EFFECT OF TURKEY MANURE AS A NUTRIENT SOURCE ON CORN YIELDS

P. M. Bongard, R. Hamer[1]

ABSTRACT

Two sites were identified in Rice County to demonstrate nutrient contributions from turkey tom-finish and brood manures to corn. Two rates of each type of manure were applied and compared to a commercial fertilizer treatment and an untreated check. Corn grain yields were measured. There were no significant differences between the low and high rates of either the brood or finish manures at either site. Yields of the manured plots were similar to the commercial fertilizer treatment yields, and significantly better than the check. Average returns over treatment costs were greatest in the plots where low rates of the finish and brood manures had been applied.

Introduction

Animal wastes can contribute substantial amounts of nutrients to crops, as well as enhance soil structure and organic matter contents over time. To date, there has been little research done with turkey manure as a nutrient source in Minnesota. The objective of this study was to demonstrate nutrient contributions from finish and brood turkey manures to corn.

Materials and methods

Two sites which had no history of previous manure applications were selected in Rice County for this demonstration. The primary soil at the Farm 1 site was a Clarion loam; the primary soils at Farm 2 were a Webster clay loam and a Clarion loam. Both sites were soil sampled in early spring (Table 1). The previous crop at Farm 1 was corn; at Farm 2, the previous crop was soybeans. Precipitation was recorded at both sites (Table 2).

Turkey tom-finish and brood manures with wood chip litter were used in this study. The tom-finish barns are cleaned each year after three to four flocks, while the brood barns are cleaned after every flock (every seven weeks). The tom-finish and brood manures for Farm 2 had been taken directly from these barn cleanings, while the manures for Farm 1 had been stored on a pile for approximately four months. The litter and manure in tom-finish and brood barns are tilled regularly.

The two turkey manures were applied at two rates and immediately incorporated in mid-April: 1) Tom-Finish manure at 4 and 8 tons per acre, and 2) Brood manure at 3 and 6 tons per acre. Manure was sampled for nutrient analysis on the day of application (Table 3), and estimates of nutrients available the first year were made (Table 4). An untreated plot and a preplant commercial fertilizer treatment was also included. The fertilizer treatment phosphorus (P) and potassium (K) was applied according to University of Minnesota recommendations based on yield goals and the soil tests; the nitrogen (N) rate was based on previous crop, yield goals, and soil organic matter contents. A randomized complete block was used with three replications at Farm 1 and four replications at Farm 2. Each of the six treatments was sixteen rows wide, and 430 feet long.

Corn grain yields were measured by harvesting and weighing the center eight rows of each plot, and adjusting the moisture contents to 15.5%.

Results

Yields

There were few significant differences in grain yields at either site (Figures 1 and 2). At both sites, the manure and commercial fertilizer treatments yielded significantly better than the untreated plot, representing an average increase of 16 bushels per acre due to manure or fertilizer. The six ton brood manure treatment at Farm 1 is the exception as it was not significantly different from the check. Grain yields in the low rate plots of the finish and brood manures were not significantly different from those in the high application rate plots.

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Returns over treatment costs

The net returns over nutrient costs for each treatment were calculated by subtracting the cost of the manure or fertilizer from the projected treatment income (Figures 3 and 4). Returns were based on the following: 1) Corn revenue of $2.00 per bushel; 2) Manure costs of $3.75 per ton tom-finish ($15/4T and $30/8T treatments) and $3.00 per ton brood ($9/3T and $18/6T treatments); and fertilizer costs of $0.20 per pound N and $0.13 per pound K.

Returns over nutrient costs ranged from $247 to $285 per acre at Farm 1, with the highest returns in the low rate finish and brood manure plots. Similar results were obtained at Farm 2, with the addition of the high rate brood manure plots. Returns ranged from $268 to $304 per acre at this site.

Summary and Conclusions

Turkey manure can contribute substantial amounts of nutrients to corn. Grain yields at the two farm sites from the low rates of finish and brood manure were equal to the commercial fertilizer treatment. It may be possible that the above normal precipitation increased N mineralization of the manure and soil, and increased fertilizer N loss.

Since more P and K were applied in the manured treatments at these sites than what was required for this year's corn crop, subsequent crops (particularly legumes) may be able to utilize these nutrients. Future work could focus on refining application rates under different environmental conditions, refining manure handling and sampling techniques, and evaluating yield responses on low testing phosphorus, potassium, and organic matter soils where greater contributions from the manure could be realized in the year of application.

Table 1. Soil test results, 1990.

SITE	ORGANIC MATTER	pH	P	K
	---%---		-----ppm-----	
Farm 1	2.6	5.9	48.7	143.5
Farm 2	4.8	6.2	28.8	136.0

Table 2. Monthly precipitation records and cumulative totals, 1990.

	FARM 1		FARM 2	
MONTH	RAIN	CUM.	RAIN	CUM.
	----------inches----------			
May[1]	3.1	3.1	3.9	3.9
June	6.0	9.1	4.9	8.8
July	7.5	16.6	8.8	17.6
August	NA		3.3	20.9

[1]Record beginning May 14.

Table 3. Average turkey manure composition as applied.

MANURE	% SOLIDS	TURKEY MANURE COMPOSITION				
		TOTAL N	NH_4^+	ORGANIC N	P_2O_5	K_2O
		lb/ton				
Tom-finish	62	23.6[1]	10.4	13.2	43.6	28.2
Brood	52	33.0	10.2	22.8	38.6	24.2

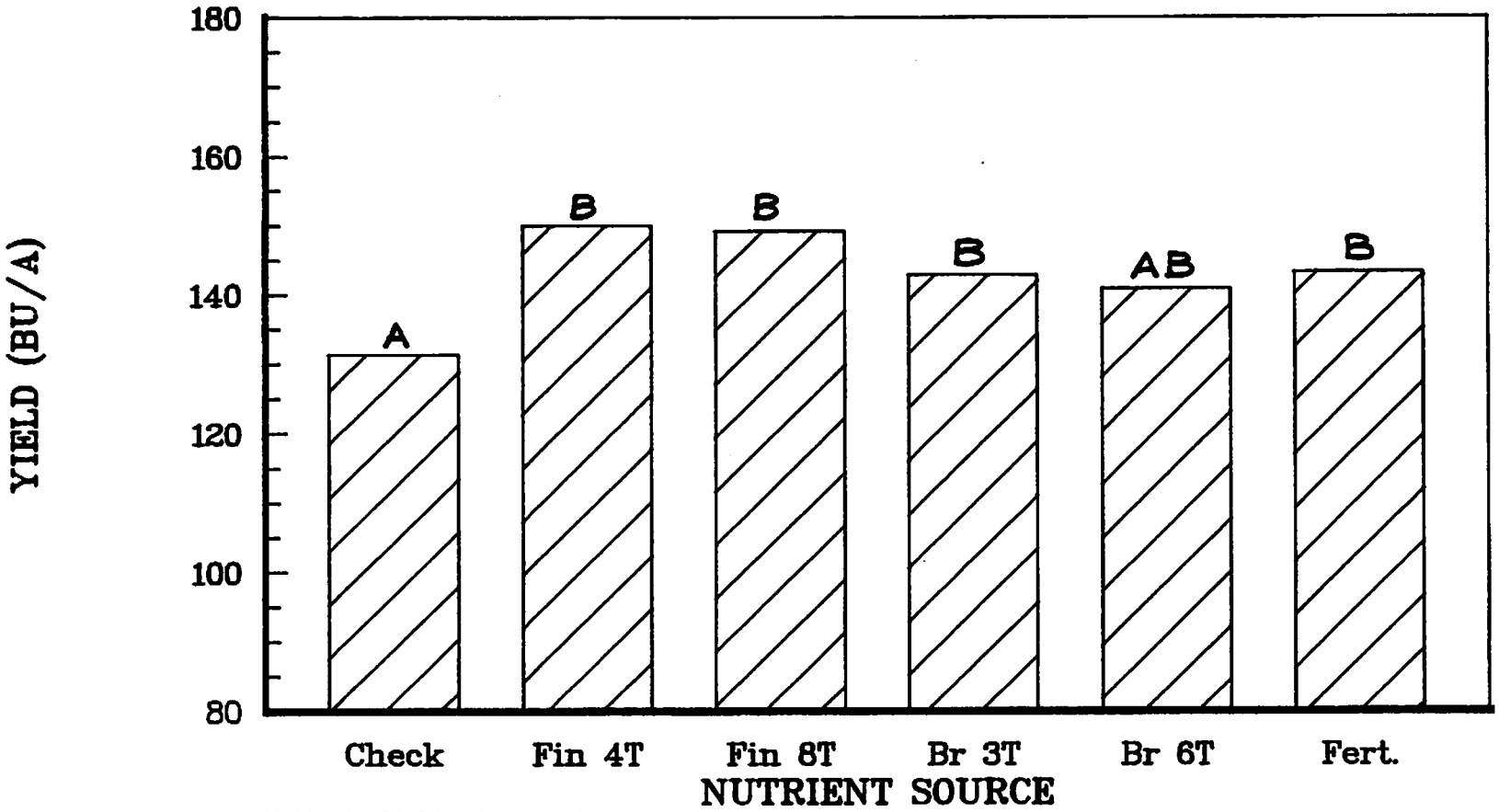
[1]Total N for finish manure was lower than average due to a higher than average moisture content. Typical values on a wet basis average 40 pounds N per ton.

