Table 3. Effect of rate of P_2O_5 on corn yield, P uptake, and soil test P at the end of the growing season at the Moritz site.

	P_2O_5 Applied (lb./acre)						
Measurement	0	20	40	60	80	100	300
Grain Yield, bu./acre	157.3	159.7	159.3	164.4	161.7	164.6	154.5
D.M. Yield, ton/acre	7.4	7.5	7.4	7.3	7.4	7.7	7.5
% P, Mature Plants	.208	.212	.233	.258	.240	.207	2.41
Total P Uptake, lb./acre	30.8	32.1	34.2	30.6	35.5	31.6	36.3
% P, Ear Leaf	.266	.273	.261	.258	.266	.255	.278
Bray P, ppm	16.5	19.1	22.0	19.1	22.3	31.6	41.3
Olsen P, ppm	10.4	13.9	15.3	12.5	14.5	24.8	36.0

Table 4. Effect of rate of P_2O_5 on corn yield, P uptake and soil test P at the end of the growing season at the Hillman site.

	P_2O_5 Applied (lb./acre)						
Measurement	0	20	40	60	80	100	300
Grain Yield, bu./acre	105.5	124.2	123.4	133.2	140.4	152.5	149.1
D.M. Yield, ton/acre	4.6	5.2	4.9	5.5	5.6	5.8	5.4
% p, Mature Plants	.100	.125	.126	.162	.175	.134	.164
Total P Uptake, lb./acre	9.4	13.4	12.6	17.9	20.6	15.5	17.9
% P, Ear Leaf	.145	.187	.178	.209	.231	.225	.282
Bray P, ppm	5.0	6.0	6.8	12.1	26.3	19.8	50.0
Olsen P, ppm	4.3	5.7	8.7	8.9	10.8	10.3	27.0

EVALUATION OF FERTILIZER RECOMMENDATIONS FROM TWO SOIL TESTING LABORATORIES IN WATONWAN COUNTY

Gary Wyatt and George Rehm[1/]

ABSTRACT: Questions about fertilizer recommendations from various soil testing laboratories still persist. This study was conducted in farmer fields in Watonwan County to compare fertilizer recommendations for corn from two laboratories (MVTL, A & L). Recommendations from the A & L Laboratory produced fertilizer costs that were $20 to $30 per acre higher than the recommendations from MVTL. The fertilizer recommendations associated with the highest costs did not increase grain yield.

Introduction:

In recent years, there have been intensive efforts to develop more uniform fertilizer recommendations that are provided by several soil testing laboratories. Yet, there are still some differences in recommendations that produce substantial differences in fertilizer costs. Therefore, there is still a need to evaluate various fertilizer recommendations. It is especially important that these evaluations take place in farmers fields.

Objective:

This project was conducted to evaluate the effect of fertilizer recommendations from two soil testing laboratories on corn yield and return to fertilizer use in south-central Minnesota.

Experimental Procedure:

For this project, there was considerable cooperation among the Watonwan County Corn Growers, the Watonwan County Extension Office, and the Watonwan Farm Service. Soil samples were collected from fields of cooperating farmers by personnel of the Watonwan Farm Service in the fall of 1988. Samples were split and sent to two soil testing laboratories (A & L, MVTL). Recommended rates of phosphate, potash, sulfur, and zinc were broadcast by the Watonwan Farm Service, in April, in the fields of cooperating farmers. These nutrients were incorporated by the secondary tillage operations.

Nitrogen fertilizer recommendations from each laboratory were nearly equal. Therefore, the same N rate was used for the corn fertilized with recommendations from each soil testing laboratory. There was also a treatment where N was applied without the use of phosphate, potash, sulfur, and zinc.

Grain yields were measured in October, 1989, and were corrected to a base of 15.5% moisture. Fertilizer costs were computed and cost per acre calculated from these values. Costs were $.21, $.14, $.45, and $.70 per pound for P_2O_5, K_2O, S, and Zn, respectively.

Cooperating farmers prepared the seedbed, planted and cultivated the corn. Recommended hybrids, plant populations, herbicides, and insecticides were used throughout the project.

Results and Discussion:

Results of the analysis of soil samples, which were sent to the two laboratories, are summarized in Table 1. The analytical results from each site were rather uniform if the major nutrients are considered. There was less agreement in analytical results if the micronutrients are considered.

Fertilizer recommendations, fertilizer costs, and grain yields are summarized in Table 2. There were differences in the rates of nutrients recommended as well as the nutrients that were suggested for a fertilizer program. Consequently, there were substantial differences in cost for the nutrients applied. Statistical analysis showed that there was no significant difference in yields that were the end result of the fertilizer recommendations. When N only was applied, the yield was 154 bu./acre at the Winkelman location and 181 bu./acre at the Samuelson location.

When compared to the use of N only, the broadcast use of P_2O_5, K_2O, and Zn produced a significant yield increase at the Winkelman location. Sulfur had no effect on yield. No S was suggested by MVTL and yields were not reduced. Considering the soil test values for P and Zn, the yield increase at this location can probably be attributed to the use of phosphate and zinc.

[1/] County Extension Agent, Watonwan County and Extension Soil Scientist, respectively.

The yield from the MVTL recommendations at the Samuelson location was significantly higher than the yield from the N only treatment. The yields from the A & L recommendation was not significantly different than the yield from the N only treatment.

Although there was no difference in yield at two locations, the recommendations from A & L Laboratories increased fertilizer costs by about $20 to $30 per acre. The results from this project are in agreement with results of similar comparisons conducted at the Southern and West-Central Experiment Stations in past years.

Table 1. Results of the analysis of soil samples taken from two farms which were analyzed by two soil testing laboratories.

	Farmer and Laboratory			
	Winkelman		Samuelson	
Analysis	A & L	MVTL	A & L	MVTL
pH	6.9	6.5	6.4	6.3
P_1 (Bray #1) ppm	13.0	10.0	15.5	20.0
P_2 (Bray) ppm	19.0	NA	55	NA
P (Olsen) ppm	NA	8.5	NA	16.5
K, ppm	107	125	126	145
organic matter, %	3.5	3.4	4.4	3.9
ENR (estimate nitrogen release), lb./acre	83	NA	93	NA
magnesium, ppm	742	715	586	550
calcium, ppm	2419	3150	2352	2900
sulfur, ppm	14.0	21.0	15.0	24.0
zinc, ppm	.9	.7	1.2	1.0
iron, ppm	62.0	25.6	53.0	25.7
copper, ppm	1.2	.9	1.0	.9
manganese, ppm	12.0	5.5	25.0	12.7
boron, ppm	1.1	2.0	1.3	2.3
Cation Exchange Capacity, meq/100 gm	18.6	22.0	18.6	19.4

NA = not analyzed

Table 2. Fertilizer recommendations, cost of fertilizer applied, and grain yields for corn production in Watonwan County in 1989.

Farmer	Soil Testing Laboratory	Recommendations P_2O_5	K_2O	S	Zn	Fertilizer Cost	Grain Yield
		- - - - - - - - lb./acre	- - - - - - - - -			$/acre	bu./acre
Winkelman	A & L	95	215	10	4.0	57.35	162 a*
	MVTL	80	45	0	8	28.70	162 a
Samuelson	A & L	35	165	9	4.5	37.65	186 a
	MVTL	45	15	0	8	17.15	192 a

* Treatment means from each location followed by the same letter are not significantly different at the .05 confidence level.

INFLUENCE OF EXPERIMENTAL DESIGNS ON ON-FARM TRIAL INTERPRETATIONS

M.A. Schmitt and S.J. Openshaw[1]

ABSTRACT: Experimental designs used in on-farm research trials are largely responsible for the precision of the research results. Three experimental designs (unreplicated strip, unreplicated strip with "tester", and randomized complete block (RCB)) were compared in terms of the experimental error term each design would give for a given trial. Trials were located at 4 experiment stations and 8 farmer fields. The RCB design provided the lowest experimental error term in all cases while the strip with "tester" design resulted in the highest experimental error term for the trials. Based on these results and the 1988 results the practice of replication and combining results across locations is recommended.

INTRODUCTION

As the trend develops to place increasing emphasis on on-farm trials, the validity of these trial results must be emphasized. The measurement that is used to evaluate the precision of the different experimental designs is the error variance. The relative size of the error variance is inversely related to the degree of precision of the design. The larger the error variance, the less precision the experiment possesses. The precision of an experiment is directly related to the confidence one can give to the data.

For example, a large relative error variance results in larger differences between treatment means in order for the treatments to be significantly different. A 10 bushel per acre difference in two corn treatment means might be significantly different if relatively low error variance was measured, but would not necessarily be different if a relatively high error variance was measured. The objectives of this project are to compare the precision of three experimental designs used in on-farm research.

MATERIALS AND METHODS

Three basic experimental designs commonly used in large plot, on-farm trials were compared. These three designs are: 1) a nonreplicated strip (strip), in which the number of plots equals the number of treatments, 2) a nonreplicated strip that has a common treatment placed in every second (strip with "tester"), in which the number of plots equals the number of treatments times 2 plus 1, and 3) a randomized complete block (RCB), in which the number of plots equals the number of treatments times the number of replications.

The experimental design used in the field trials (Figure 1) incorporated each of the three experimental designs investigated in this study. Eight of the locations in Minnesota were on farmers' fields, with the plot's width between 10-30 feet and length's from 300 to 1447 feet. Four sites were at University of Minnesota experiment stations, with width's of 10-15 feet and the length between 30 and 426 feet. All of the sites were selected based on visual uniformity of the soil.

Management practices were followed at each site that were parallel to that practiced by top corn producers. There were five treatments at each location, consisting of different hybrids: Pioneer brands 3737, 3751, 3732, 3585, and 3733. Pioneer brand 3737 was used as the "tester" in the strip with "tester" design. Grain yields were measured after physiological maturity using a combine (except at one experiment station). Grain yields were adjusted to 15.5% moisture.

The error variance for the plot area using a strip design having as many treatments as there are strips was approximated by calculating the residual mean square from a completely random design (CRD) analysis that used the unadjusted yields of the nontester plots. By using a CRD, only the treatment effects are partitioned from the trial variance--not any block effects.

The strip with "tester" design's error variance is approximated in a similar manner as the strip design's error. First, however, the yields are adjusted according to Eq. 1. The adjusted yields for the nontester hybrids are then used in a CRD analysis, partitioning out the treatment effect, resulting in the error variance associated with the total plot area as if a strip with "tester" design were used.

[1] Asst. Professors, Department of Soil Science and Department of Agronomy and Plant Genetics, University of Minnesota-St. Paul.

Equation 1:

$$Y_A = [Y_U - (\frac{T_L + T_R}{2})] + T_{Ave}$$

Y_A = Adjusted Treatment Yield
Y_U = Unadjusted Treatment Yield
T_L = Tester Yield on Left Side of Treatment Plot
T_R = Tester Yield on Right Side of Treatment Plot
$T_{Ave.}$ = Tester Yield Average for Entire Trial

The estimated experimental error for a RCB design used on the plot area is calculated by using a randomized complete block analysis. This partitions both replicate and treatment effects from the experimental error term.

1989 RESULTS

The overall error variance of the trial area using an unreplicated strip design was almost one-half the magnitude of the strip with "tester" design's error variance (Table 1). The frequency of the "tester" is not as beneficial in reducing the error variance of the area as some would expect. The best design, in terms of achieving the lowest error variance for the trial area, is the randomized complete block. As well as having the lowest error variance, the range of these values was also the smallest.

The effect of plot size was noted in 1989. The data (Table 1) indicates that the smaller plots tended to have higher experimental error terms than did the larger plots. The confounding factor of this observation is that the smaller plots all had border rows between plots that were not harvested, whereas the larger plots did not have border rows. Therefore, it cannot be fully explained as to whether the border rows do provide a more diverse group of treatment means that truly do have more variance or if the larger plots are less effected by soil variability and do provide a smaller experimental error.

Table 1. The effect of experimental design and plot size on estimating error variances (S^2) of corn hybrid trials, 1989.

Expt'l. Design	Plot Size[1]	# Sites	S^2	Range of S^2
Strip	Small	4	128.1	12.3 - 275.5
	Large	8	22.2	5.3 - 57.1
	Overall	12	57.5	5.3 - 275.5
Strip w/"Tester"	Small	4	239.4	30.5 - 500.2
	Large	8	47.9	12.3 - 129.2
	Overall	12	111.7	12.3 - 500.2
R.C.B.	Small	4	76.3	9.5 - 144.2
	Large	8	16.8	1.7 - 54.0
	Overall	12	36.6	1.7 - 144.2

[1] The "large" plots averaged 0.3012 A per plot and the "small" plots averaged 0.0504 A per plot.

2-YEAR SUMMARY

The overall mean of the strip and RCB design's error variance were not substantially different from 1988 and 1989 (Schmitt and Openshaw, 1989). While there was a large difference in the strip with "tester" design's error variance between the years, this difference should be attributed to the change made in the frequency of the "tester" made in 1989 (see materials and methods).

The RCB design with three replicates provided the lowest error variance of the three designs evaluated. The reduction in error variance was about 40-50% when compared to the unreplicated strip design. However, when using the error term for differentiating treatment means, the RCB error variance will be divided by the number of replicates to arrive at the variance of a treatment mean. The large reduction in error variance provided by the RCB is logistically offset by the fewer number of treatments that can be evaluated--still assuming that the plot size and number are fixed at a site.

To increase the precision and differentiation of treatments in agronomic trials, the practice of replication must be endorsed. Along with this, interpretability can also be improved if the trials are statistically combined from several locations. This will, in effect, increase the number of replications. While the use of the "tester" hybrid may provide an estimate as to the variability within one trial site, the results of this project show that it does not increase (and can decrease) the experimental error precision when adjusting treatment means with it.

References:

Schmitt, M.A. and S. J. Openshaw. 1988. Influence of experimental designs on on-farm trial interpretations. In A report on field research in soils, misc. publ. 2, Minn. Ag. Expt. Stn., Univ., of Minn. pp. 207-210.

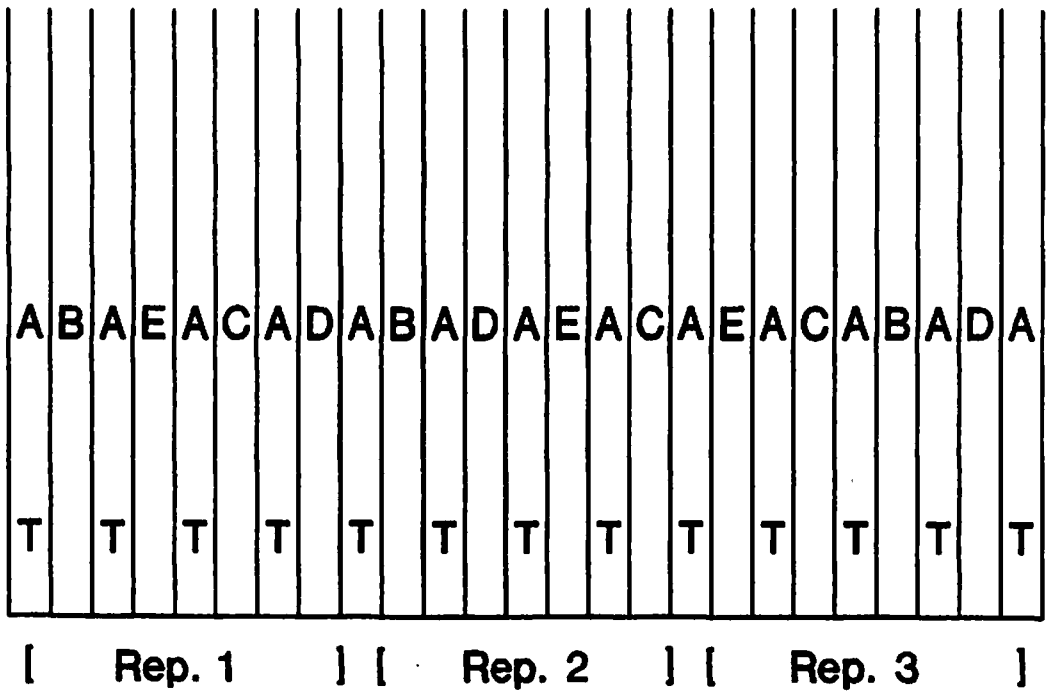

Figure 1. Experimental design used in field trials, 1989.

EVALUATION OF COMBINATIONS OF POTASSIUM FERTILIZER, VARIETY, AND FUNGICIDE USE ON PRODUCTION OF HIGH YIELDING SOYBEANS IN MINNESOTA

Ward Stienstra, George Rehm, Greg Cremers, and Andy Scobbie[1/]

ABSTRACT: Phytophthora Root Rot (PRR) continues to be a problem for soybean producers in Minnesota. This study was conducted to evaluate the effect of K fertilization, variety, and fungicide use on the incidence and severity of this disease. Potassium fertilization had no effect on severity of PRR and had no effect on yield. Variety selection was important. The use of the fungicide, Ridomil, was effective in fields where PRR was a problem.

