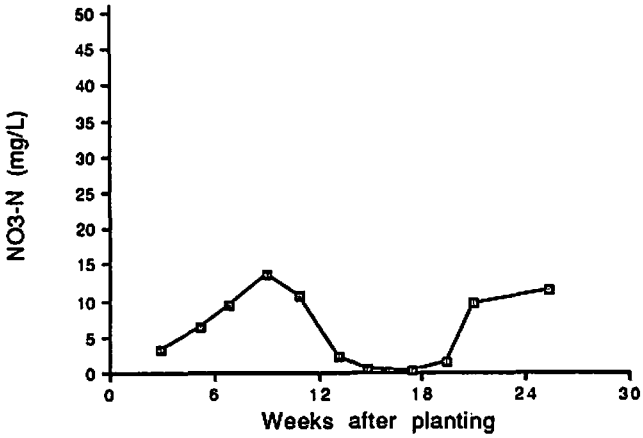

Figure 6. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 5: no leaves, 200 lbs/A nitrogen applied applied during the growing season.

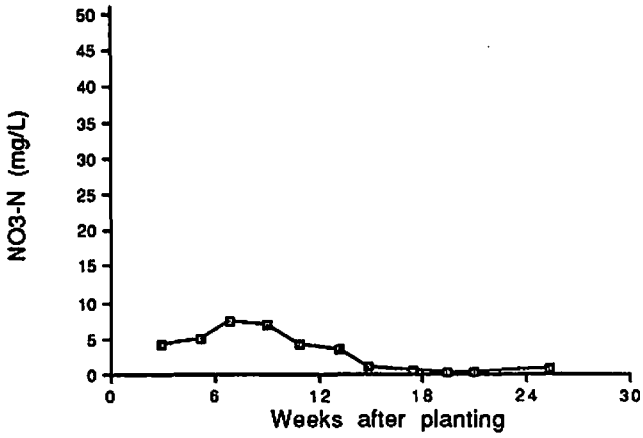

Figure 7. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 6: 20 tons/A leaves, 200 lbs/A nitrogen applied during the growing season.

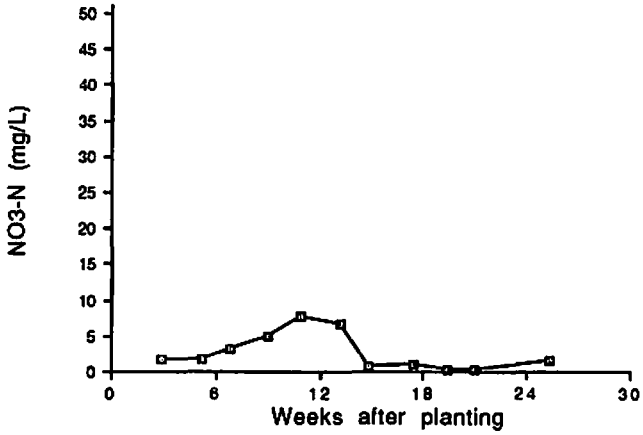

Figure 8. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 7: 40 tons/A leaves, 200 lbs/A nitrogen applied during the growing season.

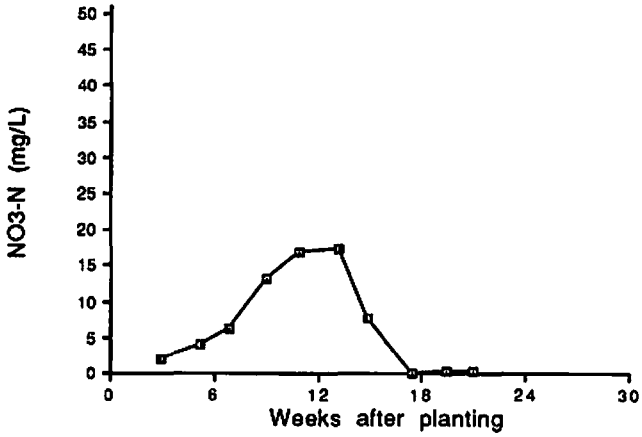

Figure 9. Nitrate-N concentration in soil water at the three ft. depth over the 1992 growing season. Treatment 8: 80 tons/A leaves, 200 lbs/A nitrogen applied during the growing season.