Table 4. Estimate of nutrients available first year[1].

NUTRIENT SOURCE	RATE	AVAILABLE NUTRIENTS				
		TOTAL N	NH_4^+	ORGANIC N	P_2O_5	K_2O
	ton/A	pounds/A				
Tom-finish manure	4	57	42	16	148	102
	8	115	83	32	296	203
Brood manure	3	51	31	20	98	65
	6	102	61	41	197	131
Farm 1 fertilizer		180			0	30
Farm 2 fertilizer		130			0	30

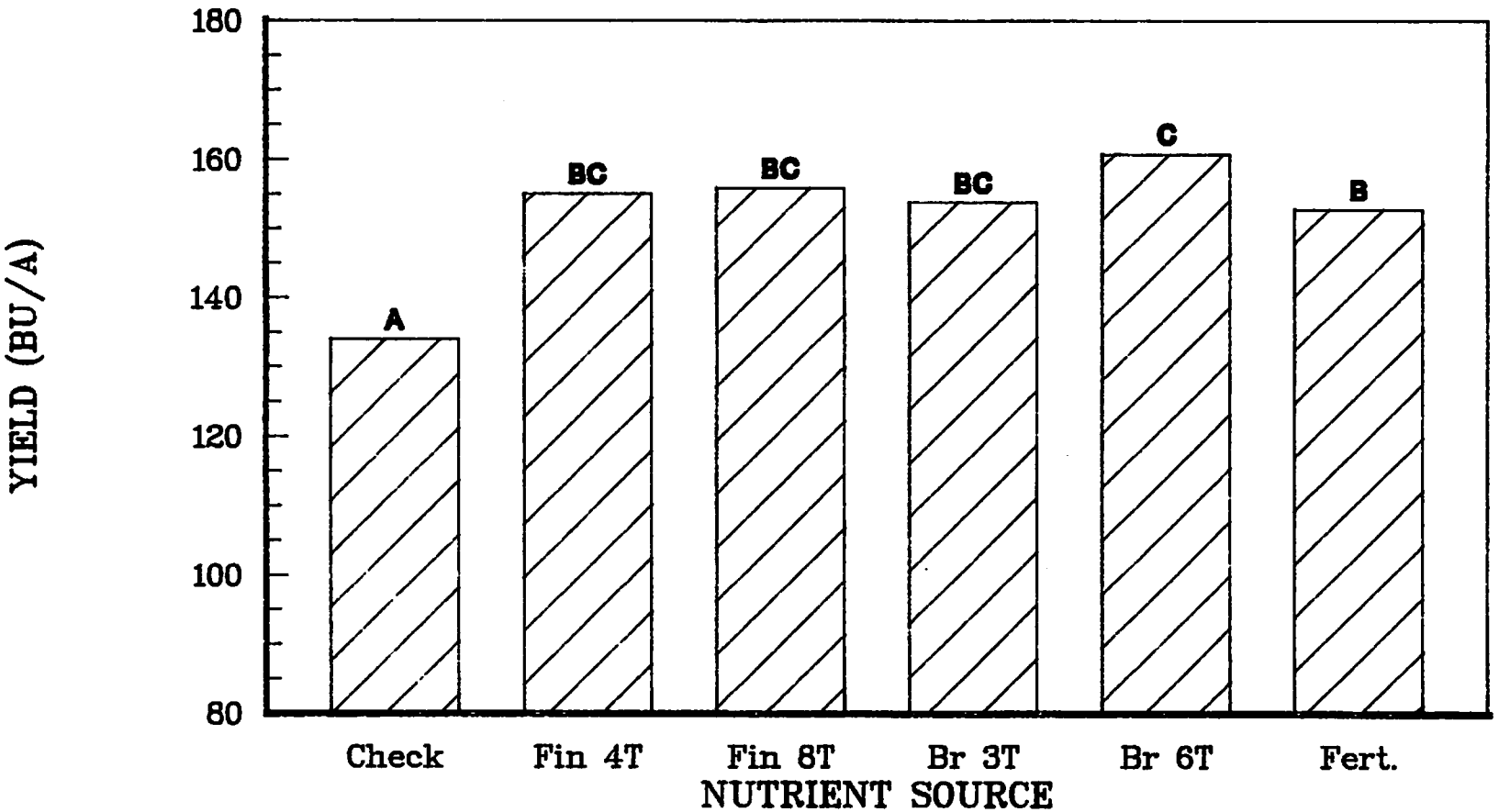
[1]Manure availability based on 100% ammonium-N, 30% organic N, 85% P_2O_5, and 90% K_2O; Fertilizer availability based on 100% applied.

Figure 1. Grain yields as affected by nutrient source at Farm 1, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level.

Figure 2. Grain yields as affected by nutrient source at Farm 2, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level.