Introduction:

Phytophthora Root Rot (PRR) is a serious and expanding problem for soybean producers in much of Minnesota. The severity of the problem is linked to several factors. Soil moisture and incidence of rainfall after planting are two of these factors. The disease is usually not a problem on well drained soils unless the soil becomes saturated in the zone of seedling development. A perched water table, heavy rainfall during the week after planting, or drought stress may allow expression of this disease in areas which are not expected to be prime sites for PRR. The disease is not limited to heavy soils with poor internal drainage. It can and does occur on soils that require irrigation.

Researchers throughout the United States have demonstrated that soybeans respond to applications of phosphate fertilizer when soil test levels for P are low or very low. However, the response of soybeans in Minnesota to K in a fertilizer program has been conflicting. In earlier studies, no response was measured when soybeans were grown on a sandy soil with a low K test. Yet, there has been some indication of a positive response to K when soil test K values were in the medium to high range.

Objective:

There are obviously unanswered questions that revolve around soybean production in Minnesota. Therefore, the study discussed in this report was conducted to evaluate the effects of: 1) rate of fertilizer K, 2) soybean variety, and 3) fungicide use on production of soybeans in a high yield environment.

Experimental Procedure:

The study was conducted at 3 sites in Mower County in southeast Minnesota in 1989. All sites had a known history of damage caused by PRR. Sites selected also had a wide range of soil test K values. Soils at the experimental sites were also representative of soils in the region.

Three factors (K rate, variety, fungicide use) were combined into a complete factorial using a split, split plot design. Four replications of each treatment were used. Rates of applied K (0, 40, 80, 160 lb./acre) were the main plots. Soybean varieties (54-254, BSR-101, Corsoy 79) were the sub plots. Fungicide use (with and without) was used for the sub-sub plots.

Soil samples from 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches were collected at the initiation of the study. Results of the analysis of these samples are summarized in Table 1.

Table 1. Relevant soil test values for the experimental sites used in the study in 1989.

Property	Depth	Arndorfer	Greeley	Meyer
	- in -			
pH	0-6	6.2	7.0	5.5
P, (Bray & Kurtz #1) ppm	0-6	24	30	35
Organic Matter, %	0-6	3.1	4.8	3.6
Zinc, ppm	0-6	1.2	.9	1.6
Soil Test K, ppm	0-6	82	127	142
	6-12	37	54	82
	12-24	50	55	75
	24-36	49	43	77
	36-48	59	37	64
	48-60	94	40	60

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

The fertilizer K was broadcast and incorporated before planting. The fungicide treatment consisted of the application of Ridomil in the seed furrow at planting at a rate of approximately 6 lb./acre. Seeding rate was approximately 10 seeds per foot of row. Row spacing was 30 inches at all sites. Appropriate herbicides were used for weed control

Stand densities were determined by counting the number of plants in 5 ft. of row at approximately 30 days after planting. The most recently matured leaflet was collected at early bloom, dried, ground, and analyzed for K. Grain yields were measured in early October.

The effect of fertilizer K applied in a starter fertilizer was measured at the Arndorfer and Greeley locations. For this study, K (supplied as 0-0-60) was applied in a band to the side of and below the seed at planting to supply 0, 20, 40, and 80 lb. per acre. All plots received a uniform application of N (18 lb./acre) and P (20 lb./acre). The Corsoy 79 variety was used and Ridomil was applied to all plots. Data collection was identical to that described in the previous paragraphs.

Results and Discussion:

The soil test P values were in the high to very high range for all sites. Therefore, no phosphate fertilizer was applied. The soil test K values (0-6 in.) were in the medium range at the Arndorfer and Greeley sites and the high range at the Meyer site. The K values decreased with depth and this is to be expected.

Soybean Yield

Application of fertilizer K had no significant effect on yield at all sites. There was no significant interaction between either applied K and variety or applied K and use of Ridomil. Therefore, the effect of K rate on yield is summarized in Table 2. Because of the high soil test value, a response to K would not be expected at the Meyer site. The soil at the Arndorfer and Greeley sites was apparently able to supply adequate K for optimum soybean production in 1989.

Table 2. Influence of applied K on soybean yield.

K Applied	Site: Arndorfer	Greeley	Meyer
lb./acre	bu./acre		
0	39.2	41.1	38.9
40	39.7	41.4	38.9
80	40.5	40.0	38.1
160	37.6	41.5	36.5

Variety had a significant effect on yield at all locations (Table 3). Highest yields at all sites were associated with the BSR-101 variety. Yields of the Corsoy 79 variety were intermediate while the 54-254 variety produced the lowest yield at all sites.

Table 3. The effect of variety and Ridomil use on soybean yield.

Variety	Ridomil Use	Site: Arndorfer	Greeley	Meyer
		bu./acre		
54-254	no	29.3	37.8	33.3
54-254	yes	37.0	36.6	35.8
BSR-101	no	43.3	44.6	42.7
BSR-101	yes	43.5	45.9	41.0
Corsoy 79	no	42.0	40.8	37.6
Corsoy 79	yes	40.5	40.3	38.0

Disease pressure from PRR was not severe in 1989. Soybean yield was increased by the use of Ridomil at the Arndorfer site only. This increase was noted with the 54-254 variety. This variety is not resistant to PRR and yield reductions from this disease would be expected if PRR races are present in a soil. The

BSR-101 is somewhat resistant to PRR and Corsoy 79 soybeans are somewhat more resistant to infection. With low levels of disease pressure, these varieties would not be expected to respond to the use of Ridomil. The application of K in a fertilizer program had no significant effect on the incidence or severity of PRR in 1989.

Plant Height

Plant height can be used as an early measure of the effect of PRR on soybean production. The application of K in the fertilizer program had no significant effect on this measurement (Table 4). This is consistent with the effect of K fertilization on yield.

The use of Ridomil increased the height of the 54-254 variety at the Arndorfer location. Otherwise, the use of this fungicide had no effect on plant height.

Soybean variety had a significant effect on plant height at all locations (Table 5). The 54-254 variety was shortest at all locations while the Corsoy 79 variety produced the tallest soybeans in 1989.

Table 4. Influence of rate of applied K on the height of soybean plants at early bloom.

K Applied	Site: Arndorfer	Greeley	Meyer
lb./acre	inches		
0	46	54	61
40	47	54	62
80	50	54	60
160	47	55	59

Table 5. The effect of soybean variety on the height of soybean plants at early bloom.

Variety	Site: Arndorfer	Greeley	Meyer
	inches		
54-254	43	50	56
BSR 101	46	54	59
Corsoy 79	54	59	67

Soybean Stand

In general, the number of emerged soybeans was lower than anticipated. Use of K in a fertilizer had no significant effect on emerged stand at all sites (Table 6). The measured stand, however, was affected by soybean variety at the Arndorfer and Meyer sites. (Table 7). Use of Ridomil had no significant effect on measured stand and there was no significant Ridomil x variety interaction.

Table 6. The effect of rate of applied fertilizer K on the population of soybeans after emergence.

K Applied	Site: Arndorfer	Greeley	Meyer
lb./acre	plants/ft.		
0	6.0	6.7	7.1
40	6.0	6.7	7.0
80	5.8	6.6	6.9
160	5.7	6.6	7.2

Table 7. The effect of soybean variety on the population of soybeans after emergence.

Variety	Site: Arndorfer	Site: Greeley	Site: Meyer
	plants/ft		
54-254	5.4	6.8	6.7
BSR-101	6.1	6.7	7.1
Corsoy 79	6.1	6.5	7.3

K Concentration in Leaf Tissue

Even though applied K had no effect on soybean yield, the K concentration in the most recently mature leaflet at early bloom was affected by the rate of K applied (Table 8). The highest K concentration at all locations was associated with the use of 160 lb K/acre. The K concentration in the tissue of the non-fertilized treatments was uniform for all locations.

Table 8. The effect of rate of applied K on the concentration of K in leaf tissue.

K Applied	Site: Arndorfer	Site: Greeley	Site: Meyer
lb./acre	% K		
0	2.08	1.96	2.16
40	2.12	2.08	2.16
80	2.19	2.06	2.12
160	2.31	2.16	2.25

This is further evidence that the soils were capable of supplying adequate K for soybean growth. The higher concentrations from the use of K are considered to be the result of luxury consumption.

The variety used had a highly significant effect on the K concentration in the leaf tissue at all locations (Table 9). Concentration was lowest in the 54-254 variety. This may be a variety trait or it may reflect a lower level of root activity caused by PRR with a subsequent effect on reduced yields. There was no statistical difference in the K concentration when the BSR-101 and Corsoy 79 varieties are considered.

Table 9. The effect of variety and Ridomil use on the K concentration in leaf tissue of soybeans.

Variety	Ridomil Use	Site: Arndorfer	Site: Greeley	Site: Meyer
		% K		
54-254	no	1.95	1.93	2.08
54-254	yes	2.07	1.95	2.08
BSR-101	no	2.27	2.15	2.25
BSR-101	yes	2.33	2.13	2.24
Corsoy 79	no	2.21	2.14	2.19
Corsoy 79	yes	2.22	2.10	2.20

The use of ridomil produced a significant increase in the K concentration of the leaf tissue of the 54-254 variety at the Arndorfer site only. This would be expected because damage from PRR was most severe at this site. Uptake of K would be restricted where root systems are damaged by PRR and the 54-254 was severely damaged by this disease at this site.

Changes in Soil Test Values

Following harvest, soil samples (0-6 in) were collected from the main plots in an attempt to measure the effect of applied K on soil test K values. These results are summarized in Table 10. There were no

major changes in soil test values. There was a small increase in soil test K values at all locations as the rate of applied K increased. The largest increase was measured when the rate of applied K was increased from 80 to 160 lb./acre. Since applied K had no effect on yield, there does not appear to b any justification to apply fertilizer K in an attempt to increase K values above those measured at th beginning of this study.

Table 10. The effect of rate of applied K on the soil test values for K at the end of the growing season.

K	Site		
Applied	Arndorfer	Greeley	Meyer
lb./acre	ppm K		
0	80	94	110
40	80	100	118
80	97	104	119
160	115	115	146

Effects of K in a Starter

The rate of K applied in a starter fertilizer had no significant effect on both soybean yield and the K concentration in the leaf tissue (Table 11). The absence of any effect of applied K on yield is consistent with the results from the companion study where fertilizer K was broadcast and incorporated. This is added evidence that the soil at all locations was capable of supplying adequate K for soybean production.

Applied K had no effect on the K concentration in the leaf tissue and this is not consistent with results from the companion study. Apparently, soybean roots did not develop near the starter band and no additional K was absorbed by the soybean plant.

Table 11. The effect of rate of K applied in a starter fertilizer on soybean yield and the K concentration in soybean leaf tissue.

K	Site			
	Arndorfer		Greeley	
Applied	Yield	K Conc.	Yield	K Conc.
lb./acre	bu./acre	%	bu./acre	%
0	39.8	2.23	47.1	2.11
20	38.1	2.14	42.9	2.10
40	39.1	2.07	43.9	2.01
80	34.6	2.15	41.2	2.13

Summary And Conclusions

The results of this study conducted in both 1988 and 1989 at a total of 6 experimental sites, have been quite consistent. Based on the analysis of the data collected, it is possible to make the following conclusions.

1. Use of K in a fertilizer program had no measurable effect on the incidence or severity of PRR. The addition of this nutrient to a fertilizer program had no effect on yield where soil test values for K were considered to be in the medium or high range.

2. The incidence and severity of PRR was highly dependent on the variety used. The presence PRR reduced yields of 54-254 (a susceptible variety) in both years of the study. The yiel

of the BSR-101 (somewhat tolerant) variety was affected by PRR at only one site. The tolerant (Corsoy 79) variety was not affected by PRR at any location.

3. The use of the fungicide, Ridomil, had a positive effect on yield where PRR was present at levels that cause yield suppression. This is especially true for the 54-254 variety. This product had the most beneficial effect on yield where disease pressure was the highest.

4. Incidence and severity of PRR appears to be highly dependent on the amount of rainfall received immediately after planting. Even though the 1988 season was dry, moderate rains were received just after planting and pressure from PRR was moderate to high at all locations. There was heavy pressure from PRR at only one location (Arndorfer) in 1989. This site did receive moderate rainfall on the day that it was planted. Rainfall immediately after planting was lacking at the other 2 locations.

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IMPACT OF AG-LIME ON SOYBEAN AND POTATO PRODUCTION ON IRRIGATED SANDY SOILS

George Rehm and Carl Rosen[1/]

ABSTRACT: The sandy soils of the Anoka Sand Plain typically have an acid pH. This is satisfactory for potato production, but may limit the yield of soybeans grown in the rotation. This study was conducted to evaluate the effect of ag lime on the yield of soybeans and potatoes. Soybeans were grown in 1989 and yield was not affected by the ag lime use at rates of 1, 2, and 3 ton per acre. Potatoes will be grown in 1990 to monitor the effect of lime use on potato yield.

The benefits of liming acid soils for soybean production are well documented in past research. A pH near neutral is required for optimum nodulation of the soybean plant thereby assuring that the soybean crop will have an adequate supply of nitrogen. In contrast, potatoes are normally grown on acid soils to reduce the incidence of scab.

Soybeans and potatoes are commonly grown in rotation on irrigated sandy soils in Minnesota. Growers face a dilemma when they use this rotation. Lime applied for optimum production of soybean may raise the pH to a point where it is difficult to grow high quality potatoes after soybeans.

The objective of this study, therefore, was to determine the effects of application of ag lime in a soybean/potato rotation.

Experimental Procedure:

The study was conducted at Big Lake, Minnesota on a Hubbard loamy sand soil. Based on farmer records, the soil pH was 5.3; however, after more extensive sampling, it was determined that the initial pH was 6.1 with a range of 5.9 - 6.3. The initial pH of the site was 6.2. Agricultural limestone was broadcast and incorporated before planting at the rates of 0, 1, 2, and 3 tons per acre. Each treatment was replicated 4 times in a randomized complete block design. Soil samples were collected at harvest and analyzed for pH. Trifoliate leaf samples were collected at mid season and analyzed for nutrient concentrations. Soybean yields were determined by measuring two 10′ rows from each plot.

Results:

Soil pH and soybean yield are presented in Table 1. As expected, soil pH tended to increase with increasing application of ag-lime. The increase, however, from the control plot to the 3 ton rate was only 0.2 units. We anticipate that the pH will continue to increase in the plots where lime was applied over the next year. The increase in the control plot over the growing season was probably due to the high pH water used for irrigation during this dry year. Soybean yields were not significantly affected by lime application. Part of the reason for this lack of response was due to the fact that the pH of the control plot was above 6.0. The probability of a response to lime decreases as the pH increases above this level. Concentrations of nutrients in trifoliate leaves are presented in Table 2. None of the nutrients measured were affected by lime application. Again, this lack of response was probably due to the high initial pH.

The experiment next year (1990) will concentrate on the effects of these same lime treatments on potato yield and quality.

Table 1. Effect of ag-lime on soil pH and soybean yields.

Treatment	Soil pH	Soybean Yield
Tons lime/A		bu/A
0	6.3	58.0
1	6.4	57.3
2	6.4	60.0
3	6.5	57.0
Significance	NS	NS

Table 2. Effect of ag-lime on nutrient concentrations in soybean trifoliate leaves sampled at mid season.

Treatment									
Tons lime/A	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%				ppm				
0	0.45	2.06	0.82	0.38	159	133	48	8	45
1	0.41	1.89	0.92	0.38	164	133	43	6	46
2	0.41	1.98	0.83	0.35	156	128	43	7	44
3	0.38	1.86	0.86	0.35	157	119	41	7	47
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1/] Extension Soil Scientists, University of Minnesota

SOIL NITRATE MOVEMENT IN IRRIGATED POTATO/CORN ROTATIONS[1]

Carl Rosen, Louise America, Peter Bierman, and Gary Korbel[2]

ABSTRACT. Soil samples from 12 irrigated fields were collected to a depth of three feet during the 1989 growing season. Fields sampled included: 6 potato fields, 4 sweet corn fields, 1 field corn field, and 1 soybean field. Soil nitrate-N and ammonium-N were determined in KCl extracts. In addition, soil water from 5 of the 6 potato fields was collected weekly using suction tube lysimeters and analyzed for nitrate-N. Results of this study indicated that N distribution during the season in potato and corn fields differed, but that total residual N at harvest was similar. Nitrate-N and ammonium-N in the soybean field were at background levels through the season. The greatest potential for residual nitrates and nitrate-N movement occured when yields were low and when high or excessive N fertilizer applications were used. The survey shows that some growers need to improve upon production and N management practices to prevent nitrate-N losses. However, the study also shows that crops can be grown on these soils with minimal nitrate-N movement below the root zone.

The irrigated soils of Sherburne county have been identified as being susceptible to nitrate leaching. These soils are characterized as having a sandy texture over gravel with an organic matter content in the top 12" of 1 to 3 percent. Levels of nitrate-N in shallow wells have reportedly increased over the years. A level less than 10 ppm nitrate-N is considered safe for drinking. Contamination of groundwater with nitrates is a concern that has many questioning N management practices on the irrigated, sandy soils of central Minnesota. While excessive applications of N fertilizer could potentially contaminate the groundwater, few studies could be found which dealt directly with how nitrates might be moving in these soils during the growing season. The objective of this report is to obtain background information on nitrate-N levels and movement in irrigated corn and potato fields under conditions defined by growers. An irrigated soybean field was also included as a crop not receiving any fertilizer N during the season. The ultimate goal is to help improve N management practices for irrigated crops.