Figure 3. Returns over nutrient costs ($/A) at Farm 1, 1990

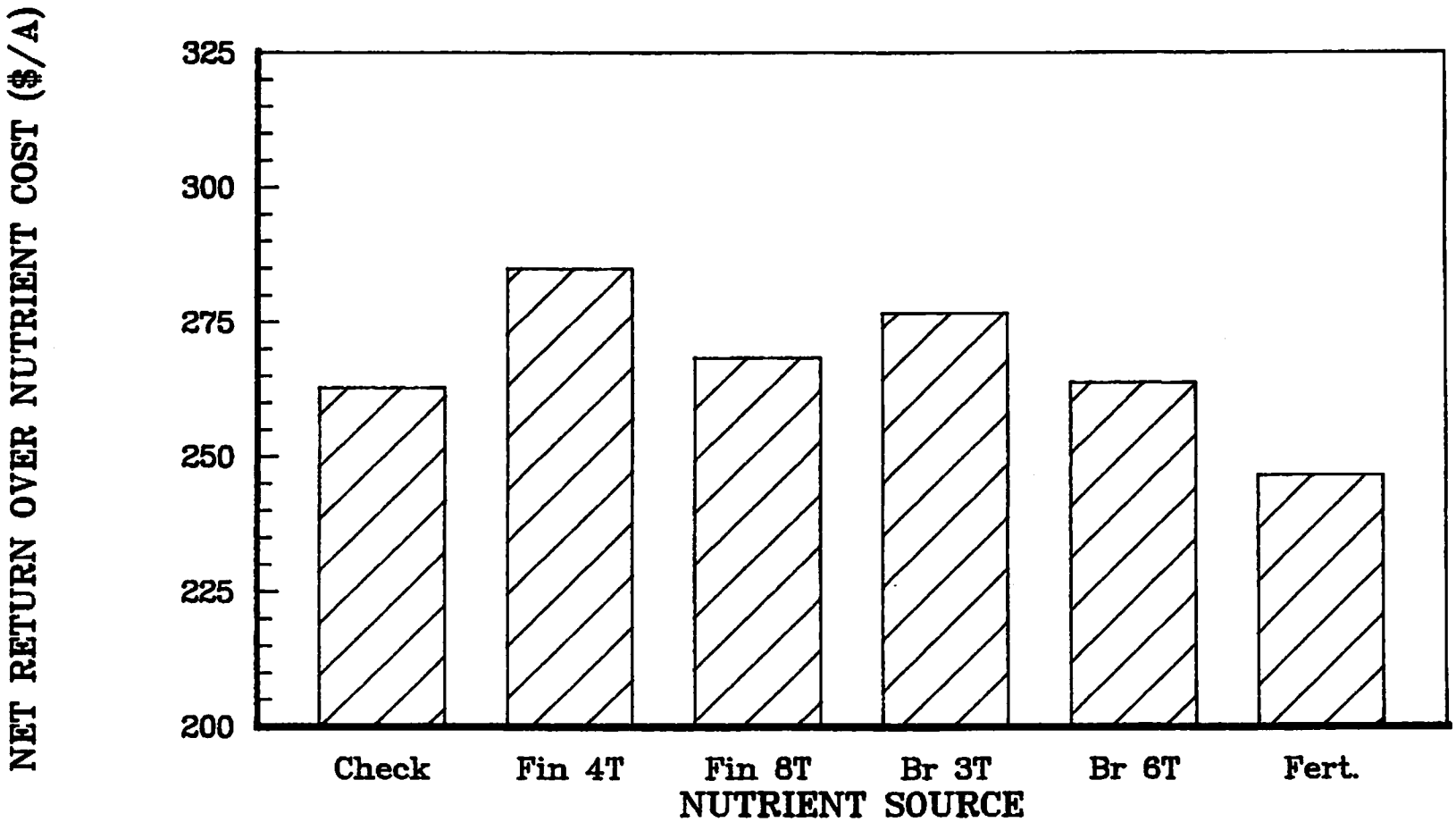
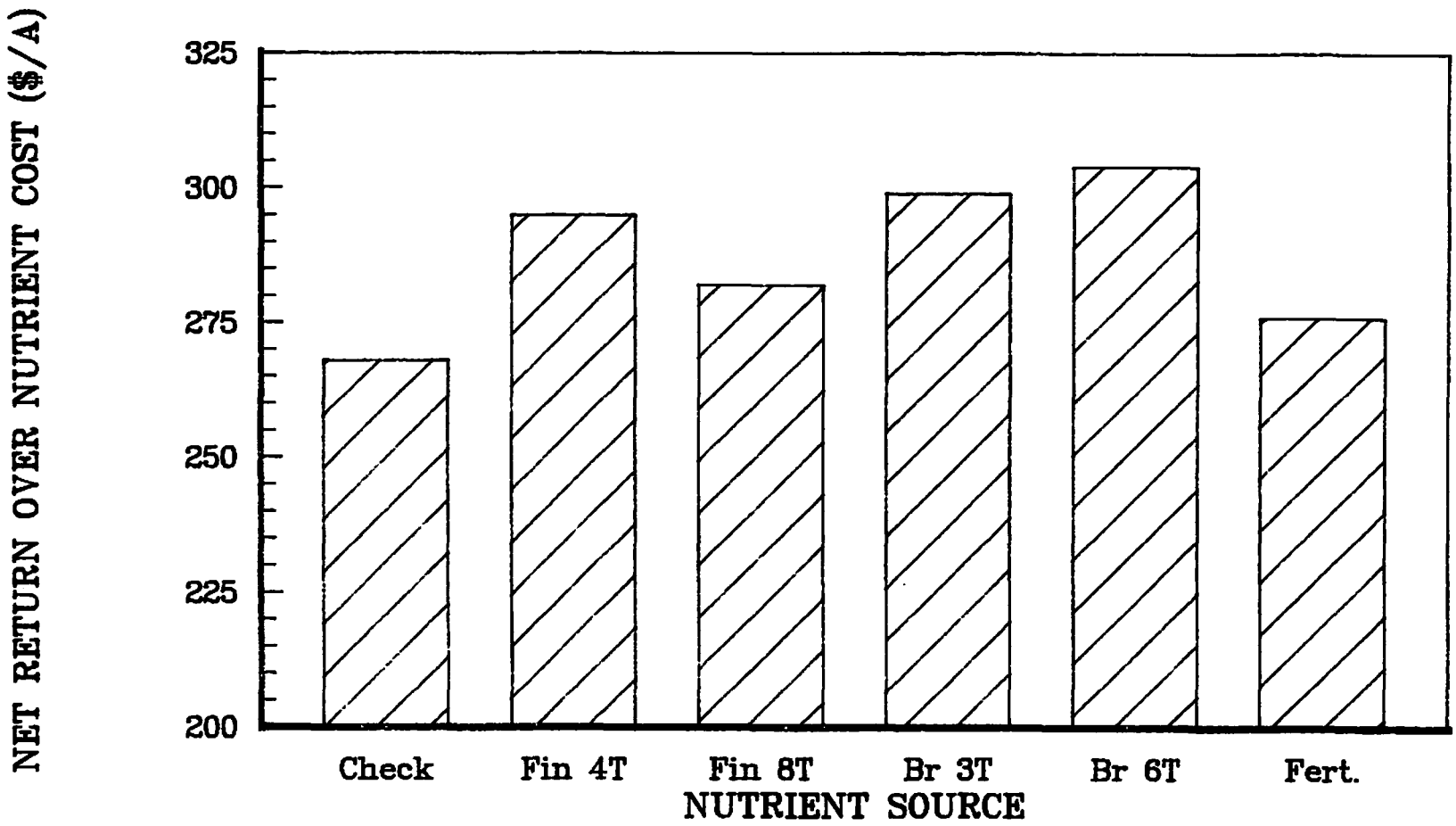


Figure 4. Returns over nutrient cost ($/A) at Farm 2, 1990.



CORN YIELDS AS AFFECTED BY NITROGEN RATE, LEGUME AND MANURE HISTORIES[1]

P. M. Bongard, T. Wager, T. Arlt, and R. Hamer[2]

ABSTRACT

Sites were selected in Freeborn, Mower, Rice, and Steele counties to demonstrate nitrogen (N) contributions from a previous crop of alfalfa or soybeans with and without histories of manure applications. Fertilizer N as urea was applied at five rates (0, 40, 80, 120, and 160 lb. N/acre). Plots were hand harvested after physiological maturity had been attained. There were no yield responses to N at the sites that had histories of alfalfa with or without manure, or soybeans with manure. The average corn grain yields were 147, 184, and 182 bu/acre for these sites, respectively. There was a significant yield response to N up to the 120 pound rate at the soybean with no manure site.

Introduction

It has long been recognized that legumes and manures can contribute substantial amounts of nitrogen (N) to following crops. Sites were chosen in Freeborn, Mower, Rice, and Steele counties to demonstrate N contributions from legumes and/or manure to corn. These demonstrations were part of the Environmental Agriculture Education Program of Cluster 16.

Materials and methods

Each of the county sites was selected based on a different field history (Table 1). Fertilizer N as urea was applied at five rates in a randomized complete block design with four replications. The fertilizer rates were 0, 40, 80, 120, and 160 pounds N per acre.

Nitrogen was applied at the four sites on April 11 or 12 and immediately incorporated. Planting, weed and other pest control, and phosphorus and potassium applications were the responsibilities of each of the farmer cooperators.

Plots were hand harvested in early October after the corn had reached physiological maturity. The corn grain from two, twenty foot plot sections was shelled, weighed, and yields were corrected to 15.5% moisture.

Results

Freeborn County (alfalfa with no manure)

There was no yield response to fertilizer N at this site (Figure 1). As a result, the return over fertilizer N costs (based on $2.00 per bushel corn and $0.20 per lb. N) decreases with added nitrogen (Figure 2). The average overall yield at this site was 184 bushels per acre.

Mower County (soybean with no manure)

At this site, there was a significant response to fertilizer N. The optimum N rate was at 120 pounds per acre, representing a 46 bushel yield increase over the 0 pound per acre N rate. The maximum net economic return based on yields and fertilizer N costs was also at the 120 pound N rate.

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[1]Funding provided by Board of Soil and Water Resources through Environmental Agriculture Education Program Grant of Cluster 16, Minnesota Extension Service.

[2]Environmental Agriculture Educator, Cluster 16; Area Extension Agent, Crops and Soils; County Extension Agent, Agriculture, Steele County; and County Extension Agent, Rice County; Minnesota Extension Service

Rice County (alfalfa with manure)

There was no response to fertilizer N at this site. Similar to the other alfalfa site, the greatest return over fertilizer cost was at the zero N rate. The overall yield for this site was 147 bushels per acre.

Steele County (soybean with manure)

There was no response to fertilizer N at this site, and thus, no financial benefit from applying N. The overall yield at this site was 182 bushels per acre.

Summary

Of the four demonstration sites, the only site where a nitrogen response was obtained was in the field where the previous crop was soybeans, and there was no history of manure applications. There were no yield responses to fertilizer N when alfalfa was the previous crop (with or without a manure history), or when manure had been applied after a soybean crop.

Table 1. Field history and primary soil type of four demonstration sites.

SITE	PREVIOUS CROP HISTORY	MANURE	SOIL TYPE	ORGANIC MATTER
Freeborn	Alfalfa	No	Mayer loam	High
Mower	Soybeans	No	Readlyn silt loam	High
Rice	Alfalfa	Yes	Hayden loam	High
Steele	Soybeans	Yes	Nicollet clay loam	High

Figure 1. Corn grain yields as affected by fertilizer N rates, 1990.