Experimental Procedures. Six potato fields, four sweet corn fields, one soybean field, and one field corn field, all located in Sherburne county, were selected for monitoring. The soils at all locations were classified as Hubbard loamy sands. Fertilizer source, rate, timing, and method of application were recorded, but actual practices were left up to each grower. Approximate yields were recorded by harvesting two 20 ft rows. Soil samples from each field were collected to a depth of three feet at one foot increments. Samples were collected from four locations (reps) in each field and the sample from each location consisted of three cores. The first sampling date was in April/May prior to planting and fertilizer application. Fields were sampled again at the same approximate locations in July during tuber enlargement for potatoes, just prior to tasselling for the corn, and during initial pod fill for the soybean field. At this time, samples were collected both between rows and within rows. A final sampling time was in August/September within one week of harvest. Samples were again collected between and within rows.

In five of the six potato fields, recently mature leaf (leaflet plus petiole) and petiole alone samples were collected July 5. Samples were dried and ground to pass through a 30 mesh sieve. Total Kjeldahl N and water soluble nitrate-N were determined using conductimetric procedures. Other elements were determined in ashed samples dissolved in 2 N HCl using ICP procedures.

All soil samples were placed in plastic bags and kept moist at 40°F until analyzed. Nitrate and ammonium were extracted with 2 N KCl using a 5 g moist sample to 25 ml extractant ratio. Percent moisture was determined in each sample, and ppm nitrate-N and ammonium-N were calculated on a dry weight basis. All results are expressed as pounds of nitrate-N or ammonium-N using the convention that ppm X 2 = lb/A for a 6" furrow slice. Bulk density of each sampling depth was not determined so the lb/A values should be considered approximate. For the July and September samples, total nitrate-N and ammonium-N in the 3 ft profile were calculated by assuming that half the field was 'within row' and the other half was 'between row'.

Suction tubes were installed in the rows of five of the six potato fields at 2.5 and 4.5 foot depths. There were two tubes at each depth in each field. Nitrates in soil water were determined in samples collected weekly during the growing season. For two of the five fields, the suction tubes were removed at harvest. For the other three fields, samples continued to be collected every other week through mid-November.

Results and Interpretations. Rainfall during the 1989 growing season was light. There were no rainfall events which totaled over 1.5 inches during any one week from mid-April to mid-August (Fig. 1). Thus, major losses of N out of the root zone at any one time during the growing season probably did not occur. Records of irrigation were not kept; however, most growers attempted to supplement rainfall to provide about 1.5" - 2" of water per week from June through mid-August.

Potato yields varied from approximately 220 cwt/A to 660 cwt/A, and N fertilizer applications ranged from 125 lb N/A to 325 lb N/A. Sweet corn yields ranged from 6.5 T/A to 9.5 T/A, and N fertilizer applications ranged from 155 lb N/A to 200 lb N/A. In both crops, highest yields were not associated with highest N applications. The field corn yield was 216 bu/A and the soybean yield was 46 bu/A.

[1] Partial support for this project was provided by the Sherburne County Farm Bureau and the East Central Irrigators Association.

[2] Extension Soil Sci., Junior Scientist, Grad. Res. Assist., Res. Technician, Dept. Soil Science.

A summary of nitrate-N levels during the growing season over all potato fields is presented in Table 1. There was an average of 50 lb/A nitrate-N in the top 3 feet before planting and fertilizer application, with a range of 17 to 116 lb/A. There was a gradual increase in nitrate from the top foot to the bottom 2-3 foot depth. The high residual nitrate in some fields indicate that excessive amounts of N were applied the previous year. The practice of hilling and placing fertilizer N in the row affects N distribution in the field. Levels of nitrate-N in the rows were about 1.5 times greater than levels between rows. At harvest, the level of nitrate-N in the top 3 feet was similar to the level recorded before planting; however, most was still concentrated in the top of the profile rather than the bottom.

Ammonium-N levels during the growing season over all potato fields are summarized in Table 2. Levels of ammonium-N did not increase substantially over the growing season. By harvest, levels were actually lower than those found in April before planting. Most of the ammonium-N applied was either converted to nitrate-N, taken up by the plant, or immobilized in the soil organic fraction.

Nitrate-N levels in the soil water at 2.5 and 4.5 feet from 5 potato fields through the season are presented in Figures 2-6. In Field 1 (Fig. 2), nitrate-N increased through the season and particularly after harvest. The high levels of nitrate-N late in the season are due to the late applications of fertilizer (late July), relatively high rates of N applied, and relatively low yields.

In Field 2 (Fig. 3), nitrate-N increased at both depths in mid-season followed by a general decline. At the 2.5' depth, nitrate-N levels reached a low in August (day 225) but then started to increase. The low level of nitrate-N probably corresponds to uptake by the potato crop. By day 225-250 the potato growth began to slow down followed by vine killing about day 260. Mineralization was still occurring, but there was no active crop to take up the nitrogen. The result was an increase in nitrate-N levels. This particular field had a long history of large manure applications before being used for potato production. The field was purchased for potato production about 25 years ago yet the residual from the manure may still have been affecting release of nitrate-N.

Field 3 (Fig. 4) represents an example of good N management as well as excellent potato production practices. Except for a small increase in soil nitrate-N levels in mid-season, levels remained relatively low, particularly after harvest. The main reasons for little nitrate-N movement in this field were: (1) the high yields resulted in uptake of a large portion of the applied N, (2) the timing of N application was such that N was provided when needed by the crop, and (3) the total rate of N was not excessive.

Fields 4 and 5 (Figs. 5 and 6) were only sampled through mid-August. Field 4 had relatively high levels of nitrate-N in the soil water reflecting the higher N application rate (260 lb N/A) and relatively high initial levels of soil nitrate-N (116 lb NO_3-N/A in the top three feet). In contrast, Field 5 had relatively low levels of nitrate-N in the soil water which reflects the low N application rate (124 lb N/A) and the lower initial levels of soil nitrate-N (68 lb NO_3-N/A in the top three feet).

Potato yields and elemental concentrations in the leaf tissue for five of the six potato fields are presented in Table 3. These five fields also correspond to the management practices presented in Figures 2 through 6. Fields 1 and 4 had high to excessive levels of tissue N based on established critical values for that sampling date. Fields 2 and 3 were in the adequate range and field 5 was deficient in N. Other nutrients were in the adequate range for all fields except field 2 which tended to be on the low side for K, Ca, Zn, B, and Cu. Tissue analysis for N should be an additional tool used by growers to help make N management decisions.

Soil nitrate-N and ammonium-N levels during the growing season over all corn/sweet corn fields are summarized in Tables 4 and 5. Field corn was included with the sweet corn since ranges for soil nitrate-N and ammonium-N levels were similar for both crops. Initial levels of nitrate and ammonium-N were generally lower than those found in fields to be planted in potatoes, which may in part be due to the previous crop. Further monitoring will have to be conducted to confirm the significance of previous crop. Nitrate-N and ammonium-N levels were substantially higher in corn/sweet corn compared to potatoes in July. Interestingly, most of the N was located between the rows for corn compared to within the rows for potatoes. This difference in N distribution is due to differences in fertilizer placement. In irrigated corn production most of the N fertilizer is sidedressed between the rows during the growing season. The level and distribution of residual nitrates in the corn fields at harvest were similar to that found for potatoes at harvest.

As expected, nitrate-N and ammonium-N soil levels in the soybean field were generally at background levels through the season (Table 6a and 6b). The previous crop in this field was snap beans which only received 40 lb N/A the previous year. Initial nitrate-N levels were low and even decreased by the end of the season. Soil ammonium-N levels remained constant throughout the season.

In summary, this survey has shown that N distribution during the growing season in potato and corn fields differed, but that total residual N at harvest was similar. The greatest potential for residual nitrates and nitrate-N movement occured when yields were low and when high or excessive N fertilizer applications were used. The survey shows that some growers need to improve upon production and N management practices to prevent nitrate-N losses. However, the study also shows that crops can be grown on these soils with minimal nitrate-N movement below the root zone.

Table 1. Summary of soil nitrate-N levels in irrigated potato fields over the growing season. Means and ranges of six commercial potato fields.

Ranges in total N fertilizer applied: 124 - 325 lb N/A
Ranges in total yield: 218 - 663 cwt/A

April 1989

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	11.6	5.8 - 19.2
1 - 2	15.7	4.2 - 42.1
2 - 3	22.3	7.1 - 59.7
Total	49.6	17.2 - 116.3

July 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	16.4	1.7 - 34.1	9.9	3.3 - 18.4
1 - 2	11.7	3.0 - 16.1	7.9	2.6 - 10.9
2 - 3	9.5	4.5 - 15.0	5.9	1.6 - 11.5
Total	37.6	10.8 - 58.7	23.7	8.3 - 33.7
Total lbs NO_3-N/A in field[2]			61.3	28.7 - 92.4

September 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	11.8	6.1 - 22.1	10.4	4.2 - 26.4
1 - 2	10.8	2.2 - 26.4	6.2	2.3 - 18.7
2 - 3	7.0	1.3 - 16.8	4.9	1.7 - 10.5
Total	29.6	10.8 - 74.2	20.7	9.4 - 54.9
Total lbs NO_3-N/A in field[2]			50.3	19.0 - 105.6

[1] Assumes half the field was row and the other half was between row.
[2] Total lbs NO_3-N in field = total in row plus total between row.

Table 2. Summary of soil ammonium-N levels in irrigated potato fields over the growing season. Means and ranges of six commercial potato fields.

April 1989

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	13.9	3.7 - 32.4
1 - 2	12.2	2.8 - 30.6
2 - 3	4.6	3.4 - 5.6
Total	30.7	10.2 - 66.0

July 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	15.5	3.0 - 40.6	3.3	1.3 - 6.4
1 - 2	3.7	1.7 - 6.4	2.4	1.5 - 2.5
2 - 3	2.1	1.5 - 2.8	2.2	1.3 - 2.5
Total	21.3	8.0 - 46.8	7.9	4.5 - 11.2
Total lbs NH_4-N/A in field[2]			29.2	13.1 - 58.1

September 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	1.8	0.9 - 3.6	1.2	0.8 - 2.1
1 - 2	1.5	0.7 - 2.8	1.0	0.7 - 1.2
2 - 3	1.1	0.7 - 1.2	1.0	0.7 - 1.4
Total	4.4	2.3 - 7.6	3.2	2.4 - 4.3
Total lbs NH_4-N/A in field[2]			7.6	6.0 - 10.5

[1] Assumes half the field was row and the other half was between row.
[2] Total lbs NH_4-N in field = total in row plus total between row.

Table 3. Yield, leaf and petiole nitrate-N, and leaf elemental concentrations from five potato fields. Yields were recorded at harvest. Leaf and petiole samples were collected July 5, 1989 (Means of 2 samples from each field).

Field Number	Yield cwt/A	NO_3-N leaf %	NO_3-N petiole %	N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm	Al ppm	Na ppm
1	285.7	0.42	2.04	4.87	0.30	4.70	0.90	0.50	207	302	30	8	50	147	19
2	491.9	0.25	1.52	4.25	0.41	3.80	0.49	0.49	88	395	18	5	22	28	23
3	661.4	0.26	1.21	4.34	0.28	4.45	1.25	0.65	82	156	22	13	30	19	17
4	449.4	0.56	2.50	5.06	0.25	4.55	0.98	0.64	173	863	69	8	31	43	16
5	398.9	0.09	0.34	3.72	0.26	5.09	0.66	0.54	104	480	28	9	30	40	20

Table 4. Summary of soil nitrate-N levels in irrigated corn/sweet corn fields over the growing season. Means and ranges of five commercial corn/sweet corn fields.

Ranges in total N fertilizer applied: 155 - 203 lb N/A
Ranges in total yield (sweet corn): 6.5 - 9.5 T/A
(field corn): 213 bu/A

April 1989

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	13.1	3.4 - 28.7
1 - 2	16.2	2.9 - 64.2
2 - 3	14.9	4.7 - 42.0
Total	40.3	9.6 - 134.7

July 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	10.3	4.1 - 28.1	53.8	15.2 - 128.1
1 - 2	9.6	4.1 - 19.3	16.6	9.6 - 31.3
2 - 3	6.2	3.3 - 11.9	9.0	5.7 - 16.7
Total	26.1	16.2 - 37.7	79.4	30.6 - 151.6
Total lbs NO_3-N/A in field[2]			105.5	68.4 - 187.4

September 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	8.5	3.5 - 19.5	16.1	8.6 - 24.9
1 - 2	4.1	1.4 - 10.9	11.4	6.7 - 16.5
2 - 3	2.8	1.4 - 6.7	7.5	5.4 - 11.4
Total	15.9	6.6 - 36.7	35.0	22.7 - 46.1
Total lbs NO_3-N/A in field[2]			50.4	30.1 - 72.1

[1] Assumes half the field was row and the other half was between row.
[2] Total lbs NO_3-N in field = total in row plus total between row.

Table 5. Summary of soil ammonium-N levels in irrigated corn/sweet corn fields over the growing season. Means and ranges of five commercial corn/sweet corn fields.

Ranges in total N fertilizer applied: 155 - 203 lb N/A
Ranges in total yield (sweet corn): 6.5 - 9.5 T/A
(field corn): 213 bu/A

April 1989

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	4.3	1.8 - 10.2
1 - 2	3.7	1.8 - 7.2
2 - 3	3.7	1.5 - 7.4
Total	11.7	5.1 - 24.9

July 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	6.6	0.7 - 24.4	95.9	7.7 - 195.1
1 - 2	1.9	0.4 - 4.0	17.6	5.3 - 34.9
2 - 3	1.7	0.6 - 2.6	9.0	2.8 - 20.3
Total	10.2	1.7 - 31.0	122.5	15.7 - 247.9
Total lbs NH_4-N/A in field[2]			132.7	46.7 - 253.1

September 1989

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	1.5	0.8 - 2.2	3.8	1.6 - 7.5
1 - 2	1.2	1.0 - 1.6	2.4	1.1 - 6.7
2 - 3	1.2	0.9 - 1.5	1.8	1.0 - 4.4
Total	3.9	2.9 - 5.3	8.0	3.8 - 14.5
Total lbs NH_4-N/A in field[2]			11.9	6.8 - 17.4

[1] Assumes half the field was row and the other half was between row.
[2] Total lbs NH_4-N in field = total in row plus total between row.

Table 6a. Summary of nitrate-N levels in sandy soils used for soybean production. Means and ranges of one soybean field (4 samples per field).

N Fertilizer Management: 0 N applied
Estimated Soybean Yield: 50 bu/A

	Sampling Date				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NO_3-N/A	lb NO_3-N/half acre[1]			
0-1	8.9 ± 3.0	2.7 ± 0.4	3.8 ± 1.8	4.4 ± 1.6	3.8 ± 0.8
1-2	7.8 ± 1.0	4.8 ± 2.1	4.7 ± 2.2	2.6 ± 1.2	1.9 ± 0.4
2-3	6.7 ± 2.4	3.7 ± 1.1	5.0 ± 1.5	1.8 ± 0.5	1.3 ± 0.4
Total	23.4 ± 4.4	11.2 ± 2.9	13.5 ± 4.8	8.7 ± 2.4	7.0 ± 0.9
Total lbs NO_3-N/A in field[2]		24.7 ± 7.3		15.7 ± 3.0	

Table 6b. Ammonium-N levels in sandy soils used for soybean production (means of 4 samples per field).

	Sampling Date				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NH_4-N/A	lb NH_4-N/half acre[1]			
0-1	2.4 ± 0.5	1.0 ± 0.7	0.4 ± 0.1	1.0 ± 0.2	1.0 ± 0.2
1-2	2.6 ± 0.4	0.6 ± 0.5	1.1 ± 0.7	1.6 ± 1.2	1.1 ± 0.3
2-3	2.6 ± 0.4	1.1 ± 0.6	1.3 ± 1.0	1.6 ± 0.8	1.0 ± 0.1
Total	7.6 ± 0.9	2.7 ± 1.0	2.8 ± 1.7	4.2 ± 1.2	3.1 ± 0.5
Total lbs NH_4-N/A in field[2]		5.4 ± 2.0		7.3 ± 1.4	

[1] Assumes half the field was row and the other half was between row.
[2] Total lbs NH_4-N in field = total in row plus total between row.

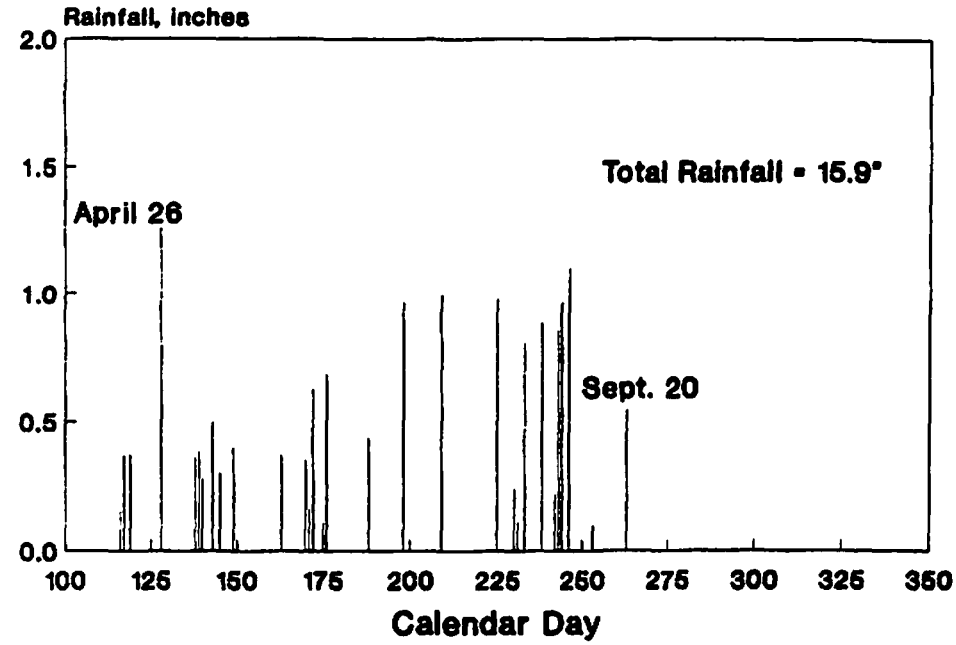
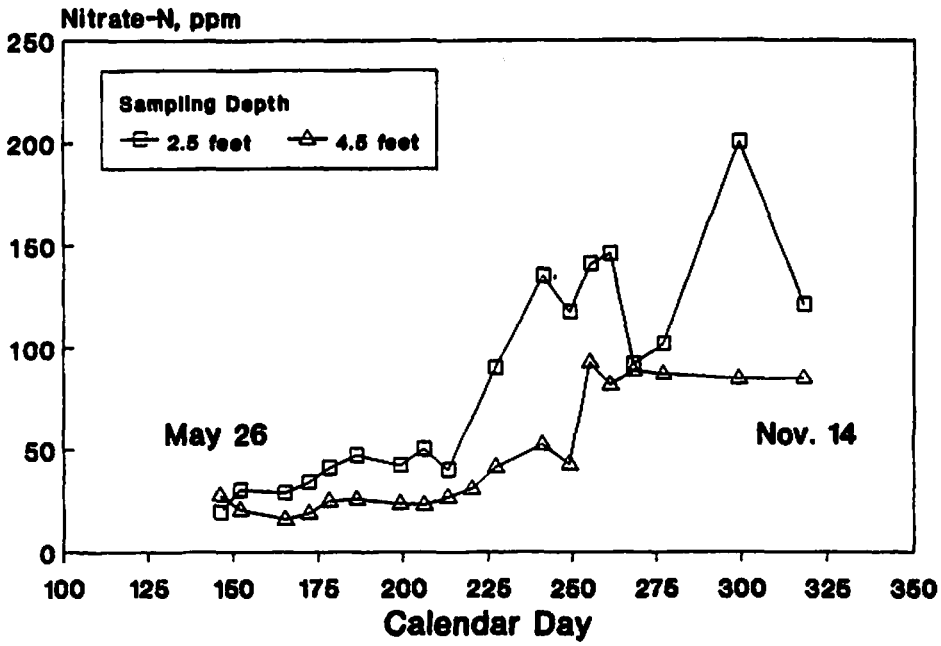


Figure 1. Rainfall distribution during the growing season at Big Lake, MN. This location was within a 15 mile radius of all fields sampled. April 26 indicates begining of rainfall measurments, Sept. 20 indicates final rainfall measurement.

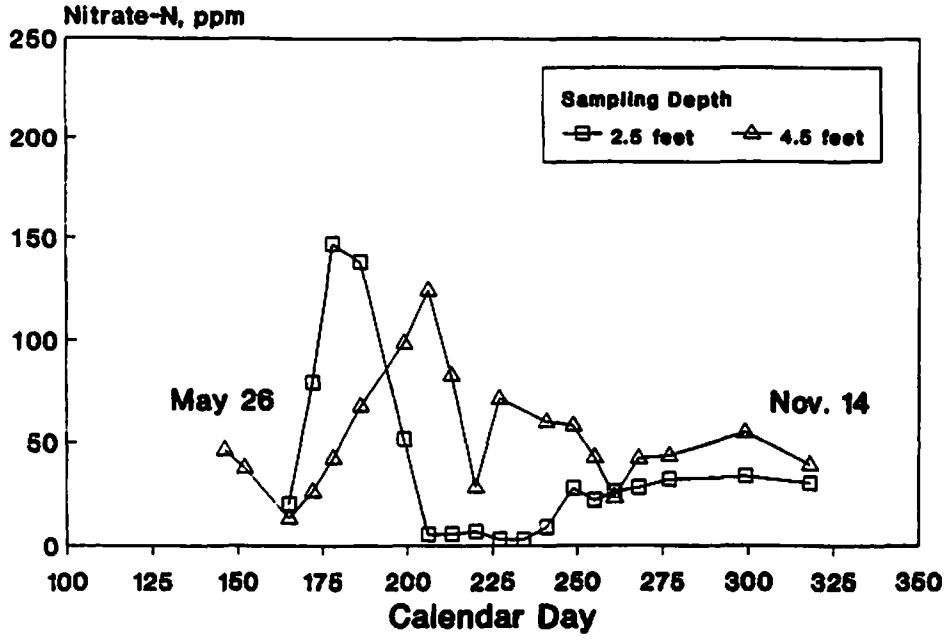


Cultivar - Norkota
Planting Date - May 12
Harvest Date - Sept. 20

N rate and mgmt. -
80 lb N/A starter
90 lb N/A hilling
90 lb N/A irrigation (late July)
Total 260 lb N/A

Total Yield - 280 cwt/A

Figure 2. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 1. May 26 indicates the first sampling date and Nov. 14 indicates the last sampling date.

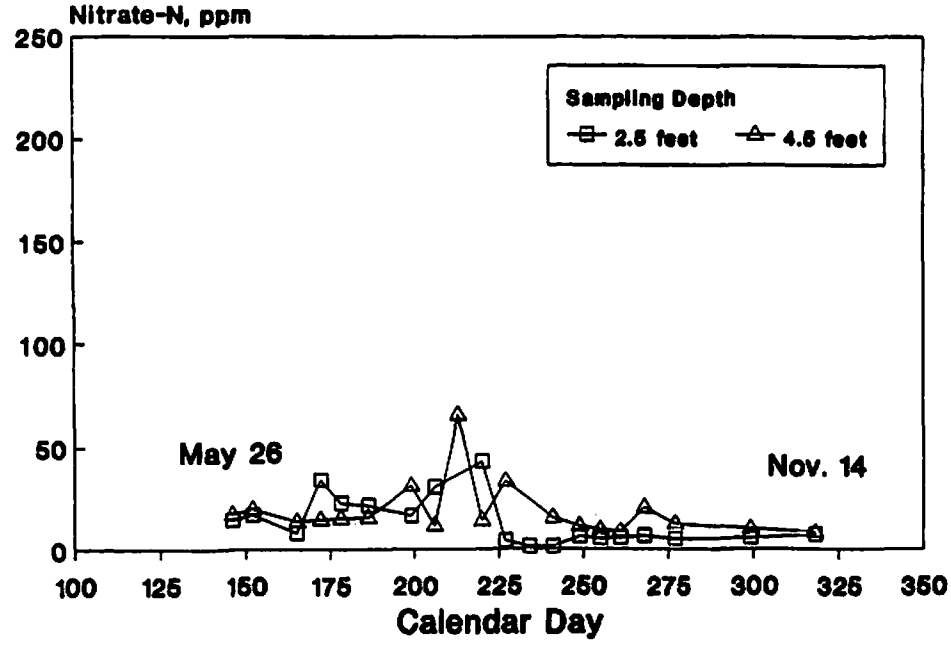


Cultivar - Russet Burbank
Planting Date - April 18
Harvest Date - Sept. 20

N rate and mgmt. -
70 lb N/A starter
180 lb N/A emergence (82-0-0)
75 lb N/A hilling
Total 325 lb N/A

Total Yield - 490 cwt/A

Figure 3. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 2. May 26 indicates the first sampling date and Nov. 14 indicates the last sampling date.

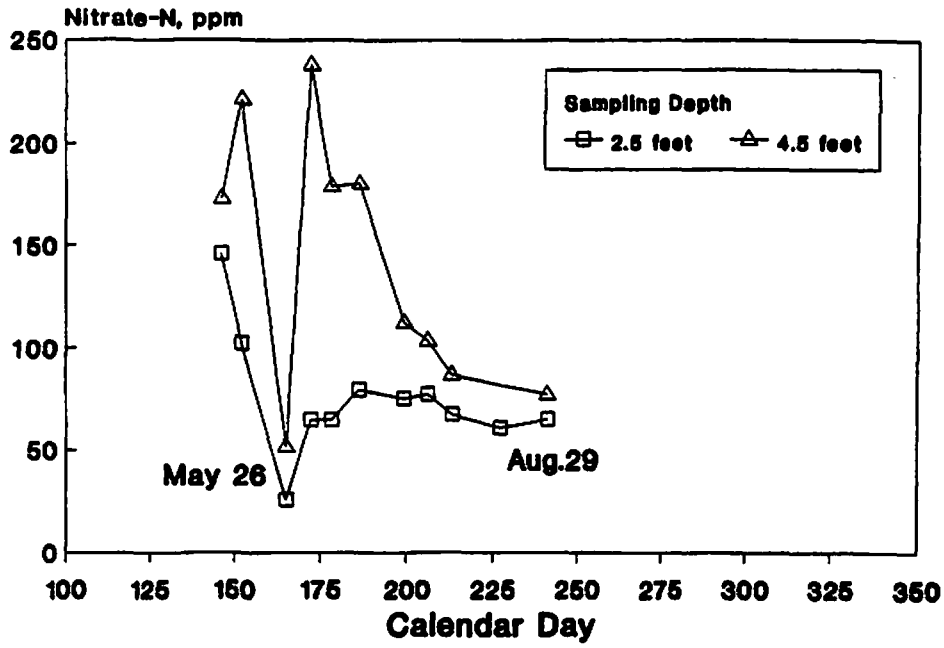


Cultivar - Russet Burbank
Planting Date - April 20
Harvest Date - Sept. 25

N rate and mgmt. -
60 lb N/A starter
80 lb N/A hilling
60 lb N/A irrigation (mid-July)
Total 200 lb N/A

Total Yield - 660 cwt/A

Figure 4. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 3. May 26 indicates the first sampling date and Nov. 14 indicates the last sampling date.

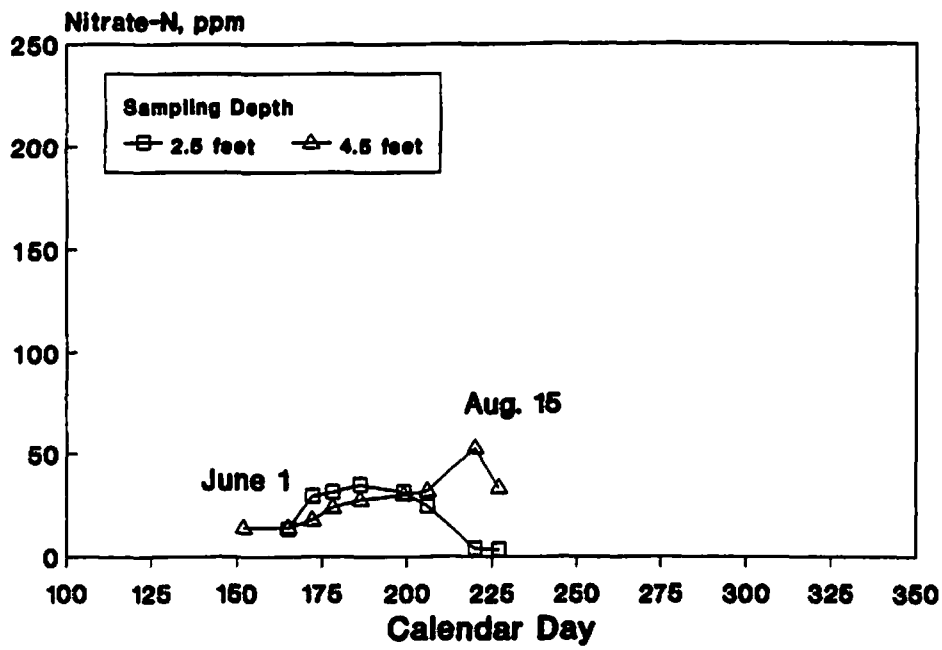


Cultivar - Norkota
Planting Date - April 20
Harvest Date - August 29

N rate and mgmt. -
60 lb N/A starter
100 lb N/A emergence
110 lb N/A hilling
Total 270 lb N/A

Total Yield - 450 cwt/A

Figure 5. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 4. May 26 indicates the first sampling date and Aug. 29 indicates the last sampling date.



Cultivar - Norchip
Planting Date - April 25
Harvest Date - August 29

N rate and mgmt. -
90 lb N/A starter
35 lb N/A emergence
Total 125 lb N/A

Total Yield - 400 cwt/A

Figure 6. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 5. June 1 indicates the first sampling date and Aug. 15 indicates the last sampling date.

EVALUATION OF N-HIB AS A NITROGEN AND CALCIUM SOURCE FOR POTATOES[1]

Carl Rosen, Duane Preston, and John Lamb[2]

ABSTRACT: Two field experiments were conducted to evaluate the effects of N-hib as a Ca and N source for potato production. One experiment was conducted at Becker, MN under irrigated conditions using the cultivar 'Reddale'. The other experiment was conducted at Grand Forks, ND under nonirrigated conditions using the cultivar 'Norchip'. Under the conditions of these studies, N-hib did not improve yields or tuber quality over conventional sources of Ca and N. Adding Ca as gypsum or N-hib had no effect on potato yield or tuber quality indicating that the amount of Ca added from these amendments was low in relation to that supplied by the soil.

N-hib is a recently introduced product that has been promoted to improve potato yield and quality. The product has an analysis of 12% calcium and is registered as calcium monocarbamide monohydrogen chloride. N-hib is intended to be mixed with urea or urea containing solutions, reduce nitrification, and supply calcium. Little research has been conducted to evaluate the effects of N-hib on potato production. The objectives of these experiments, therefore, were to determine the effects of N-hib on potato yield and tuber quality and to compare these effects to those obtained with conventional N and Ca sources.

EXPERIMENTAL PROCEDURES:

Field experiments were conducted at two locations: the Sand Plains Research Farm in Becker, MN under irrigation and the Potato Research Farm in Grand Forks, ND. Procedures varied with each location and therefore each location will be discussed separately.

Sand Plains Research Farm, Becker, MN: the soil at this location is classified as a Hubbard loamy sand and had the following soil test values: pH - 6.3; Organic matter - 2.5%; Bray P1 - 95 lb/A; NH_4OAc K, Mg, Ca - 282 lb/A, 409 lb/A, 1473 lb/A respectively; Hot Water B - 0.2 ppm; 2 N KCl nitrate-N (0-2 ft)- 14 lb/A. The cultivar 'Reddale' was planted April 20, 1989. This cultivar was selected because it usually has low levels of tuber Ca which may be the cause of the high incidence of internal browning under irrigated conditions. All plots received the fertilizer pretreatment which was 875 lbs 8-10-30 banded at planting and 100 lbs 34-0-0 at emergence. The N-hib was mixed with liquid urea to give a final analysis of 18-0-0-7Ca. There were six treatments:

1. 70 lbs N/A as urea at hilling
2. 70 lbs N/A as urea at hilling, 80 lbs Ca/A as gypsum at emergence
3. 70 lbs N/A as urea at hilling, 80 lbs Ca/A as gypsum at emergence, 2 lbs B/A at hilling
4. 70 lbs N/A as urea plus 30 lbs Ca/A as N-Hib at hilling
5. 70 lbs N/A as urea plus 30 lbs Ca/A as N-Hib at hilling, 2 lbs B/A at hilling
6. 70 lbs N/A as urea plus 30 lbs Ca/A as N-Hib at hilling, 2 lbs B/A (foliar) split at hilling and three weeks after hilling

All plots were hilled June 9. The experimental design was a randomized complete block with 4 replications. Irrigation was used to supplement rainfall to provide approximately 1.5 - 2" of water per week. Vines were killed August 1 and tubers were harvested August 28. Leaf (petiole plus leaflets) samples were collected July 13 and a subsample of tubers was collected at harvest for elemental analysis. A subsample of 25 tubers from each size category was cut to determine the incidence of brown center and/or hollow heart.