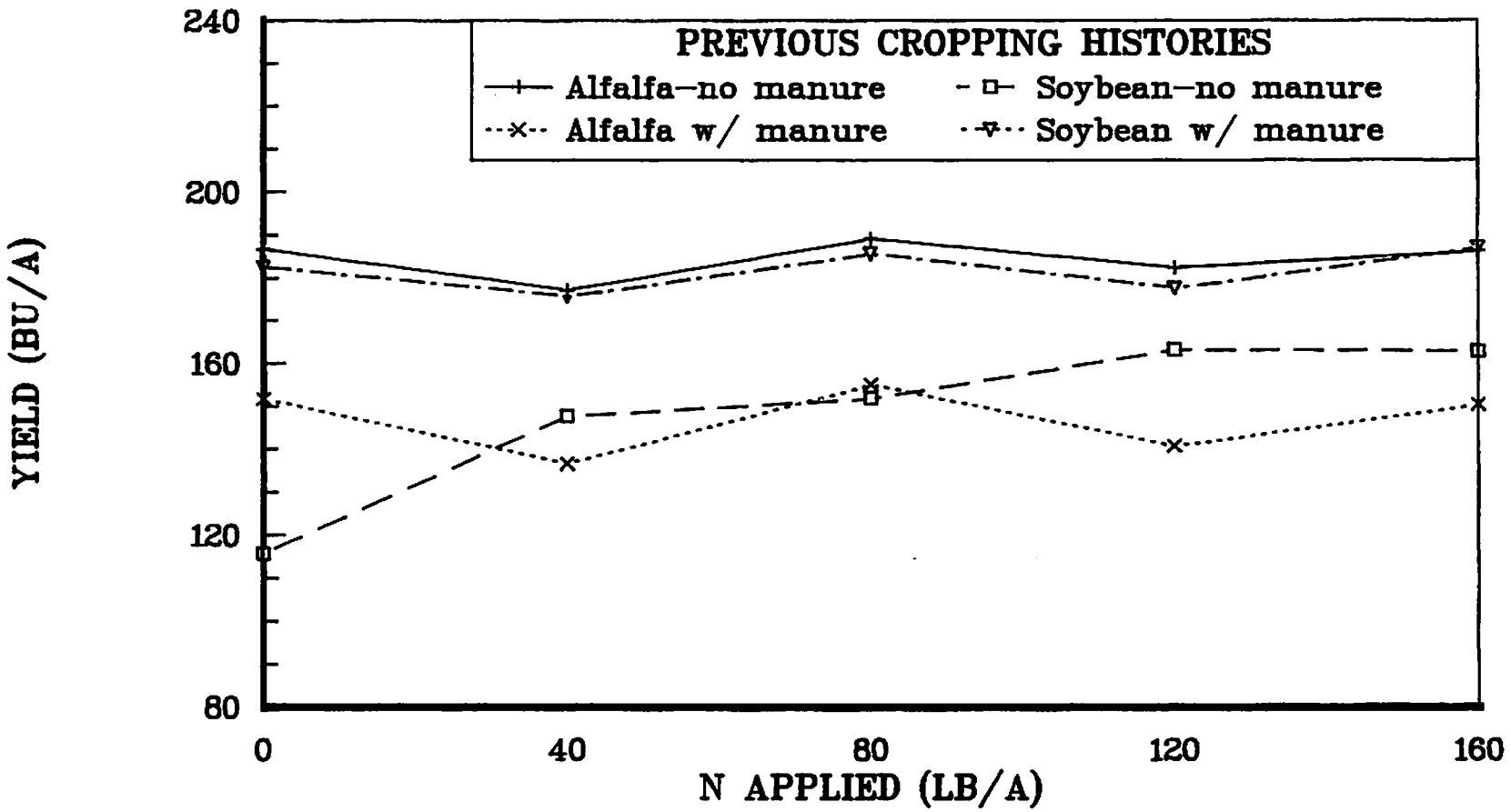
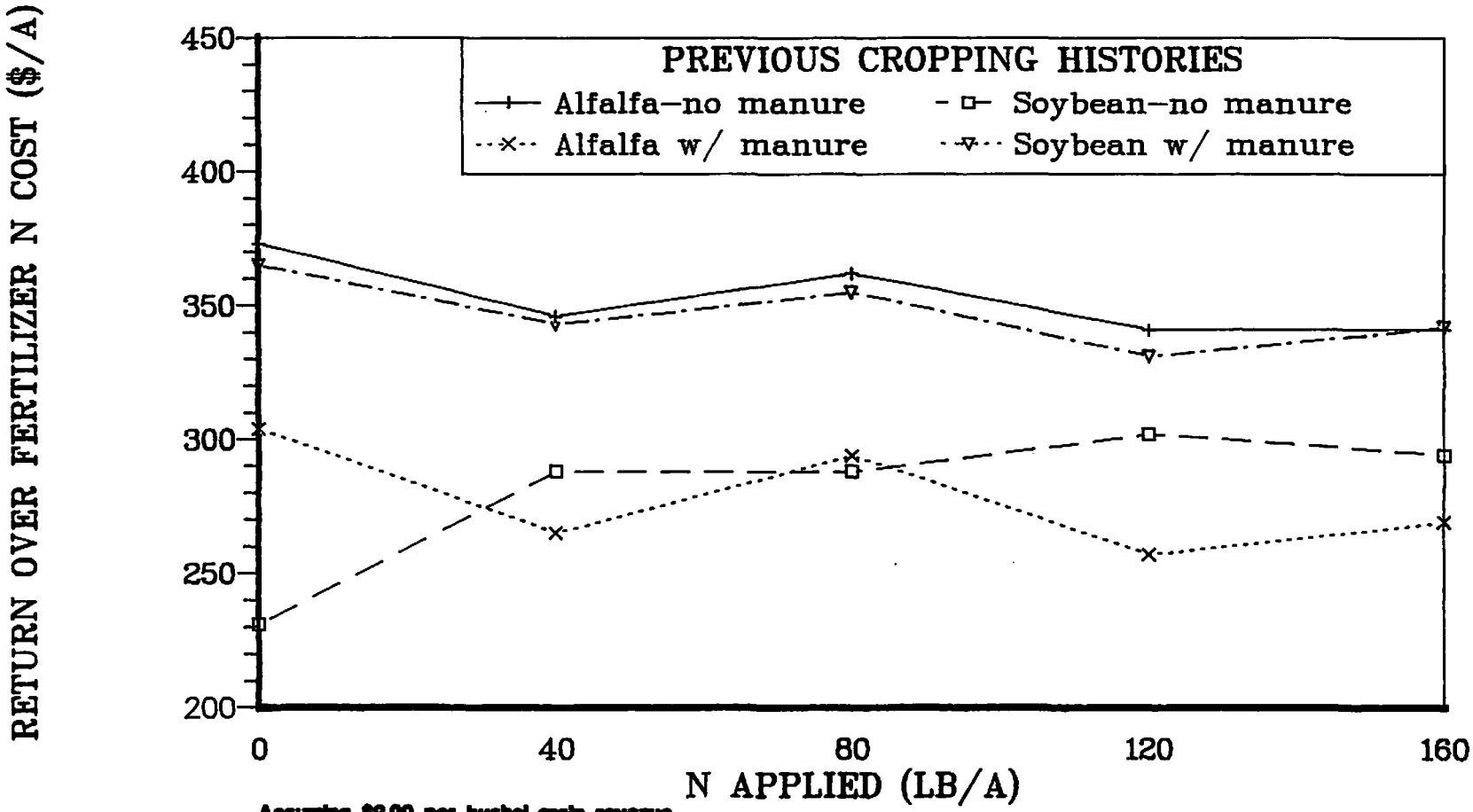


Figure 2. Economic returns as affected by fertilizer N rates and previous crop history, 1990.



Assuming $2.00 per bushel grain revenue and $0.20 per pound N costs.

EVALUATION OF AMMONIUM SULFATE AS A CORRECTIVE TREATMENT FOR IRON CHLOROSIS IN SOYBEANS

George Rehm, Jerome Lensing, Andy Scobbie, and Dan Schmitz[1/]

ABSTRACT: Lime induced iron chlorosis is a major problem for soybean producers in western Minnesota. There were claims that the soil application of ammonium sulfate (21-0-0-24) would correct the problem. This fertilizer material was evaluated at 4 locations in southwestern Minnesota. Both broadcast and row applications were used. There was no consistent effect of the use of this product on yield. Variety selection still remains as the best management practice for reducing yield loss.

Introduction:

Lime induced iron chlorosis has been a persistent problem with soybeans in western Minnesota for several years. Past research has shown that a foliar application of chelated iron materials would help the problem if the plants were sprayed early in the growing season. This treatment, however, is expensive. Recently, there have been claims that the broadcast on banded use of ammonium sulfate 21-0-0-24 would correct the problem.

Objective:

The objective of these field trials was to measure yields of several soybean varieties as affected by either the broadcast or banded application of 21-0-0-24.

Experimental Procedure:

This study was conducted at 4 sites in southwestern Minnesota. Ammonium sulfate (21-0-0) was either broadcast and incorporated before planting or applied in a starter band. The rate of application was 100 lb. per acre for both situations. Two or more varieties were compared at each location. Management practices conducive to the production of high yields were used. Grain yields were measured in late September and corrected to 13.5% moisture.

Results and Discussion:

Grain yields are summarized in the table that follows. The "t" test was used to determine if the use of 21-0-0-24 had an impact on yield for each variety at each site.

Treatment had a significant effect on yield in 4 situations. In 2 situations, the use of 21-0-0-24 produced a significant reduction in yield. However, the 21-0-0-24 increased grain production at 2 other locations. So, the results are inconclusive at best. All sites selected had experienced a serious reduction in yield caused by lime induced iron chlorosis in the past.

The data collected do not substantiate the claim that the use of 21-0-0-24 corrects iron chlorosis problems. The importance of variety selection is illustrated by the yields from the Bussing site. This still remains as the major management tool that can be used for alleviating the problem.

[1/] Extension Specialist; Agronomist, Pioneer Hybrids; Assistant Scientist and Junior Scientist, respectively.

The effect of ammonium sulfate on yield of various soybean varieties of several locations in southwestern Minnesota.

Site Location	Variety	21-0-0-24 Used		21-0-0-24 Not Used
		- - - - - - - bu./acre - - - -		
Schultz	9111	46.5		46.0
	9091	44.3		43.0
Schuller	9181	50.7	*	48.6
	9161	50.7		47.0
	9171	49.2	*	55.4
	9251	45.3	*	49.8
Bussing	9091	49.3		51.9
	9061	3.8		4.1
Burns	9202	43.8	*	38.6
	9091	38.7		37.5

* There is a significant difference between the 2 averages at the .05 confidence level. Treatment means are averages of 4 replications.

THE EVALUATION OF BANDED APPLICATIONS OF POTASH FERTILIZER FOR IMPROVED CORN AND SOYBEAN PRODUCTION IN A RIDGE-TILL PLANTING SYSTEM

George Rehm, Andy Scobbie, Dan Schmitz[1/]

ABSTRACT: Banded application of K_2O in the center of existing ridges has increased corn yields. This study was designed to evaluate the frequency of banded K_2O applications on yields in a corn/soybean rotation. In 1990, the test crop was soybeans. Soybean yields were increased by the rate of K_2O applied in a band in the fall of 1988 as well as rate of K_2O applied in a band in the fall of both 1988 and 1989.

Background and Justification:

During the mid-1980's farmers who were growing corn in ridge-till planting systems observed potassium (K) deficiency symptoms with certain corn hybrids. These symptoms appeared even though soil test values for K were considered to be high or very high. The frequency of these observations increased substantially during the very dry 1988 growing season. Observations were not limited to one soil type or one localized area in Minnesota. This was a situation that appeared in all parts of the state.

It was also apparent from the reports that the severity of the deficiency symptoms varied with hybrid. The most acute symptoms were reported where Pioneer 3732 was the hybrid of choice. Using only visual symptoms as a guide, there appeared to be no problem with Pioneer 3737. In Minnesota, Pioneer hybrids are used on a large number of acres where the ridge-till planting system is used. So, this apparent K deficiency became a very real problem that had to be addressed.

There's general agreement that K uptake by corn is reduced in ridge-till planting systems regardless of hybrid. To help overcome this problem, Dr. Barber of Purdue University has suggested a banded application of potash fertilizer. His suggestions evolve from a root growth model developed from laboratory and greenhouse data. He also suggested that banding of immobile plant nutrients be further evaluated in field situations. Reports of consultants who worked closely with farmers who used ridge-till planting systems suggested that banded applications of potash fertilizer in the center of the ridge in the previous fall could help to overcome K deficiency symptoms and subsequent yield reductions.

It was obvious that there was a pressing need to evaluate the impact of banded potash fertilizer in ridge-till planting systems. This was especially true when soil test values for K are in the high and/or very high range.

Objective:

Based on the situation just described, the overall objective of this study is to evaluate the effect of rate and frequency of potash application in the center of existing ridges on both corn and soybean production. The impact of this method of fertilizer application on soil test values will also be measured.

Experimental Procedure:

This project was initiated in Murray County in the fall of 1988. The site had a history of creating K deficiency symptoms in corn. Prior to fertilizer application, detailed soil samples were collected from several locations in the plot area. The sample collection pattern was designed to measure the amount of extractable K at various positions in the ridge. When results of the analysis were averaged, the K concentration was 145 ppm.

The study initiated in 1988 was a factorial combining 4 rates of K_2O (0, 40, 80, 160 lb/acre) with 3 hybrids (Pioneer 3902, Pioneer 3732, Pioneer 3737) using 4 replications. In the fall of 1989, the design was changed so that the impact of both K_2O rate and frequency of application could be measured. Three frequencies (1 in 3 years, 2 in 3 years, 3 in 3 years) were combined with 4 rates of K_2O (0, 40, 80, 160 lb K_2O/acre) in a complete factorial with 4 replications.

The second application of K_2O (supplied as 0-0-60) was made in the fall of 1989. For all treatments in both years, a coulter system set to operate at a depth of approximately 5 inches placed the 0-0-60 at a depth of about 3 to 3.5 inches below the soil surface.

[1/] Extension Specialist, Assistant Scientist, Junior Scientist, respectively.

Soybeans were grown as the test crop in 1990. They were planted on May 25 at a population of about 10 seeds in a linear foot. The most recently mature leaflets were collected at early to mid-bloom. These tissue samples were dried, ground, and analyzed for K. Soybean grain yields were measured in October and corrected to 13.5% moisture.

Yield

Results and Discussion:

Soybean yield was affected by both frequency and rate of K_2O applied (Table 1). There was no residual effect from the application of 40 and 80 lb K_2O per acre in the fall of 1988. There was, however, some residual effect from the 160 lb K_2O per acre applied at that time.

The yield data also suggest that the annual application of K_2O is most beneficial. When the K_2O was applied in both 1988 and 1989, there was a significant increase in yield with each rate of K_2O applied.

These data also show that the banded application of K_2O has a positive effect on the yield of both corn and soybeans. It is possible that the potassium problem could have limited yields of soybeans grown in a ridge-till planting system in previous years.

Table 1. Effect of frequency of application and rate of K_2O used on soybean yield. Murray County. 1990.

K_2O Applied	Rate of K_2O Used	Yield
	lb./acre	bu./acre
1988 only	0	49.6
	40	49.6
	80	49.7
	160	52.5
1988 and 1989	0	49.5
	40	51.0
	80	51.5
	160	54.3

K in Plant Tissue

In contrast to yields, neither frequency of application nor rate of K_2O used had a significant effect on the concentration of K in the soybean leaflets at early to mid-bloom (Table 2). There's general agreement that the critical concentration of K in soybean leaf tissue is 2.0%. The K concentration for all treatments was higher than this value indicating that, under conventional planting systems a response to K_2O use would not be expected. It's obvious that K concentration in leaf tissue is not indicative of response to K_2O for soybean production in ridge-till planting systems.

Table 2. Effect of frequency of application and rate of K_2O used on K concentration in soybean tissue at early to mid-bloom. Murray County. 1990.

K_2O Applied	Rate of K_2O Used	K Conc.
	lb./acre	%K
1988 only	0	2.11
	40	2.17
	80	2.22
	160	2.21
1988 and 1989	0	2.12
	40	2.21
	80	2.12
	160	2.34

MECHANICAL AND CHEMICAL WEED CONTROL DEMONSTRATIONS IN CORN AND SOYBEANS[1]

P. M. Bongard, F. Breitenbach, T. Arlt, and R. Hamer[2]

Introduction

Timely cultural weed control practices may reduce reliance on chemical measures, and thus reduce the inherent risk of pesticide contamination to groundwater. The objective of this demonstration was to show different combinations of herbicide applications and mechanical practices for optimum weed control in corn and soybeans. This demonstration is part of the Environmental Agriculture Education Program of Cluster 16.

Materials and methods

Two corn and two soybean demonstration sites were selected in the Cluster 16 area. The corn sites were located in Freeborn and Rice counties; the soybean sites were located in Mower and Steele counties. All sites were located on medium textured soils which were high in natural fertility and organic matter contents (Table 1).

A split-plot arrangement with four replications was used at each site. Three herbicide treatments (main plots) were used: 1) No herbicide; 2) a pre-plant incorporated herbicide; and 3) a pre-emergence herbicide in corn and a post-emergence herbicide in soybeans. Within each of the main herbicide plots, there were four mechanical weed control treatments (sub-plots): 1) Rotary hoe (5-7 and 10-14 days after planting); 2) Cultivation (four weeks after planting and again by lay-by); 3) Combination of rotary hoe and cultivation; and 4) No mechanical practices. Sub-plots were six or eight rows wide (dependant upon cooperators' equipment), and 100 feet long.

Corn demonstration

Dual 8E at 3 pints/acre (3 lb a.i./acre) was used for both the pre-plant incorporated and pre-emergence herbicide applications. At Freeborn County, the pre-plant incorporation, planting, and the pre-emergence application was completed on May 8. At Rice County, the pre-plant application was made on May 15, but incorporation was delayed twelve days due to rain. Planting and the pre-emergence application was completed by May 29. Pioneer 3751 was planted at both locations. Farmer cooperators followed the mechanical control schedule described above as closely as was possible (Table 2).