Potato Research Farm, Grand Forks, ND: The soil at this location is classified as a Nutley/Aberdeen silty clay loam and had the following soil test results: pH - 7.8; Organic matter - 5.3%; Olsen P - 30 lb/A; NH_4OAc K, Mg, Ca - 445 lb/A, 795 lb/A, 5000 lb/A respectively; Hot Water B - 1.3 ppm; 2 N KCl nitrate-N (0-2 ft)- 46 lb/A. The cultivar 'Norchip' was planted June 1, 1989. There were five treatments:

1. Control, no fertilizer applied
2. Conventional: 50 lbs N/A as urea broadcast and incorporated before planting
3. Conventional plus 70 lbs N/A as 28% prior to emergence banded near the row
4. Conventional plus 70 lbs N/A plus 30 lbs Ca/A as N-Hib before emergence banded near the row
5. Conventional plus 70 lbs N/A plus 30 lbs Ca/A as N-Hib before emergence banded near the row plus 2 lbs B/A (foliar) split in 2 applications (at hilling and 3 weeks after hilling)

All plots except the controls received 20 lb P_2O_5/A as a broadcast application before planting. All plots were hilled July 20. The experimental design was a randomized complete block with 6 replications. Leaf samples were collected on July 31 and subsamples of tubers were collected at harvest for elemental analysis. Tubers were harvested September 28, 1989.

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[1] Partial support for this project was provided by Stoller Chemical Co.
[2] Assoc. Prof., Dept. Soil Science; Area Exten. Agent-Potato; Assist. Prof., North West Expt. Sta.

RESULTS:

Becker, MN: Yields of Reddale potatoes were significantly lower with N-hib plus foliar B compared to the other treatments (Table 1). Yields with N-hib and N-hib plus soil applied B were similar to yields with urea and urea plus gypsum. Surprisingly, the highest yields were obtained when urea was applied with gypsum and soil B. Further experimentation is needed to confirm this apparent response to soil applied B. None of the treatments significantly affected the internal browning disorder, which was generally high in all treatments (Table 2). Boron applications increased boron levels of leaves (Table 3). Nitrogen concentrations in tubers and leaves were not significantly affected by treatment, but levels tended to be higher in the N-hib treatments. Calcium levels in leaf tissue were not affected by treatment. Zinc levels in leaves tended to be low in all treatments and may indicate the need for supplemental zinc. Calcium levels in tubers were not affected by treatment, but tended to be highest when Ca was applied either in the form of gypsum or N-hib (Table 4). Boron levels in tubers tended to be higher when boron was applied, although the overall effect was slight and nonsignificant.

Grand Forks, ND: This experiment was conducted without irrigation which simulates conditions for over 90% of the growers in the Red River Valley. Unfortunately, the summer of 1989 was extremely dry which caused severe crop stress, low yields, and high experimental variability. Yields were not affected by any of the treatments, although the no fertilizer control tended to be lower than the other treatments (Table 5). Chip color and specific gravity of the tubers were not affected by treatment (Table 6). Magnesium concentrations in leaf tissue were highest in the control plot and boron concentrations were highest when boron was applied (Table 7). Other nutrient levels in the leaves were not affected by treatment. Nutrient concentrations in tubers were not affected by treatment (Table 8). In general, these results indicate the drought was severe enough to override any treatment effects.

SUMMARY:

Under the conditions of these studies, N-hib did not improve yields or tuber quality over conventional sources of Ca and N. Adding Ca as gypsum or N-hib had no effect on potato yield or tuber quality, indicating that the amount of Ca added from these amendments was low in relation to that supplied by the soil.

Table 1. Comparative effects of N-hib, urea, and supplemental calcium and boron on Reddale potato yields (Becker, 1989).

Treatment	Tuber Size				
	<1"	1-2"	2-3.5"	>3.5"	Total
	cwt/A				
urea	11.5	105.8	291.9	59.0	468.2
urea+gyp	11.1	110.9	296.9	51.6	470.5
urea+gyp+B	12.0	114.2	333.6	54.8	514.6
N-Hib	14.7	110.6	290.9	55.8	472.0
N-Hib+B (soil)	14.8	104.6	283.4	68.8	471.7
N-Hib+B (foliar)	11.4	109.1	258.9	59.8	439.1
Significance	NS	NS	*	NS	**
LSD (0.05)	--	--	42.9	--	27.3

NS = Nonsignificant, * = Significant at 5%,
** = Significant at 1%.

Table 2. Comparative effects of N-hib, urea, and supplemental calcium and boron on internal browning of Reddale tubers (Becker, 1989).

Treatment	Tuber Size		
	1-2"	2-3.5"	>3.5"
	% infected		
urea	6.0	25.3	73.0
urea+gyp	2.0	17.5	70.0
urea+gyp+B	2.0	21.0	76.0
N-Hib	1.0	15.0	72.0
N-Hib+B (soil)	3.0	11.5	76.3
N-Hib+B (foliar)	7.0	21.5	78.3
Significance	NS	NS	NS

NS = Nonsignficant.

Table 3. Comparative effects of N-hib , urea, and supplemental calcium and boron on nutrient concentrations in Reddale leaf tissue sampled July 13 (Becker, 1989).

Treatment	Nutrient										
	NO3-N	Total-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	ppm	%					ppm				
Urea	1971	4.50	0.30	4.35	1.28	0.55	80	99	15	24	39
Urea+gypsum	2025	4.52	0.32	4.70	1.25	0.52	79	86	16	27	37
Urea+gypsum+Boron	1687	4.31	0.31	4.76	1.32	0.55	79	92	14	22	97
N-hib	2453	4.56	0.30	4.37	1.19	0.50	81	93	17	21	36
N-hib+Boron (soil)	2446	4.70	0.32	4.55	1.21	0.55	82	96	19	24	82
N-hib+Boron (foliar)	2155	4.43	0.33	4.39	1.17	0.54	78	88	19	21	53
Significance	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	**
LSD	--	--	--	--	--	--	--	--	3	--	19

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%.

Table 4. Comparative effects of N-hib , urea, and supplemental calcium and boron on nutrient concentrations in Reddale tubers sampled at harvest August 25 (Becker, 1989).

Treatment	Nutrient									
	Total-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%			ppm						
Urea	1.48	0.29	2.33	240	1255	183	10	21	7	8.5
Urea+gypsum	1.42	0.29	2.32	279	1224	138	10	21	7	8.3
Urea+gypsum+Boron	1.50	0.30	2.45	284	1266	135	10	21	7	9.2
N-hib	1.57	0.29	2.38	276	1262	140	10	23	7	9.0
N-hib+Boron (soil)	1.61	0.30	2.40	294	1243	153	10	23	7	9.8
N-hib+Boron (foliar)	1.60	0.30	2.50	276	1261	125	10	24	7	9.6
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant.

Table 5. Effect of N-hib, supplemental nitrogen, and foliar boron on Norchip tuber yield (Grand Forks, 1989).

Treatment	Tuber Size				
	<1"	1-2"	2-3.5"	>3.5"	Total
	cwt/A				
Control	1.2	36.5	83.3	14.8	135.8
Conventional	0.8	34.3	95.9	25.8	156.8
Conventional + urea	0.7	33.2	91.2	17.3	142.4
Conventional + N-Hib	1.0	34.2	94.2	24.8	154.2
Conventional + N-Hib + B	0.6	33.8	95.0	25.2	154.6
Significance	NS	NS	NS	NS	NS

NS = Nonsignificant.

Table 6. Effect of N-hib, supplemental nitrogen, and foliar boron on Norchip tuber specific gravity and chip color.

Treatment	Specific gravity	Color
Control	1.077	46.3
Conventional	1.077	47.5
Conventional + urea	1.080	46.2
Conventional + N-Hib	1.077	45.8
Conventional + N-Hib + B	1.076	44.3
Significance	NS	NS

NS = Nonsignificant.

Table 7. Effect of N-hib, supplemental nitrogen, and foliar boron on nutrient concentration in Norchip leaf tissue sampled July 31 (Grand Forks, 1989).

Treatment	Nutrient												
	NO3-N	Total-N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	ppm	%					ppm						
Control	1082	4.41	0.33	3.94	1.39	1.46	103	154	79	90	29	19	40
Conventional	986	4.40	0.32	3.87	1.36	1.26	105	156	61	88	30	21	38
Conventional+urea	980	4.29	0.31	4.01	1.37	1.29	105	157	90	89	29	20	44
Conventional+N-hib	1157	4.37	0.31	3.97	1.33	1.23	104	153	109	84	28	19	37
Conventional+N-hib+boron	1239	4.31	0.32	4.03	1.39	1.25	105	159	40	94	29	19	69
Significance	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	**
LSD	--	--	--	--	--	0.17	--	--	--	--	--	--	11

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%.

Table 8. Effect of N-hib, supplemental nitrogen, and foliar boron on nutrient concentration in Norchip tubers sampled at harvest (Grand Forks, 1989).

Treatment	Nutrient											
	Total-N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	%			ppm								
Control	1.70	0.24	2.52	492	1286	18.3	139	37	8	28	10	6.3
Conventional	1.67	0.24	2.49	451	1282	14.6	111	31	8	27	10	6.4
Conventional+urea	1.59	0.24	2.50	487	1223	13.7	146	42	7	27	9	5.8
Conventional+N-hib	1.61	0.24	2.49	499	1221	18.7	138	39	7	27	10	6.0
Conventional+N-hib+boron	1.66	0.24	2.47	437	1241	11.7	105	42	7	27	9	5.6
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant.

NITROGEN SOURCES, RATES, AND TIME OF APPLICATION FOR HARD RED SPRING WHEAT

J.A. Lamb, S.D. Evans, and G.W. Rehm[1]

A renewed interest in foliar application of nitrogen on spring wheat occurred in 1986. This interest came from a hefty discount on protein below 14% at the elevator and increased attention by producers to intensify their management of small grains similar to what has occurred in western Europe and Eastern United States. Another factor is although the producers have superior varieties (Marshall and Wheaton) at their disposal with regard to yield and lodging, these varieties produce notoriously low protein grain. Many questions about application of liquid N materials relative to source, time of topdress application, and rate applied. To answer these questions, a study was established at the Northwest and West Central Experiment Stations with the objective to determine proper source, rate, and time of application of foliar applied N for optimum grain yield and protein content on spring wheat.

MATERIALS AND METHODS:

This study was conducted at two locations each year; Crookston and Morris in 1987 and 1988 and Mahnomen and Morris, MN in 1989. These locations represent a majority of the 3 million acres of hard red spring wheat grown in western Minnesota. The treatments involved all combinations of two sources (liquified Urea, and Urea Ammonium Nitrate solution), three times of application (tiller, boot, and heading - Zadoks 2.1, 4.3, and 5.6 respectively), and five N rates (0, 10, 20, 40, and 80 lb N A^{-1}). The plot area was soil tested and fertilized with Urea to a level of 120 lb N A^{-1}, Soil NO_3^--N 0-2' + fertilizer N). This corresponded to the Minnesota N recommendation for a 60 bu A^{-1} yield goal in 1987. The spring wheat variety 'Marshall' was used at both locations. This is a high yielding semi-dwarf variety planted on 70% of the Minnesota wheat acreage which produces a low protein grain. The seeding rate was 100 lb A^{-1}. The wheat was seeded with a double disc press wheel drill mid-April all three years. The treatments were applied with a sprayer delivering a volume of 50 gallon A^{-1} at 30 psi pressure. Leaf burn was visually evaluated one week after each application. Whole plant samples were taken at soft dough and N concentration was determined in 1987 and 1989. The grain was harvested by small plot combine in late July 1987 to 1989 and grain protein concentration was determined on the grain in 1987 and 1989.

RESULTS AND DISCUSSION:

During every year for this study, the wheat crop experienced drought stress at some point in the growing season. Most noteable was the 1988 drought which seriously reduced grain yields at both Crookston and Morris. The season started with no subsoil moisture and no spring precipitation. Only a late-May rain brought the crop through to any production at all. Both 1987 (Crookston and Morris) and 1989 (Mahnomen and Morris), had enough precipitation and soil moisture to raise reasonable crops.

Grain Yield: At all six site-years, grain yield was affected only in 1987 at Crookston (Table 1). A significant increase of 2.4 bu/A occurred with 40 lb N/A. The time of application or N source did not affect grain yield. At the other five-site-years, topdress N application did not effect grain yield. This suggests that the preplant N application supplied more than adequate N for the grain yields obtained at the five-site-years and additional N applied during the growing season was not needed.

Grain Protein and Plant N Uptake: Grain protein and plant N uptake was measured in 1987 and 1989. Because of the severe drought in 1988, grain protein and plant N uptake were not measured. In 1987, N rate increased grain protein concentration 1.0 and 0.6% at Crookston and Morris, respectively (Table 2).

Please refer to title page of this publication for information regarding application and use of this article.

[1] Soil Scientist, Northwest Experiment Station, University of Minnesota, Crookston, MN; Soil Scientist, West Central Experiment Station, University of Minnesota, Morris, MN; and Extension Soil Specialist, Dept. of Soil Science, University of Minnesota, St. Paul, MN.

Table 1. Grain yield as affected by topdress N, source, and time of application at Crookston and Morris, MN, 1987-1989

N Rate	Crookston* 1987	Crookston* 1988	Crookston* 1989	Morris 1987	Morris 1988	Morris 1989
lb/A	bu/A					
0	49.0	25.5	48.4	58.2	8.6	56.1
10	46.9	27.4	48.6	56.6	8.2	57.0
20	50.3	27.1	47.4	59.2	8.2	55.9
40	51.4	26.1	45.8	56.1	6.9	55.6
80	49.5	25.9	45.2	55.9	8.2	54.7
Source						
UAN	49.5	26.5	46.3	56.2	8.1	55.8
Urea	49.5	26.8	47.2	57.7	7.7	55.8
Time						
Tiller	51.1	26.8	49.5	54.5	6.7	55.8
Boot	46.6	27.9	46.2	57.5	7.3	56.6
Head	50.9	25.2	44.6	58.8	9.6	55.1
Statistical Analyses						
Time	NS	NS	NS	NS	NS	NS
Source	NS	NS	NS	NS	NS	NS
Rate	.04	NS	NS	NS	NS	NS
Source*Rate	NS	NS	NS	NS	NS	NS
Time*Source	NS	.05	NS	NS	NS	NS
Time*Rate	NS	NS	NS	NS	NS	NS
Time*Source*Rate	NS	NS	NS	NS	.06	NS
C.V.	10.1	12.1	13.8	10.0	32.7	5.7

* Crookston location was actually in Mahnomen County in 1989.

Nitrogen source and application time did not affect this response. In 1989 there was a significant source by N rate interaction at both locations (Table 2). At Mahnomen the UAN increased grain protein 0.6% while Urea had no effect (Table 3). At Morris, both sources increased grain protein 0.3% but the maximum protein occurred at the 20 lb N/A rate for UAN and at 80 lb N/A for Urea (Table 3). Also in 1989 at Morris the effect of N rate on grain protein was different depending on time of application. The N applied at tiller and boot growth stages increased protein concentration up to the 80 lb N/A rate (Table 4). The N applied at heading had a maximum grain protein concentration at 20 lb N/A and actually decreased protein at the 80 lb N/A rate (Table 4).

The application of N significantly effected the N uptake at soft dough only in 1987 at Morris. This 10.8 lb/A increase was maximized at the 40 lb N/A application rate. Again time of application and N source did not effect the N uptake by the wheat.

Table 2. Grain protein and whole plant N uptake as affected by topdress N, rate, source, and time of application at Crookston and Morris, 1987 and 1989.

	Crookston*				Morris			
	Grain Protein		Plant N Uptake		Grain Protein		Plant N Uptake	
N Rate lb/A	1987	1989	1987	1989	1987	1989	1987	1989
	---- % ----		-- lb/A --		---- % ----		-- lb/A --	
0	12.2	13.0	83.2	81.4	13.4	15.3	102.9	146.9
10	12.7	13.0	82.2	82.8	13.7	15.3	99.7	147.7
20	12.8	13.2	90.5	80.7	13.7	15.5	112.6	144.9
40	13.0	13.3	92.3	85.9	13.9	15.5	113.7	146.9
80	13.2	13.4	94.1	77.7	14.0	15.4	113.7	148.9
N Source								
UAN	12.9	13.2	89.1	84.7	13.8	15.4	107.4	147.0
Urea	12.9	13.3	90.5	78.9	13.9	15.5	112.4	147.2
Time								
Tiller	12.9	13.0	91.7	91.7	14.0	15.5	104.4	146.4
Boot	12.9	13.0	83.7	68.9	13.8	15.5	116.9	146.7
Head	12.9	13.7	93.9	84.8	13.7	15.3	108.5	148.2
Statistical Analyses								
Time	NS	.10	NS	NS	NS	NS	NS	NS
Source	NS	NS	NS	NS	NS	NS	NS	NS
Rate	.0001	NS	NS	NS	.0001	NS	.08	NS
Source*Rate	NS	.10	NS	NS	NS	.09	NS	NS
Time*Source	NS	NS	NS	NS	NS	NS	NS	NS
Time*Rate	NS	NS	NS	NS	NS	.06	NS	NS
Time*Source*Rate	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	3.0	4.8	21.6	29.1	2.3	2.9	17.7	10.9

* Crookston location was actually in Mahnomen County in 1989.

SUMMARY:

At the time of this report, high protein wheat grain is being discounted so it is not economically feasible to consider the practice of N topdressing to increase grain protein concentration. The data implies that the use of topdress N in a situation where adequate preplant has been applied and not lost to denitrification or leaching will not increase grain yields under normal growing conditions (1987). Grain protein content can be increased with the use of topdress N. The N source and time of application did not consistantly effect this increase.

Table 3. The interaction of N rate and N source on grain protein concentration at Crookston and Morris, 1989.