Early season weed control was evaluated visually on a scale of 1 to 10 (1=poor, 10=excellent) approximately six weeks after planting. Plots were harvested with the farmers' equipment, weighed, and yields adjusted to 15.5% moisture.

Soybean demonstration

The herbicides selected for the soybean demonstrations were Treflan (pre-plant incorporated treatment) and Pursuit (post-emergence treatment). Treflan 4E was applied at 2 pt./acre (1 lb. a.i./acre) and incorporated at the Mower and Steele county sites on May 31. Hardin soybeans were planted within 24 hours of the pre-plant treatment at both sites. Pursuit was applied on June 22 at the 4 oz./acre rate (0.063 lb. a.i./acre). Cooperators followed the mechanical weed control schedule described above as closely as possible (Table 2).

Early season weed control was visually evaluated approximately six weeks after planting. Plots were harvested with the farmers' equipment, weighed, and yields adjusted to 12.0% moisture.

Results and discussion

Nineteen-ninety was an interesting year to conduct weed control trials. After three dry years, the unusually wet and cool 1990 season provided different weed control challenges. A late flush of weeds seemed to result in greater overall weed competition.

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[1]Funding provided by Board of Soil and Water Resources through Environmental Agriculture Education Program Grant of Cluster 16, Minnesota Extension Service.

[2]Environmental Agriculture Educator, Cluster 16; Area Extension Agent, Crop Pest Management; County Extension Agent, Agriculture, Steele County; and County Extension Agent, Rice County; Minnesota Extension Service.

Late season weed pressure varied greatly between demonstration sites. Weed pressure was high at the Freeborn County corn and Steele County soybean sites, while pressure was low at the Rice and Mower county demonstration sites. Due to differences in weed pressure, analyses for each site were kept separate.

Corn demonstration

Early season weed control in the pre-plant and pre-emergence application plots was very good at both sites (Table 3). Mechanical measures had the greatest impact in the plots where no herbicide had been applied. This was quite evident at the Freeborn site where weed pressure was high. Rotary hoeing at this site was only slightly better than using no mechanical measures, and much less effective than cultivation. A late flush of weeds emerged after plots could be rotary hoed, but while cultivation was still a viable control option. The primary weed species at both sites was giant foxtail.

Differences in weed pressure had an interesting effect on yields and returns over weed control costs. At the high weed pressure site (Freeborn County), there were no statistical yield differences between any of the pre-plant or pre-emergence treatments. However, yields in the no herbicide plots were severely reduced (Figure 1). Since there was no yield advantage to mechanical control in the herbicide plots, the highest returns over weed control costs was in these no mechanical, pre-plant or pre-emergence herbicide plots (Figure 2). At the low weed pressure site in Rice County, no herbicide plots that had been rotary hoed + cultivated or cultivated only yielded as well as the plots where herbicide had been applied (Figure 3). As a result, the highest returns were from these cultivated no herbicide plots (Figure 4). The low weed pressure encountered at this site may have been a function of the later than average planting date.

Soybean demonstration

Early season weed control at the Mower County site, where weed pressure was low, was excellent (Table 3). At Steele County, early season control was best in the Pursuit and cultivated Treflan plots. (Since cultivation and the rotary hoe + cultivation treatments performed similarly, they will be referred to collectively as cultivated plots.) Similar to the Freeborn County corn site, the rotary hoe only treatment missed a late flush of weeds in the no herbicide and Treflan plots. Treflan lost some effectiveness in the unusually wet and cool conditions, resulting in higher weed pressure in the rotary hoe and no mechanical treatment plots. At Steele County, giant foxtail and giant ragweed were the predominant weed species. The slight weed pressure at Mower County was primarily from giant foxtail.

These differences in weed pressure were reflected in yield and return differences between the two sites. At the Mower County site, yields were not significantly different between the Pursuit plots and the cultivated Treflan and no herbicide plots (Figure 5). Highest returns over weed control costs were realized in the Pursuit, no mechanical control plots (Figure 6). At the high weed pressure site, yields were equally good among the Pursuit plots and the cultivated Treflan plots (Figure 7). Soybean yields were severely reduced in the no herbicide and rotary hoed Treflan and no mechanical control plots, as the late weed flush had transformed these plots into giant ragweed and giant foxtail forests. It is no suprise that the greatest returns were obtained in the Pursuit and cultivated Treflan plots (Figure 8).

Summary

These demonstrations reinforce the need for producers to be familiar with weed species and pressures of individual fields. At low weed pressure sites, yields in the cultivated no herbicide plots were as good as herbicide treated plots, suggesting that mechanical control measures can be more heavily relied on under certain conditions. If, on the other hand, no herbicide had been used on a whole field basis at the high weed pressure sites, losses to the producer would have been substantial. Risks of contaminating groundwater with pesticides may be reduced by carefully selecting and applying herbicides when needed, and relying on mechanical measures to a greater extent when appropriate.

Table 1. Soil types and histories of demonstration sites, 1990.

County	Demonstration crop	Primary soil	O.M. content	Previous crop
Freeborn	Corn	Spicer silt loam	High	Corn
Rice	Corn	Clarion loam	High	Corn
Mower	Soybeans	Readlyn silt loam	High	Corn
Steele	Soybeans	Clarion loam	High	Sweet corn

Table 2. Mechanical weed control practice schedule, 1990

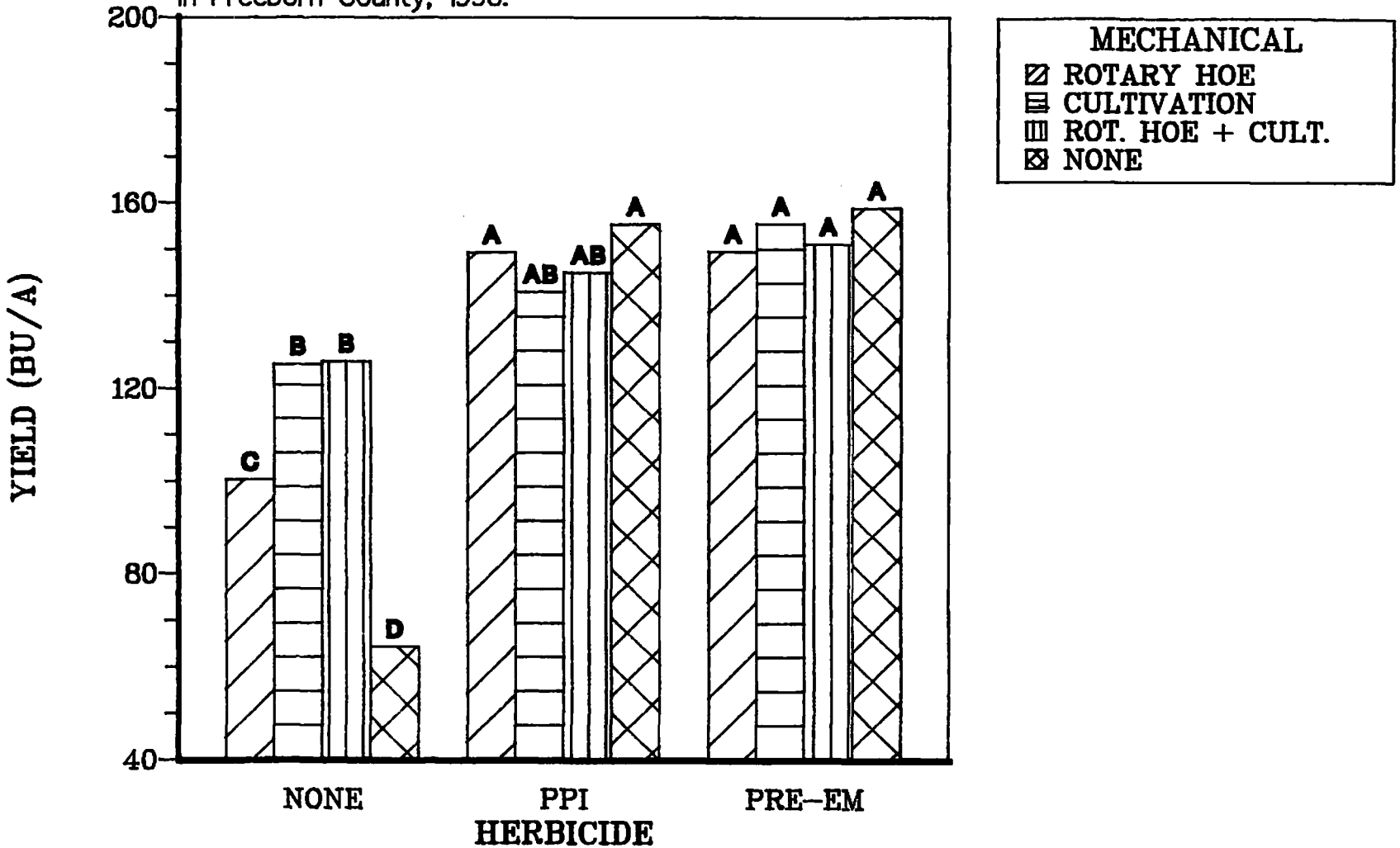
County	Crop	1st rot. hoe	2nd rot. hoe	1st cult.	2nd cult.
		----------DAP[1]---------		------WAP[2]-------	
Freeborn	Corn	20	-	3	6
Rice	Corn	10	17	4	6
Mower	Soybeans	6	-	4	6
Steele	Soybeans	7	14	4	6

[1]DAP = days after planting
[2]WAP = weeks after planting

Table 3. Visual weed control evaluations (1=poor to 10=excellent). Scores followed by the same letter in the same column are not significantly different at the 0.05 level.