N Rate	Crookston*		Morris	
	UAN	Urea	UAN	Urea
lb/A	-------- %	-------	------- %	------
0	13.0	13.1	15.3	15.3
10	12.8	13.2	15.3	15.4
20	13.0	13.4	15.6	15.3
40	13.3	13.2	15.5	15.5
80	13.6	13.2	15.2	15.6

* Crookston location was actually in Mahnomen County in 1989.

Table 4. The interaction of N rate and time of application on grain protein concentration in 1989 at Morris.

N Rate	Tiller	Boot	Head
lb/A	----------	%	----------
0	15.3	15.3	15.2
10	15.2	15.3	15.4
20	15.3	15.5	15.5
40	15.7	15.6	15.2
80	15.7	15.5	15.1

NITROGEN AND SULFUR FERTILIZATION OF HARD RED SPRING WHEAT IN GOODHUE COUNTY

Brian Schreiber, Greg Cremers, Andy Scobbie, George Rehm[1/]

ABSTRACT: Studies were conducted at two locations in Goodhue County to determine the effect of N rate, method of N application, and S usage on the yield and protein content of hard red spring wheat in southeast Minnesota. Split applications were not superior to single applications of fertilizer N. A rate of 60 lb. N/acre was adequate for optimum yield. Use of S had no significant effect on either grain or straw yield as well as the protein content of the grain.

Introduction:

Hard red spring wheat is not commonly grown in eastern and southeastern Minnesota. Yet, it might be considered as an alternative to corn for the region.

Fertilizer requirements for profitable production of this crop in northwestern and west-central Minnesota have been the focus of many research trials. The environment of southeastern Minnesota, however, is much different than the environment in western Minnesota. Soils are also different. Therefore, it is reasonable to expect that fertilizer management practices might be unique for each region of the state.

Profitable production of hard red spring wheat is dependent on both yield and protein content of the grain. Therefore, a measurement of the protein percentage should be included in any evaluation of fertilizer management practices.

Sulfur, S, is a major component of plant proteins. The importance of S in a fertilizer program for spring wheat production in southeast Minnesota has also been questioned. Therefore, it's important to also fully evaluate the effect of S fertilization on spring wheat production in the region.

Objectives:

Recognizing the needs cited above, this study was conducted to:

- Determine the effect of N management practices on the yield and protein content of spring wheat grown in southeastern Minnesota.
- Measure the effect of the addition of S to a fertilizer program on grain yield and protein percentage.

Experimental Procedure:

This study was conducted at 2 locations in Goodhue County in 1989. Soils at the experimental sites were typical of soils in the area. Prior to initiation of the study, soil samples were collected from 0-6, 6-12, 12-24, and 24-36 inches. Results of the analysis of these samples are summarized in Table 1.

Nitrogen management variables consisted of 3 rates (0, 60, 120 lb. N/acre) applied in 3 timing options (single application; 1/2 of total N preplant; 1/2 at flag leaf stage; 1/2 of total N preplant; 1/4 at the tiller stage; 1/4 at the flag leaf stage. The impact of fertilizer S was evaluated by comparing the use of 60 lb. N/acre with 30 lb. S/acre applied preplant with the application of 60 lb. N/acre preplant. This comparison was also made for the 120 lb. N/acre rate. Urea (46-0-0) was used to supply the needed N for each method of application. Granular gypsum was used to supply the needed S. Each plot also received a preplant application of 100 lb./acre of 0-46-0 and 100 lb./acre of 0-0-60. All preplant fertilizers were incorporated with a disk prior to planting. The N applied (46-0-0) at tiller and boot stage was broadcast to the established stand without mechanical incorporation. All treatments were arranged to fit a randomized complete block design with 4 replications.

Cooperating farmers were responsible for seedbed preparation, planting, and herbicide usage to control major weed pests. Plots were harvested in mid-to-late July, samples were threshed with a stationary combine. Straw was collected and weighed, and grain samples were analyzed for protein N.

[1/] County Extension Agent, Goodhue County, Assistant Scientist, Junior Scientist, Extension Soil Scientist, respectively.

Table 1. Relevant soil test values for the experimental sites.

Soil Property	Depth	Site: Lindstrom	Site: Davidson
	- in -		
pH	0-6	6.0	6.1
P, (Bray & Kurtz #1), ppm	0-6	21.3	33.0
K, (1M $NH_4C_2H_3O_2$), ppm	0-6	141	123
Organic Matter, %	0-6	2.5	2.6
NO_3-N, lb./acre	0-6	12.8	24.6
"	6-12	25.2	22.4
"	12-24	58.3	23.4
"	24-36	35.0	10.1
	Total	131.3	80.5

Results and Discussion:

Yield and protein data for the Lindstrom and Davidson sites are summarized in Tables 2 and 3, respectively. At the Lindstrom site, neither grain nor straw yield was affected by the method of N application for both rates of fertilizer N used (Table 2). Yields were lower than expected which can be attributed, in part, to dry conditions during the early part of the growing season.

The method of N application did have a significant effect on the protein content of the grain. Both split applications produced a higher protein percentage. Yet, there was no significant difference in the 2 methods used for the split application.

Grain yield, straw yield, and protein content of the grain were increased by the rate of N used. The rate of 60 lb. N/acre was adequate. The lack of a response to the higher N rate can be attributed, in part, to the large amount of carryover NO_3-N measured to the depth of 3 feet (131.3 lb./acre). The response to the rate of N applied was not affected by the method of application.

In agreement with the results at the Lindstrom site, the split application of N produced a significant increase in the protein percentage at the Davidson location. The use of 3 instead of 2 N applications had no effect on protein percentage.

Neither straw nor grain yield was affected by the number of N applications used at the Davidson location (Table 3). Based on the results obtained from these 2 locations, it would appear that split applications of fertilizer N are not needed for the production of hard red spring wheat in southeast Minnesota.

The protein percentage as well as the grain and straw yield was increased by the rate of N used. The use of 60 lb. N/acre was certainly adequate for top production at these sites. The previous crop at this location was soybeans and there was a considerable amount of carryover NO_3-N at the start of the growing season. Therefore, a large response to fertilizer N would not be expected.

The application of 30 lb. S/acre in combination with either 60 or 120 lb. N/acre had no significant effect on either grain or straw yield. There was also no effect on the protein content of the grain. This was true for both locations. These data show that there is no need for S in a fertilizer program for hard red spring wheat in southeast Minnesota.

Table 2. The effect of nitrogen rate, timing of nitrogen application and sulfur use on grain and straw yield and protein content of hard red spring wheat at the Lindstrom site.

N			S	Straw	Grain	Grain
Preplant	Tiller	Flag		Yield	Yield	Protein
- - - - - - - - - - - - lb./acre - - - - - - - - - - - -				ton/acre	bu./acre	%
0	0	0	0	1.52	29.4	13.6
30	15	15	0	2.03	37.7	14.7
30	0	30	0	2.00	37.0	15.1
60	0	0	0	1.94	33.0	13.4
60	0	0	30	2.06	34.4	14.4
60	30	30	0	1.85	31.2	16.1
60	0	60	0	1.91	31.3	15.5
120	0	0	0	1.68	33.2	14.9
120	0	0	30	2.07	32.7	15.6

Table 3. The effect of nitrogen rate, timing of nitrogen application and sulfur use on grain and straw yield and protein content of hard red spring wheat at the Davidson site.

N			S	Straw	Grain	Grain
Preplant	Tiller	Flag		Yield	Yield	Protein
- - - - - - - - - - - - lb./acre - - - - - - - - - - - -				ton/acre	bu./acre	%
0	0	0	0	1.42	33.1	11.8
30	15	15	0	1.69	40.3	14.0
30	0	30	0	1.67	40.3	13.6
60	0	0	0	1.62	41.5	12.9
60	0	0	30	1.77	42.6	13.1
60	30	30	0	1.74	39.0	14.4
60	0	60	0	1.74	43.7	14.2
120	0	0	0	1.66	38.7	13.0
120	0	0	30	1.74	39.7	13.8

EFFECTS OF NUTRIENT SOURCES, APPLICATION TIMING, AND RATE ON ALFALFA PRODUCTION (AND SUBSEQUENT CORN CROPS)

M.A. Schmitt, G.W. Randall, and C.C. Sheaffer[1/]

ABSTRACT: The application of manure and inorganic fertilizer both increased forage yields when applied as a plowdown treatment. While the manure resulted in poor stands of alfalfa due to a compaction problem at Waseca, the response due to the fertilizer was significant. At Rosemount, the forage responded positively to the manure applications, except with the highest rate. The high levels of inorganic nitrogen measured in the soil in the summer were not present, except for the highest manure rate, in the fall.

A long-term project was started in 1989 to examine the effects of manure and alfalfa on nitrogen (N) credits for the following corn crops. An initial result of this project is the effects of various rates of manure and inorganic fertilizer on new alfalfa. Farmers often have questions regarding yields, forage quality, and nodulation when applying manure onto alfalfa ground. This paper will look specifically at first cutting forage yields and first-year soil N fluctuations due to the manure treatments. All producers handling manure need to be aware of environmental concerns of N in the groundwater.

OBJECTIVES

1. Evaluate the effects of plowdown and topdress fertilizer application, commercial and manure fertilizer sources, and rates of nutrient application on alfalfa.

2. Evaluate alfalfa nutrient uptake, forage quality, stand density, and dry matter production as a function of the various fertilizer treatments.

3. Monitor soil N forms from the manure treatments and correlate values with soil N data and corn production values in the N equivalency plots.

4. Compare and evaluate the overall economic feasibility of the fertility treatments in a 5-year rotation.

Materials and Methods

Trials were established at agricultural experiment stations at Rosemount and Waseca. At Rosemount, hog manure was used on a shallow silt loam lying on outwash gravel soil. At Waseca, dairy manure was used on a clay loam soil. Three rates of manure (3000, 6000, and 12000 gallons per acre) were broadcast and incorporated immediately. Inorganic fertilizer was also used as treatments--applied to give equivalent phosphorus and potassium rates as provided in the manure. Alfalfa was seeded directly at both sites, on April 25 in Rosemount and May 16 in Waseca.

Results

Rosemount Location. The effect of the three rates of preplant inorganic fertilizer and manure treatments on forage dry matter production at Rosemount is listed in Table 1. No visible stress was seen during the early growing season. The treatments with manure did produce taller, darker appearing alfalfa than did the inorganic fertilizer treatments. The first cutting yields increased with the manure treatments up until the highest manure rate, at which the alfalfa was noticeably lodged. Crude protein content was not affected by the treatments. The second cutting yields were not statistically different due to the treatment effects. The second half of the growing season was extremely dry and the plots also had leafhopper pressure. The weed component of the overall forage yields was positively correlated with increasing manure rates.

Since the soil tests at Rosemount were categorically "high" (Bray P at 35 ppm and K at 200 ppm) the response of the alfalfa was most likely due to factors other than just the P and K. Note, however, that yields increased with the inorganic fertilizer additions as well.

The elemental composition of the first cutting alfalfa was made using inductively coupled plasma emission spectroscopy (ICP). Nitrogen and phosphorus concentrations were unaffected by treatments (Table 2). The potassium concentrations increased with increasing manure and fertilizer rates. Other nutrient means

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[1/] Extension Soil Scientist-Soil Fertility, Department of Soil Science, Soil Scientist, Southern Experiment Station, and Agronomist, Department of Agronomy and Plant Genetics, respectively.

with significant treatment effects included: a) a lower magnesium content with manure treatments, and b) a lower zinc content with the fertilizer treatments, both compared to the control.

Waseca Location. The increasing rates of manure resulted in lower yields of alfalfa at the Waseca site (Table 3)--which tested "low for P (8.5 ppm) and K (94 ppm). However, the forage yields increased significantly as the rate of inorganic fertilizer increased. As was true at Rosemount, the amount of weeds increased as the manure rates increased.

A major stand problem at Waseca was most likely the cause for the lower yields with the manure additions. The application equipment created a severe compaction problem, resulting in almost no stand in the wheel tracks. In addition, the alfalfa was stressed throughout the growing season by a shortage of rainfall and by leafhoppers. Due to the extremely stressed condition of the alfalfa at harvest, plant nutrient analysis was not conducted.

Soil N Status. The N status of the soil can affect alfalfa's nodulation and overall growth as well as have a direct influence on the risk of groundwater contamination. At Rosemount, the inorganic N concentrations were a function of the manure rate (Table 4). The control treatment characterizes the natural inorganic N fluctuations throughout the growing season. The manured plots' available N peaked during June and steadily decreased through late summer. At November 1, only the highest rate of manure resulted in higher inorganic N concentrations in the soil. Ammonium N dominated the inorganic N fraction early in the season whereas nitrate N was dominant later.

Summary

The application of low to medium rates of manure can result in a significant yield increase in newly established alfalfa with proper management. Inorganic fertilizer applications can result in similar increases with fewer potential management problems. The key in making this manure/alfalfa system work is applying the manure so that seedbed quality is maintained. Although the manure brings certain weed problems to the stands, these generally do not last past the first cutting. While manure adds substantial amounts of N to the soil, the treatments result in few to no soil N differences at the end of the growing season.

This is the first year of a 5-year study.

Table 1. Forage yields and composition as influenced by treatments, Rosemount, 1989.

	1st Cutting				2nd Cutting
	Total D.M.	Alfalfa D.M.	Lodging Score	Crude Protein	Total D.M.
	- - - Ton/A - -		(1-5)	- % -	- Tons/A -
Control	1.552	1.503	4.75	20.78	0.848
Manure-Low	1.792	1.680	2.00	20.76	0.645
Manure-Medium	1.963	1.818	2.00	21.73	0.978
Manure-High	1.623	1.483	2.50	21.06	0.587
Fertilizer-Low	1.600	1.580	4.00	21.19	0.820
Fertilizer-Medium	1.703	1.677	4.25	21.09	0.830
Fertilizer-High	1.760	1.610	3.00	20.17	0.742
Pr $\geq$ F	0.000	0.052	0.000	0.890	0.185
LSD (0.10)	0.147	0.183	0.790	1.690	.300

Table 2. Elemental composition of the first cutting of forage as affected by treatment, Rosemount, 1989.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	- - - - - - - - % in plant - - - - - - - -					- - - - - - - - - - - - - - ppm in plant - - - - - - - - - - - - - -						
Control	3.323	0.304	2.088	1.483	0.290	95.91	112.84	477.53	26.43	18.46	6.872	27.81
Manure-Low	3.322	0.299	2.427	1.408	0.249	79.81	96.94	475.84	25.13	22.16	5.687	27.75
Manure-Medium	3.478	0.314	2.564	1.532	0.278	106.44	119.68	690.24	31.50	21.62	5.465	30.51
Manure-High	3.368	0.308	2.649	1.549	0.271	152.05	149.51	468.43	39.15	23.18	5.777	30.55
Fertilizer-Low	3.393	0.300	2.073	1.556	0.291	110.11	124.81	547.59	31.96	17.94	6.510	27.99
Fertilizer-Medium	3.375	0.306	3.199	1.554	0.292	111.19	125.53	416.16	32.26	17.22	5.825	28.48
Fertilizer-High	3.225	0.289	2.540	1.476	0.251	146.49	144.51	211.46	34.53	16.10	4.930	29.82
PR ≥ F	0.890	0.352	0.000	0.155	0.000	0.283	0 .343	0.012	0.028	0.024	0.034	>1
LSD (0.10)	0.272	0.016	0.247	0.114	0.019	76.73	51.55	175.64	6.76	3.52	0.981	3.02

Table 3. Yields of first cutting forage as infuenced by treatments, Waseca, 1989.

	Total D.M.	Alfalfa D.M.	Chlorosis Score
	- - - - - Tons/A - - - - -		(1-5)
Control	1.360	1.330	3.00
Manure-Low	1.445	1.375	4.00
Manure-Medium	1.163	1.063	4.00
Manure-High	1.298	0.958	4.00
Fertilizer-Low	1.482	1.380	3.00
Fertilizer-Medium	1.583	1.498	3.00
Fertilizer-High	1.583	1.498	3.00
Pr ≥ F	0.002	0.003	0.000
LSD (0.10)	0.147	0.205	0.0

Table 4. Soil nitrogen concentration as affected by manure rate and sampling date, Rosemount, 1989.

Sampling Date	Manure Rate	0-12"		12-24"	
		NO_3-N	NH_4-N	NO_3-N	NH_4-N
		ppm N			
May 1	none	7.6	19.1	6.6	11.6
	low	10.4	42.8	7.2	15.9
	medium	9.0	54.1	7.9	17.0
	high	8.9	67.9	8.9	21.0
May 31	none	8.9	9.3	8.0	6.7
	low	32.6	11.2	8.8	6.9
	medium	67.0	14.3	12.5	7.9
	high	93.2	34.5	13.0	10.2
June 22	none	9.2	16.2	8.7	13.3
	low	29.8	17.2	12.7	10.1
	medium	49.4	18.1	19.4	13.4
	high	74.0	22.9	29.3	13.6
July 11	none	2.9	8.7	1.9	4.7
	low	9.5	8.7	4.5	5.3
	medium	25.6	10.1	8.9	6.7
	high	57.2	9.9	13.6	5.0
August 3	none	2.4	6.7	0.8	5.8
	low	3.2	7.8	1.0	6.2
	medium	10.7	8.1	3.4	5.7
	high	30.2	9.1	8.2	5.7
August 28	none	2.3	3.6	2.7	0.5
	low	2.2	3.7	2.1	1.5
	medium	2.1	12.1	2.2	3.4
	high	2.8	32.8	2.0	7.1
November 1	none	1.5	6.5	0.1	3.7
	low	1.5	6.4	0.2	3.5
	medium	1.7	7.2	0.2	4.2
	high	8.3	6.5	7.1	4.1

USE OF NITRO ALFALFA IN SOUTHERN MINNESOTA

Neal P. Martin, Timothy L. Wagar, Duane A. Schriever, and George W. Rehm[1]

ABSTRACT: Trials are in progress in southeastern Minnesota to detrmine the amount of N supplied by 'Nitro' to a corn crop in rotation. The N supplied by the 'Nitro' alfalfa is compared to the amount of N supplied by perennial varieties of alfalfa and red clover. In 1989, corn following alfalfa yielded more than corn following corn and this is expected. The amount of N supplied by 'Nitro' was equal to the amount of N supplied by other varieties in the trial.

'Nitro' alfalfa is an "annual" (nondormant variety) alfalfa developed by the USDA-ARS and the University of Minnesota to provide increased amounts of nitrogen over dormant alfalfa varieties in the seeding year through symbiotic fixation of nitrogen (N). Minnesota farmers, especially dairymen, have used alfalfa in a crop rotation with corn very successfully. Alfalfa provides forage as hay or low-moisture silage which supplies high amounts of protein, energy, calcium and vitamins, while corn for silage supplies high energy feed with some protein, minerals and vitamins. The alfalfa is used in stands three-to-five years old and it boosts corn yields the first two years that corn follows alfalfa due to a rotation effect and the addition of N through symbiotic N^2 fixation. Nitro provides a new technology in crop rotations by supplying, in one year, almost as much N as a five-year old stand plus allowing 3 cuttings of forage.

Nitro was selected for higher N concentration in roots and larger root mass than available from other nondormant varieties of alfalfa. Minnesota research, Sheaffer et al, 1989, showed Nitro has 5.4, 3.6, and 3.8 percent more N in forage, N in crowns and N in roots, respectively, than other nondormant alfalfa varieties. Tests conducted at Becker, Lamberton, Rosemount and Waseca (Sheaffer et al., 1989) showed Nitro averaged 94 pounds per acre of N for plowdown in the fall of the seeding year. This was 10 and 38 pounds per acre more than nondormant and dormant alfalfa varieties, respectively. Farmers want to know how Nitro alfalfa will produce on their farms.

Objectives: A field evaluation was established at two sites (Lyle Tjosaas Farm, Byron, and Tom Pyfferoen Farm, Rochester) in southeastern Minnesota to evaluate seeding year yields of Nitro compared to dormant varieties of alfalfa available to Minnesota producers and 'Arlington' red clover. These represented a range in fall growth score (Saranac, 4.5; Ranger, 5.4; and Wrangler, 7.0). A second objective was to examine corn grain yield response following alfalfa at four rates of N (0, 50, 100 and 150 lbs/A of N).

Materials and Methods: At each site, alfalfa was direct seeded at 12 lb/A in April, harvested three times for forage, with the fall growth incorporated into the soil and corn seeded the following spring. The alfalfa varieties and red clover were planted in a randomized complete block arrangement (2 drill widths wide x 160 ft. long) and N rates were split randomly within corn plots and alfalfa plots. Each treatment was replicated 3 times.

Crop conditions at Lyle Tjosaas' Farm:

1988:
Soil Test: Soil texture- silt loam; soil pH, 6.7; Bray 1 phosphorus, 77 lb/A; potassium, 387 lb/A, and sulfur, 10 ppm.
Seeded: April 20, 1988 with 8' Brillion Seeder (16' x 160' plots), 12 lbs/A for alfalfa - 10 lbs/A for red clover
Balan @ 1 gal/A was pre-plant incorporated
Harvest dates: 6/24, 7/29, and 9/07
Fall growth determination: 10/27
Rainfall 1988 - Haverhill (Olmsted County)
April, 2.22; May, 2.22; June, 1.69; July, 1.87; August, 2.9; Sept., 5.64 and Oct., .75; inches. Total of 17.3 inches April thru October; 5.67 inches below normal.

1989: Corn @ 0, 50, 100 and 150 lb/A N over entire plot area. (Four row plots at 27,000-28,000 plants/A)

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[1]Extension Agronomist-Forages, Area Crops and Soils Agent, Associate Scientist and Extension Soil Scientist-Soil Fertility, Departments of Agronomy and Plant Genetics, Minnesota Extension Service and Soil Science, University of Minnesota, St. Paul, MN.

Crop conditions at Tom Pyfferoen's Farm :

1989:
Soil Test: NA
Seeded: April 20, 1989 with Brillion seeder 200 lbs of 0-0-60/A were applied and incorporated preplant with 1-1/2 pt/A Eptam, impregnated
'Poast' was sprayed 6/17/89

Rainfall 1989 - Rochester
April, 3.56; May, 1.74; June, 2.58; July, 2.75; August, 5.62; Sept., .61 and Oct., 1.6 inches. Total April thru October 18.46 inches.
Harvest dates: 7/7, 8/9, and 9/15.
Fall growth determination: 11/06

Results and Discussion

Alfalfa yields of Nitro were below those reported at Waseca, 3.0 vs 2.4 and 2.5, T/A of DM, for 1988 and 1989, Table 1, respectively (Sheaffer et al. 1988).

Table 1. Dry matter yield by cutting in 1988 (Tjosaas and 1989 (Pyfferoen Farm).

Alfalfa variety	Dry matter yield, T/A 1	2	3	Total
	- - - - - - - - - Tjosaas Farm - - - - - - - - -			
Nitro	0.7	0.8	0.9	2.4
Saranac - IN[1]	0.7	0.5	0.8	2.0
Saranac	0.7	0.6	1.1	2.5
Ranger	0.7	0.6	0.9	2.2
Wrangler	0.7	0.7	1.0	2.4
Redclover	0.5	0.7	0.9	2.0
	- - - - - - - - - Pyfferoen Farm - - - - - - - -			
Nitro	1.1	0.8	0.6	2.5
Saranac - IN[1]	0.8	0.5	0.5	1.8
Saranac	1.1	0.6	0.8	2.5
Ranger	1.0	0.6	0.7	2.3
Wrangler	1.1	0.6	0.6	2.3
Red Clover	0.9	1.2	1.0	3.2

[1] Line of Saranac alfalfa developed that produces nodules that are ineffective in N^2 fixation.

However, the Waseca Study was conducted under normal rainfall, an annual amount of 25 inches while our field trials in both years were below normal rainfall. In 1989, rainfall was above the 1988 drought, 18.5 vs. 17.2 inches, but severe insect damage on all alfalfa varieties on the second cutting in 1989 depressed yields by at least 25%. The insect damage resulted in red clover yields greater than alfalfa in 1989. These field trials however, do agree with the Waseca research in the comparison of Nitro to another dormant variety, Saranac AR; the summer yields were not different, 3.0 vs. 2.9, respectively, Table 1. Nitro also produced more herbage in the fall at both of our locations and at Waseca.

Corn yields at the Tjosaas' location varied most between years, 111 vs. 193 bu/A continuous corn, Table 2. Corn following alfalfa resulted in higher corn yields than corn after corn, regardless of nitrogen fertilizer level, 193 vs 206 bu/A. This finding is not new. However, the Waseca research showed corn following Nitro alfalfa cut 3 times produced an extra 30 bu/A (80 vs 50 bu/A) of corn over continuous corn at no N fertilization or an extra 37 bushels at 100 pounds of actual N (137 vs 100 bu/A). Although corn following Nitro at Tjosaas' resulted in an extra 11 bushels (204 vs. 193 bu/A, Table 2; this agrees with Sheaffer et al, 1989), our trial did not show Nitro different from other alfalfa varieties in subsequent corn yields. We did not measure N produced by Nitro, thus, we hypothesize the lack of response was due to two different problems. First, Nitro may not have produced as much extra N as reported by Sheaffer et al., 1989 (Nitro produced 32 more lb/A of N than Saranac AR) or second, the N

available in the soil was excessive. N production during the fall could have been prevented from drought; eliminating Nitro's advantage. We expect N was excessive because corn grown after Saranac-IN (the ineffective variety of alfalfa which does not fix N) produced similar corn yield as other alfalfa varieties 202 vs 204, 205, 203, and 209 bushels per acre, respectively, Table 2. Tjosaas regularly uses dairy manure on his fields and his soil has a higher organic matter content. Therefore, we are not surprised with this response.

Table 2. Corn yields at Tjosaas Farm in 1988 and 1989 at three levels of N in continuous corn and corn-on-corn on following alfalfa or red clover.

			Corn grain yield, bu/A					
N level	Continuous		Following legume - 1989					
lb/A	1988	1989	Nitro	Sar-IN	Saranac	Ranger	Wrangler	R. Clover
0	110	193	204	202	205	203	209	196
50	115	192	201	207	206	202	204	202
100	109	194	212	209	210	211	208	212
150	111	191	198	216	213	204	207	206
Avg	111	193	204	209	208	205	207	204

Economics of Nitro

We made a cost-and-return comparison using yields and quality data collected at Waseca (Recommended column - Table 3): 3.0 ton/acre DM; 29.4% ADF; 37.8% NDF; and 162 RFV index. Hay price was calculated using quality-tested hay auction data collected 1985-89 (Y = -69.453 + 1.2464X where Y = $/T and X = RFV index). Yield and quality values were deducted for harvest losses. The demonstration yield was 2.45 tons per acre of dry matter; quality was estimated.

Table 3. Cost of returns of Nitro from research and demonstration plots.

Item	Inputs	Recommended	Demonstration
		- - - - - - - - - $/T	- - - - - - - - -
Income[1]	2.5 Ton 116.30 $/ton	290.95	208.68
Expenses			
Cash			
Lime & Fertilizer[2]	3 ton lime 30 lb P_2O_5 40 lb K_2O	50.40	---
Herbicide	(Eptam)	19.00	19.00
Harvest & Twine	3X	12.30	12.30
Seed	12 lb x $2.50	30.00	30.00
Repair & maintenance		6.24	6.24
Interest	12%	14.15	8.10
Subtotal		132.09	75.64
Overhead costs		112.50	112.50
Total		224.59	188.14
Return over cost costs		158.86	133.04
Return over total cost		46.36	20.54
Break even yield (88 $/T)			
Cash cost, T/A		1.50	.86
Total cost, T/A		2.78	2.14

[1]Yields and quality (RFV index were adjusted for harvest loss (DM x .84). Price calculated from the statistical relationship Y = -69.453 + 1.2464X, where Y = $/T and X = RFV index.

[2]Assumed soil test of soil pH 6.3, P, 21-30 161A; and K, 151-225 lb/A. Yield goal -3 T/A.

SOURCE: Adapted from Fuller, Earl I. and Dale Nordquist. 1989.

Returns per acre were greater for the recommendation than the demonstration because the expected yield was higher (3.0 vs 2.45 T/A of DM before harvest loss) and we estimated quality of alfalfa in the demonstration to be 8% less than at Waseca. Cash cost was less on the demonstration because the soil fertility level did not require lime nor fertilizer.

Break-even yields (1.5 and 2.8 T/A, respectively) for cash and total costs were calculated using Minnesota's average hay price in 1989 (88 $/ton, Minnesota Agricultural Statistics). We have not figured the yield benefit to corn (37 extra bushels at Waseca) following alfalfa, the N fertilizer savings nor the savings in insecticide use of corn production. Profitability of Nitro alfalfa is dependent on the yield obtained, quality of hay harvested, price obtained for the hay, the fertility status of your soil and your production costs. Hay prices have been high enough the last four years to justify the use of Nitro in a corn-alfalfa rotation, unless one applies a deficiency payment to corn.

References

1. Sheaffer, Craig C., Donald K. Barnes, and Gary H. Heichel. 1989. "Annual" alfalfa in crop rotations, Station Bulletin 588 (Item No. AD-SB-3680). Minnesota Agricultural Experiment Station. University of Minnesota.

2. Sheaffer, C. C., D. K. Barnes, G. H. Heichel, G. C. Marten and W. E. Lueschen. 1988. Seeding your nitrogen and dry matter yields of nondormant and moderately dormant alfalfa. J. Prod. Agric. 1:261-265.

INFLUENCE OF POTASSIUM AND SULFUR ON THE YIELD OF RED CLOVER

George Rehm, Greg Cremers, Andy Scobbie[1/]

ABSTRACT: Red clover can tolerate lower soil pH values when compared to alfalfa. Therefore, less lime is required and it can be a profitable crop in North-Central Minnesota. Yet, little is known about nutrient requirements. This study evaluated the effect of the application of K and S. The use of S, but not K, increased dry matter yield. The lack of a response to K was surprising in view of the low soil test values for K. Soil test values for K increased with repeated K application.

Introduction:

The red clover crop will grow well at lower soil pH values when compared to alfalfa. Therefore, it can be an alternative legume in areas of Minnesota where low pH values and high lime costs limit the production of alfalfa. In contrast to alfalfa, few research projects have focused on determining the nutrient requirements for profitable production of this legume crop.

Objectives:

This study was designed to meet the following objectives:

- Determine the rate of fertilizer K and S needed to provide for optimum production.
- Measure the uptake of K and S by a high-yielding crop of red clover.
- Measure the effect of K application on soil test values for K.

Experimental Procedure:

This study was conducted at the Staples Irrigation Center. A good stand of red clover was established in August of 1987 in a seedbed prepared with conventional tillage techniques. Six rates of K and 3 rates of S were evaluated.

The various rates of K and S were topdressed to the established stand in early spring of 1988. Treatments were re-applied on April 20, 1989.

Two cuttings were harvested in 1989. The first harvest was on June 15 when the red clover was in the early bud growth stage. The second cutting was taken in mid-July when the red clover was in full bloom.

Whole plant samples were collected from each plot at both harvests. These samples were dried, weighed, ground and analyzed for K and S. Uptake of K and S was computed from yield and nutrient concentration data.

Soil samples (0-6 inches) were collected from each plot in early September. These samples were analyzed for extractable K in an attempt to measure the effect of 2 years of repeated K application on soil test values for K. Prior to the start of the study in 1987, results of the analysis of soil samples showed a pH of 7.0, a P level of 19.5 ppm, and a soil test value for K of 54 ppm (considered to be low to very low).

Results and Discussion:

In 1989, the yield of red clover was significantly affected by the use of fertilizer S (Table 1). Potassium use had no influence on yield (Table 2) and there was no significant interaction. Considering sulfur, the use of 25 lb. S per acre was adequate for optimum yields. This observation is consistent with the results of sulfur trials with irrigated alfalfa on sandy soils where 25 lb. S/acre was adequate for optimum yield. The largest response to S occurred with the first cutting and this was reflected in the total yield. Sulfur application had no effect on the yield of the second cutting.

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

Table 1. The effect of rate of applied S on yield of irrigated red clover.

S Applied	Cutting 1	Cutting 2	Total
lb./acre	---------- ton dry matter/acre		--------
0	1.40 a*	1.26 a	2.79 a
25	1.72 b	1.23 a	2.95 b
50	1.75 b	1.31 a	3.06 b

* Treatment means in any one column followed by the same letter are not significantly different at the .05 confidence level.

Table 2. The effect of rate of fertilizer K on yield of irrigated red clover.

S Applied	Cutting 1	Cutting 2	Total
lb./acre	---------- ton dry matter/acre		---------
0	1.53 a	1.26 a	2.79 a
20	1.59 a	1.27 a	2.86 a
40	1.64 a	1.28 a	2.92 a
80	1.81 a	1.27 a	3.08 a
160	1.55 a	1.33 a	2.88 a
320	1.63 a	1.35 a	2.98 a

As would be expected, the concentration of K in the whole plant tissue increased with rate of applied K. This increase was linear for both cuttings (Table 3). Rate of applied S had no significant effect on the concentration of K in the red clover tissue.

Likewise, the concentration of S increased with the rate of S applied (Table 4). For the 1st cutting, the use of both 25 and 50 lb. S/acre increased the S concentration when compared to the check. There was no additional increase when the 50 lb./acre rate is compared to the 25 lb./acre treatment. For the 2nd cutting, the highest S concentration was associated with the application of 50 lb S./acre.

Table 3. The influence of rate of applied K on the K concentration in red clover.

K Applied	Cutting 1st	Cutting 2nd
lb./acre	-------- %	--------
0	2.06 d*	2.00 e
20	2.48 c	2.17 d
40	2.60 c	2.43 c
80	2.70 b c	2.78 b
160	2.91 b	2.82 b
320	3.16 a	3.28 a

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

Table 4. The effect of rate of applied S on the S concentration in red clover.

S Applied	Cutting 1st	2nd
lb./acre	- - - - - - - % S - - - - - - -	
0	.147 b*	.147 b
25	.176 a	.154 b
50	.183 a	.165 a

* Treatment means in each column followed by the same letter are not significantly different at the .05 confidence level.