Herbicide	Mech. control	Corn		Soybeans	
		Freeborn	Rice	Mower	Steele
None	Rot.hoe	2.5 f	6.2 cd	7.8 cd	1.2 f
	Cult.	4.8 e	7.2 bc	9.5 a	7.2 d
	R.H. + cult.	5.8 d	8.5 ab	9.0 ab	7.2 d
	None	1.2 g	4.8 d	7.0 d	1.2 f
PPI	Rot. hoe	9.2 abc	9.5 a	9.0 ab	6.5 d
	Cult.	9.0 bc	9.8 a	9.8 a	9.2 abc
	R.H. + cult.	10.0 a	9.8 a	10.0 a	9.5 abc
	None	8.5 c	8.8 ab	8.2 bc	5.0 e
Pre-em	Rot. hoe	9.5 ab	9.2 a	9.5 a	8.8 bc
or	Cult.	9.5 ab	9.0 a	10.0 a	10.0 a
Post	R.H. + cult.	10.0 a	9.8 a	9.8 a	9.8 ab
	None	9.0 bc	8.2 ab	9.2 ab	8.5 c

Figure 1. Corn yields as affected by mechanical and chemical weed control practices in Freeborn County, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level

Figure 2. Returns over weed control costs at Freeborn County, 1990.

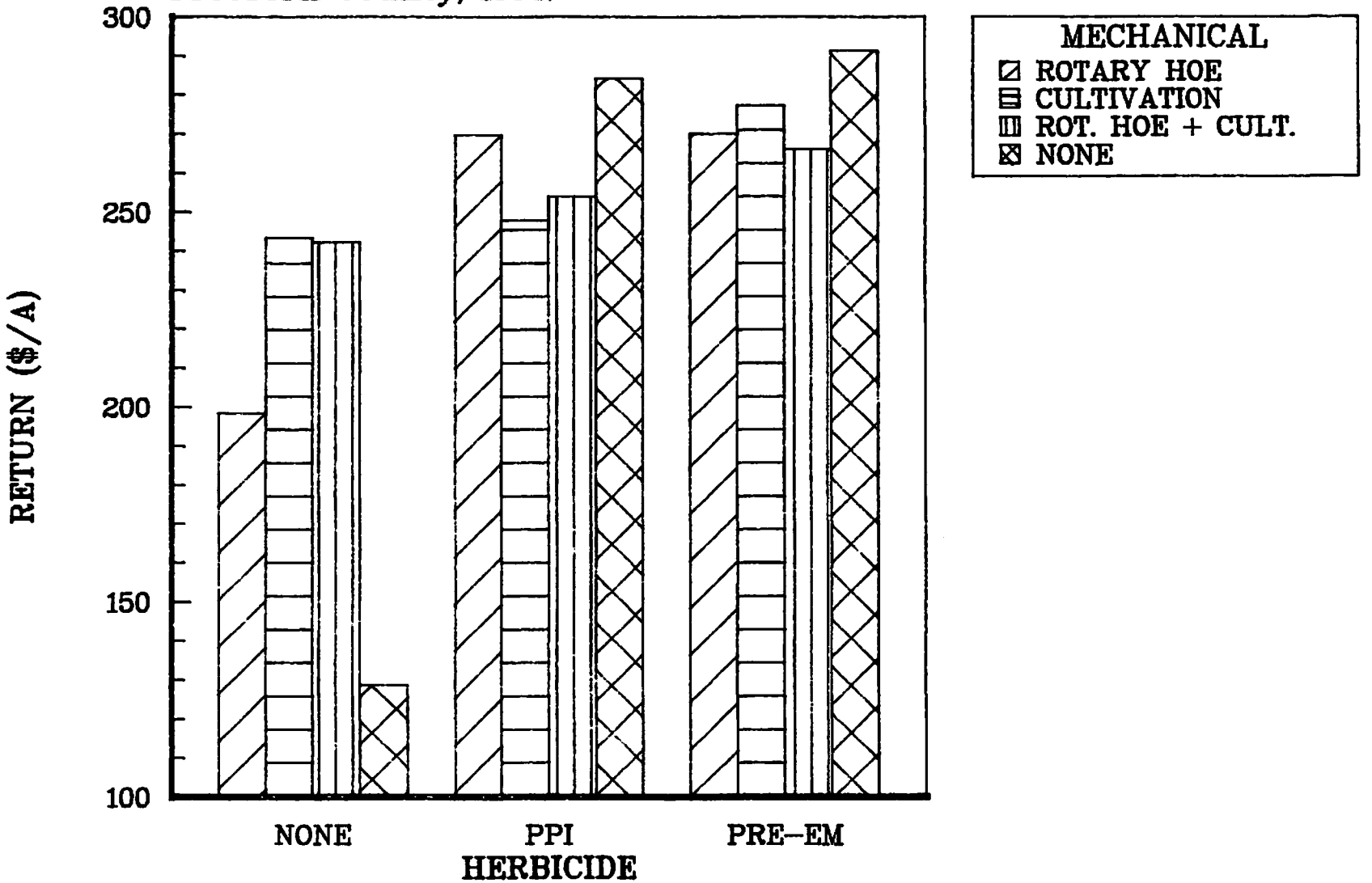
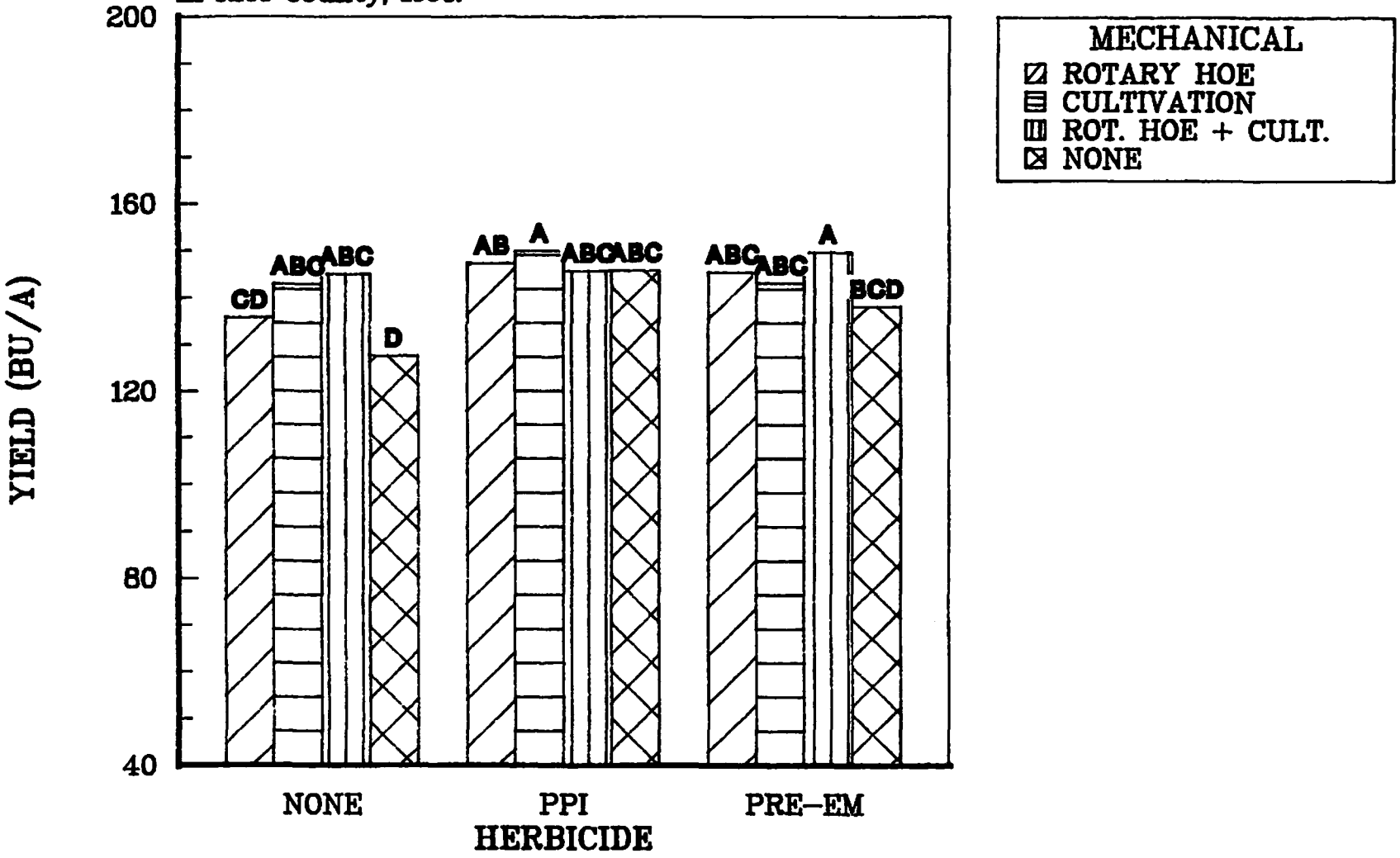


Figure 3. Corn grain yields as affected by mechanical and chemical weed control practices in Rice County, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level.