Uptake of both K and S was computed by multiplying dry matter yields by concentration values. The application of both K and S had a significant effect on K uptake for each cutting (Tables 5, 6) as well as the total K uptake for the growing season (Table 7).

This would be expected because of the increased K concentration with added K. The effects of S on K uptake were erratic and closely paralleled the effect of rate of applied S on yield.

Table 5. Potassium uptake by the first cutting of red clover as affected by the rate of K and S applied.

S Rate	K Rate (lb./acre) 0	20	40	80	160	320
lb./acre	- - - - - - - - - - - - - - lb. K/acre - - - - - - - - - - - - - -					
0	53.2	69.9	81.3	79.6	74.9	87.7
25	65.9	77.7	94.5	89.7	100.0	112.5
50	65.1	87.1	80.6	125.9	96.2	110.4

Table 6. Potassium uptake by the 2nd cutting of red clover as affected by the rate of K and S applied.

S Rate	K Rate (lb./acre) 0	20	40	80	160	320
lb./acre	- - - - - - - - - - - - - - lb. K/acre - - - - - - - - - - - - - -					
0	49.8	56.6	62.4	92.1	82.5	86.4
25	50.0	50.8	61.4	55.8	69.1	91.2
50	50.2	56.4	62.4	65.7	74.1	85.6

Table 7. Total uptake for the growing season by red clover as affected by the rate of K and S applied.

S Rate	K Rate (lb./acre) 0	20	40	80	160	320
lb./acre	- - - - - - - - - - - - - - lb. K/acre - - - - - - - - - - - - - -					
0	103.1	126.6	143.7	171.6	157.4	174.1
25	115.9	128.5	156.0	145.5	168.9	203.8
50	115.3	143.5	143.0	191.6	170.2	196.0

Uptake of S was increased by the use of fertilizer S, but rate of K applied had no significant effect. For the 1st cutting, S uptake increased as the rate of applied S increased (Table 8). For the 2nd cutting, the 50 lb./acre rate produced an increase in S uptake. Total uptake for the growing season shows a linear response to applied S. It's also obvious that the uptake of S is much less than the uptake of K.

Table 8. Uptake of S as affected by the rate of S applied.

S Applied	Cutting 1st	2nd	Total
lb./acre	- - - - - - - lb. S/acre - - - - - - -		
0	4.1 a*	3.9 a	8.0 a
25	6.1 b	3.8 a	9.9 b
50	6.5 b	4.3 b	10.8 c

* Treatment means in each column followed by the same letter are not significantly different at the .05 confidence level.

The soil samples taken at the end of the 1989 growing season were used to measure the effect of 2 years of repeated K application on the soil test level for K. These results are summarized in Table 9. The increase was linear with rate of applied K. There was very little change in the soil test value with the repeated application of 20 lb. K/acre. In general, the soil test K value increased by approximately .7 ppm for each pound of K applied.

Table 9. The effect of repeated application of K on the soil test value for K.

K Applied	Soil Test K
lb./acre	ppm
0	60.0
20	58.5
40	75.5
80	101.5
160	135.5
320	259.0

Conclusions:

Results of this study showed that yield of irrigated red clover was increased substantially by the use of fertilizer S, but K applications had no effect. The lack of a response to K is surprising when the relatively low soil test for K is considered. The yield increases would appear to be large enough to pay for the added S.

The concentration of K in plant tissue increased with rate of applied K. Likewise, the S concentration increased with the rate of S applied. These increases, however, were not associated with increases in yield.

Repeated application of fertilizer K increased the soil test value for K. In general, the soil test K value increased by about .7 ppm for each pound/acre of K applied.

NITROGEN APPLICATION FOR HIGH QUALITY SUGARBEET IN SOUTHERN MINNESOTA

John A. Lamb[1]

OBJECTIVE:

Nitrogen management is important for high quality sugarbeet production. American Crystal Sugar growers since 1983 have been paid based on the amount of sugar extracted at the factory. In December 1989, Southern Minnesota Beet Sugar Cooperative growers voted for a payment which also stressed quality and recoverable sugar at the factory. A considerable amount of N information exists for the American Crystal growers but little data exists for the high sugar varieties currently used in the southern Minnesota area. The objective of this study is to generate N application information for high sugar varieties under a quality payment system for the southern Minnesota sugarbeet growing area.

MATERIALS AND METHODS:

Two N rate experiments were conducted in southern Minnesota; one near Maynard, MN in 1988 with 5 N rates (0, 30, 60, 90, and 120 lb N/A) and one near Sacred Heart, MN in 1989 with 6 N rates (0, 30, 60, 90, 120, and 150 lb N/A). The spring two foot nitrate-N soil tests were 71 lb/A and 70 lb/A in 1988 and 1989, respectively. In both locations Urea (46-0-0) was broadcast applied and incorporated in the spring. Variety KW 1745 was overplanted and thinned to 125 plants per 100 foot of row (29,700 plant/A). Root yields were determined by machine harvest and quality run at American Crystal Sugar Company's Quality Lab at East Grand Forks, MN.

RESULTS AND DISCUSSION:

The location at Maynard in 1988 was under considerable moisture stress. The root yields, Table 1, reflect this stress. The use of N fertilizer did decrease sugar concentration from 17.0 % at 30 lb N/A to 15.9 % at 120 lb N/A. The recoverable sugar per ton of sugarbeet mimics this reduction. The reduction of sugar recovered was caused by significant increase in amino N in the sugarbeet root from the application of N fertilizer. Using American Crystal's quality payment system and expressing the gross returns as a percentage of the 0 lb N/A treatment on a per ton and per acre basis, the 0 and 30 lb N/A applications, respectively, were optimum in 1988. This would equate to 71 and 101 lb N/A as soil test 0-2 ft + fertilizer N.

The growing conditions at the Sacred Heart location in 1989 were more favorable. The root yields were greater than 1988 but there was not a significant yield increase to N application, Table 2. Neither sugar concentration or recoverable sugar per ton were effected by N application. The loss to molasses was significantly increased. This increased loss was caused by the increase in amino N concentration in the root from N fertilization. Again N application did not effect root Na or K concentrations. Gross returns per ton and per acre were maximized at 30 lb N/A or 100 lb N/A, soil test N 0-2 ft + fertilizer applied.

Particularly in 1989, the optimum soil test + fertilizer level appears to be low according to data from the Red River Valley. Root yield of the high sugar varieties being used today does not respond to N fertilization like the tonnage varieties of a decade ago. Because of the smaller amounts of N are needed for maximum root growth, the use of N must be based on what the effect will be to sugarbeet quality particularly amino N. More studies are planned to better determine optimum N fertilizer application.

Please refer to title page of this publication for information regarding application and use of this article.

[1] Soil Scientist, Northwest Experiment Station, University of Minnesota, Crookston, MN.

Table 1. Nitrogen fertilization effects on root yield, sugar concentration, recoverable sugar, loss to molasses, impurities, and gross returns at Maynard, MN, 1989.

N Rate	Yield	Sugar	Recoverable Sugar	LTM	Na	K	An	Gross Return $/T	Gross Return $/A
lb N/A	T/A	%	lb/T	%	------ ppm ------			% of check	
0	14.9	16.9	309	1.45	122	2204	382	100	100
30	15.5	17.0	309	1.55	111	2190	439	100	104
60	13.3	16.3	297	1.45	134	2044	450	93	83
90	13.9	16.2	293	1.55	125	2062	521	90	84
120	14.1	15.9	286	1.60	133	2120	504	86	82
Statistical Analyses									
N Rate	NS	**	**		NS	NS	**		
Linear	NS	**	**		NS	NS	**		
Quadratic	NS	NS	NS		NS	NS	NS		
C.V.%	18.9	3.9	4.6		31.6	7.3	11.9		

** is 0.01 significance level.

Table 2. Nitrogen fertilization effects on root yield, sugar concentration, recoverable sugar, loss to molasses, impurities, and gross returns at Sacred Heart, MN, 1989.

N Rate	Yield	Sugar	Recoverable Sugar	LTM	Na	K	An	Gross Return $/T	Gross Return $/A
lb N/A	T/A	%	lb/T	%	------ ppm ------			% of check	
0	21.0	14.8	269	1.27	290	2142	289	100	100
30	26.8	15.2	278	1.23	200	2134	306	107	137
60	24.7	15.3	277	1.30	190	2262	347	106	125
90	21.7	15.0	270	1.40	240	2258	396	101	104
120	25.4	15.3	275	1.47	204	2337	436	105	127
150	20.2	15.1	267	1.55	184	2154	555	98	95
Statistical Analyses									
N Rate	NS	NS	NS	*	NS	NS	**		
Linear	NS	NS	NS	**	NS	NS	**		
Quadratic	NS	NS	NS	NS	NS	NS	NS		
C.V.%	12.4	2.4	2.9	6.7	16.6	7.9	10.6		

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

NITROGEN FERTILITY STUDIES ON GRAPES[1]

Carl Rosen, Peter Bierman, Emily Hoover, Jim Luby, and Peter Hemstad[2]

ABSTRACT: Two field experiments were conducted to determine the effects of N fertilizer application on grape nutrition, yield, and quality. Application of N fertilizer increased extractable levels of NO_3-N in the soil, but had no significant effect on yield. Differences due to cultivar were far greater than differences due to N rate. There was a slight trend for titratable acidity to increase with increasing N, although this effect was also dependent on cultivar. Tissue levels of NO_3-N varied with site and cultivar and levels generally decreased as the season progressed. Petiole NO_3-N levels tended to increase with increasing N rate at the later sampling dates. The results of this experiment indicate that N requirements for grapes grown in Minnesota appear to be low and that several years without N fertilization would be necessary before a response to N could be detected at these sites.

Interest in growing grapes for wine production and fresh consumption in Minnesota has recently increased. Little is known, however, about the fertility requirements of cold hardy grape cultivars. The objective of the present study, therefore, was to characterize the response of various grape cultivars to nitrogen fertilizer over the growing season.

MATERIALS and METHODS

Field trials were conducted at two sites: the Horticultural Research Center (HRC) in Excelsior, MN and a commercial vineyard near Hastings, MN. Both sites were nonirrigated. Experimental procedures were similar at both sites, although minor variations occurred as noted below.

Site Characterization and Experimental Design. The soil at the HRC site was a Hayden loam with medium organic matter levels. Vines were trained to a unilateral low cordon and spaced 6 ft. in the row and 9 ft. between rows. Vines were laid out in a split plot design with two cultivars, Seyval and Vignoles, arranged in subplots with four vines of each cultivar. Nitrogen fertilizer rates were the main plot treatments and there were three replications of each fertilizer x cultivar combination. The commercial vineyard was on a Hubbard loamy sand with low organic matter levels and had Marechal Foch and Millot in separate plantings. Vines were trained in the standard J system and spaced 8 ft. in the row with 9 ft. between rows. Fertilizer treatments were arranged in a randomized complete block design with three replications for each cultivar. There were four vines per fertilizer treatment in each block.

Fertilizer Treatments. A uniform N application, soon after bud break, was made at each site according to customary vineyard practices. In early May either 25 lb. (HRC) or 30 lb. (commercial vineyard) of actual N/A was broadcast and disced in between rows. Soil test levels of P and K were adequate at both sites, so no supplemental applications of these nutrients were made. Additional N was applied at both locations on May 17. Ammonium nitrate was broadcast by hand around each vine and the surface was raked to a depth of 1-2 in. At the HRC the N fertilizer treatments were 0, 37.5, and 75 lb. actual N/A. At the commercial vineyard treatments were 0, 30, and 60 lb. N/A.

Soil samples were collected on May 17, prior to fertilizer treatment applications, and also on June 6 (HRC) and June 7 (commercial vineyard). Three soil cores were taken from each fertilizer plot and samples were separated into three depths: 0-1 ft., 1-2 ft., and 2-3 ft. Moist samples from all three depths were extracted with 2M KCl (1:5 w/v) and analyzed for NH_4-N and NO_3-N by conductimetric methods. Per cent moisture was also determined, so that results could be expressed on a uniform dry weight basis. Measurements of pH (1 soil:1 H_2O, w/v) were made only on the surface layers from the May 17 soil samples.

Petiole N Determinations. Petiole samples from the most recently matured leaves of randomly chosen shoots were collected every two weeks from June 6 to Aug 31. The outer two vines in each fertilizer plot were treated as border plants, so petiole sampling consisted of 7-8 petioles from each of the inner two plants in the four vine plots at the commercial vineyard, and five petioles/vine from the inner three plants of each cultivar in the split plot design at the HRC.

Ten petioles from each sample were dried, ground, extracted with H_2O, and analyzed for NO_3-N conductimetrically. Results were expressed on a petiole dry weight basis. The remaining 4-5 petioles were used in a 'quick test' for NO_3-N in petiole sap using EM Quant Nitrate Test strips. Sap was squeezed from fresh petioles with needle-nose pliers, mixed, and the reagent pad of a strip was dipped into the sap. The time required to reach maximum, deep purple color development was measured with a stopwatch to the nearest 0.01 sec. Time measurements were converted to petiole sap concentrations using a standardized mathematical equation [nitrate (ug/ml) = $10^{(4.9-1.085 \log t)}$ where t = seconds to reach dark purple]. For samples not reaching full color development after 2 min., the NO_3-N sap concentration was estimated from the color chart provided with the strips. The results of the quick test and the conventional laboratory analysis were compared and correlated to develop a model for converting quick test, petiole sap concentrations to petiole concentrations on a dry weight basis.

[1] Funding provided by the Minn. Agric. Expt. Sta.
[2] Assoc. Prof., Dept. Soil Science; Grad. Res. Assist., Dept. Soil Science; Assoc. Prof., Dept. Hort. Science; Assoc. Prof., Dept. Hort. Sci.; Assist. Scientist, Dept. Hort. Sci., respectively.

Yield and Fruit Quality. Harvest dates for the commercial vineyard were Sept. 9 (Foch) and Sept. 10 (Millot). Both cultivars were harvested at the HRC on Sept. 11. Fruit clusters were harvested from the middle two vines in each four vine plot, weighed, and yield was expressed on a fresh weight/vine basis. Subsamples of 40-50 berries were collected from randomly chosen clusters in each treatment group, making sure that berries were selected from different parts of each cluster. The subsamples were frozen and later analyzed for brix, pH, and titratable acidity. Results from different fertilizer treatments were compared to evaluate the effect of N fertilizer rate on the wine making quality of the fruit.

RESULTS

Soil Analysis. Nitrate-N levels in the soil to a depth of 3 ft. prior to application of differential N fertilizer treatments are presented in Tables 1 and 2. In general, highest levels were in the 0-1 ft depth at both sites. When sampled three weeks after differential N fertilizer application, levels of soil nitrate-N tended to increase with increasing N fertilizer rate (Tables 3 and 4). As on the previous sampling date, highest nitrate-N levels were in the top foot of the soil profile.

Tissue Analysis. Despite increases in soil N levels with increasing N fertilizer applications, there was little effect on N nutritional status of the petioles as measured by quick tests on fresh petioles or water extractable nitrate-N on dried petioles (Tables 5 and 6). None of the levels at flowering (June) were in a range considered to be N deficient. Toward the end of the season there was a slight trend in some cultivars for higher nitrate-N in petioles sampled from the higher N treatments. Tissue nitrate-N levels decreased over the season with initial levels in June about 10 times those of the last sampling date in August. Significant differences due to cultivar were apparent at HRC: Seyval generally had higher nitrate-N levels than Vignoles. Although a direct comparison cannot be made at the Hastings site due to experimental design, Millot tended to have greater petiole nitrate-N levels than Foch.

The correlation between the quick test and the conventional water extract on dried tissue was good ($r = 0.84$), but probably not accurate enough to be used as a quantitative measure of N status of the petiole. The best use of the quick test for grape production would be as a qualitative method for determining N status of the vines, ie. whether the N level is low, medium, or high. One note of caution is that there were some differences between different lots of strips. On two sampling dates (Aug. 3 and Aug. 17), the color development was poor and did not relate to water extractable levels. This inconsistency may limit the usefulness of this product.

Yield and Fruit Quality. Nitrogen did not significantly affect yield of the grapes in the present experiment. This lack of a response could be due to high levels of N stored within the vine which may have masked any effect of applied N. There was a slight trend for an increase in titratable acidity with increasing N rate, although this varied with cultivar. Differences due to cultivar were far greater than differences due to N rate. The results of this experiment indicate that N requirements for grapes grown in Minnesota are low and that several years without N fertilization would be necessary before a response to N could be detected at these sites.

Table 1. Initial soil NO_3-N levels at HRC. Samples were collected May 17, 1989. Mean ± Standard Deviation.

Depth (ft.)	Soil Nitrate-N ----- ppm NO_3-N -----
0-1	8.6 ± 4.6
1-2	6.7 ± 5.7
2-3	6.7 ± 6.4

Table 2. Initial soil NO_3-N levels at Hastings. Samples were collected May 16, 1989. Mean ± Standard deviation.

Depth (ft.)	Cultivar: Foch	Cultivar: Millot
0-1	5.4 ± 1.5	11.5 ± 4.0
1-2	1.1 ± 0.3	1.9 ± 0.5
2-3	0.7 ± 0.2	0.7 ± 0.2