Figure 4. Returns over weed control costs at Rice County, 1990.

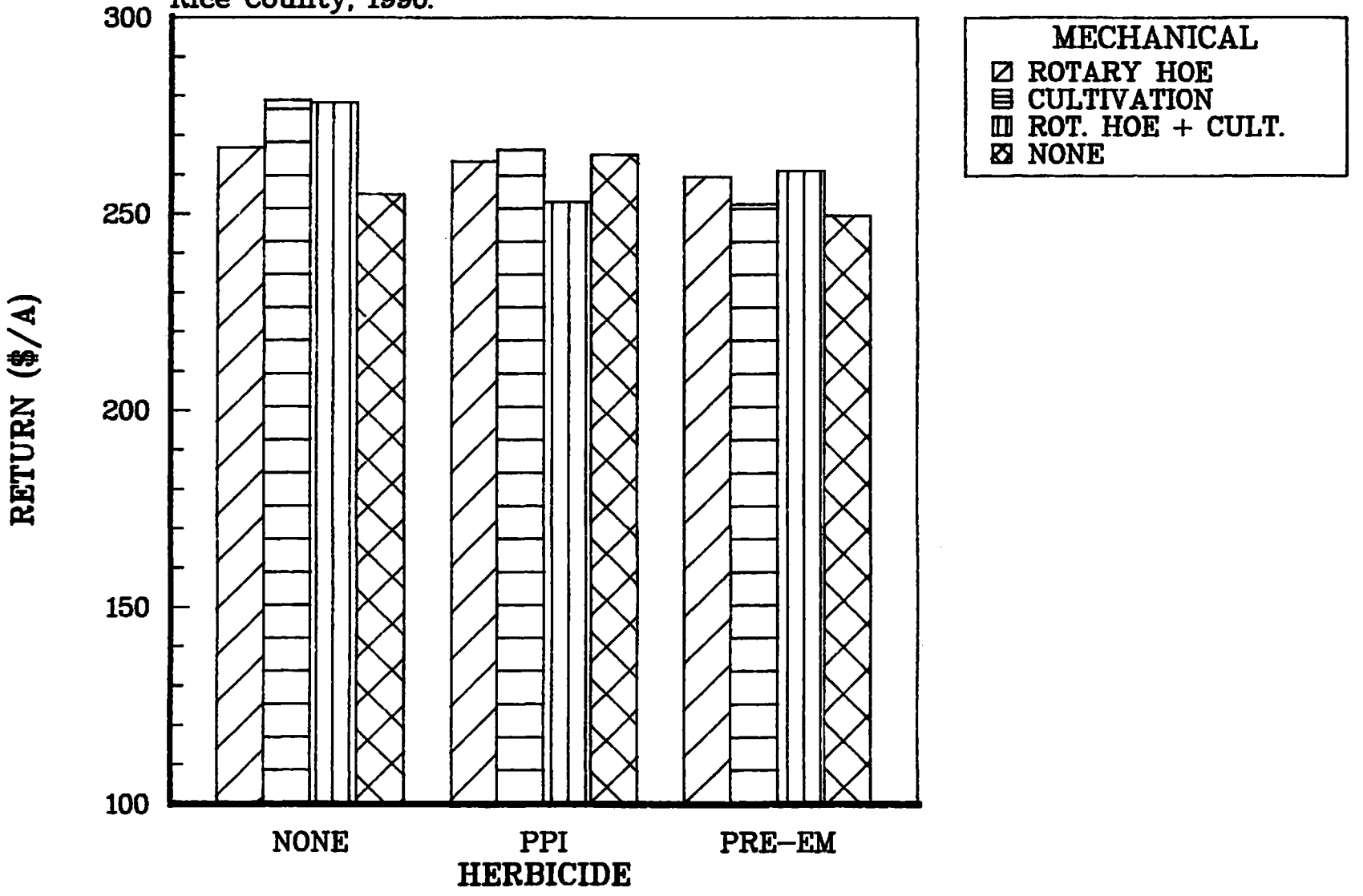


Figure 5. Soybean yields as affected by mechanical and chemical weed control practices in Mower County, 1990.

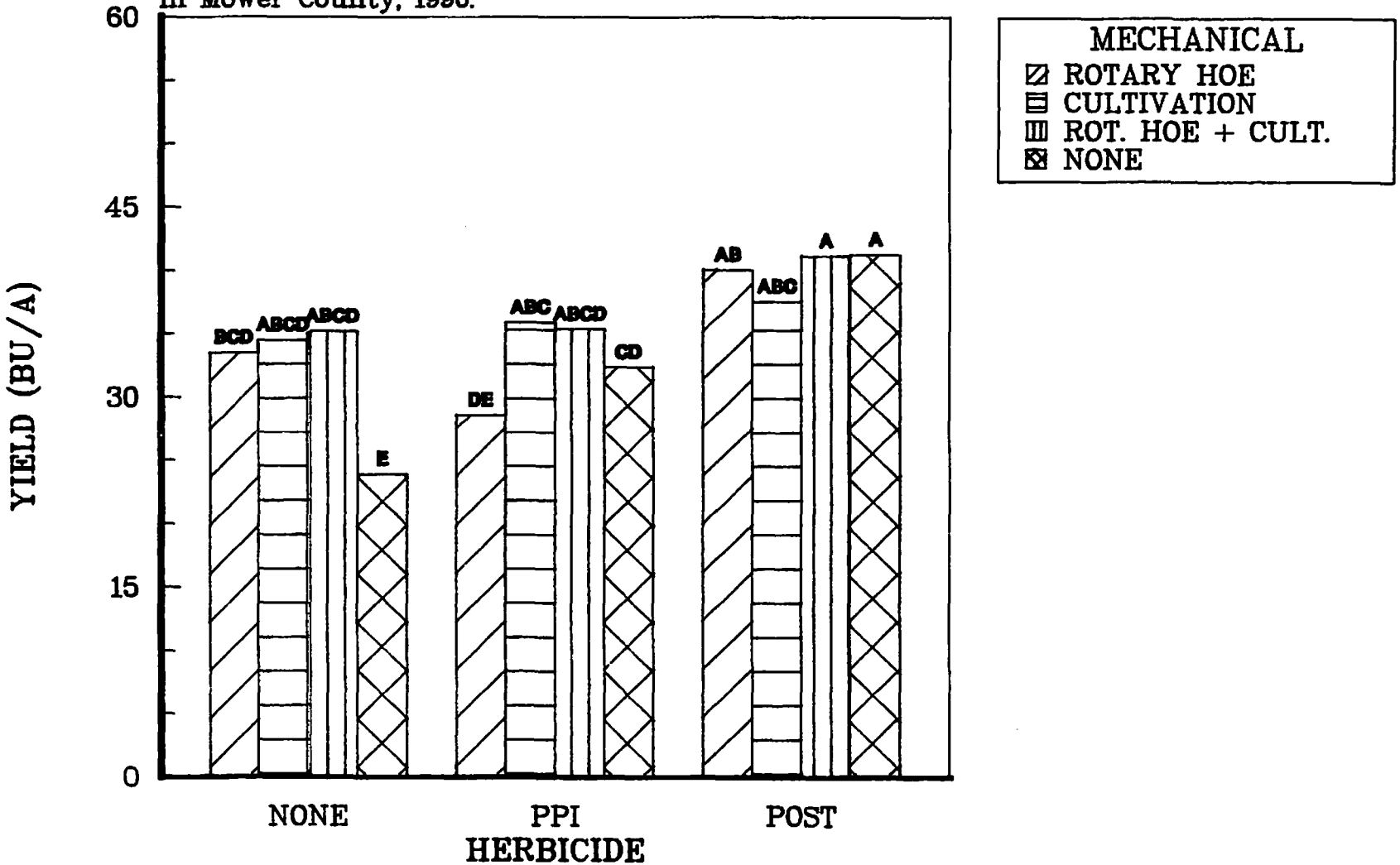


Figure 6. Returns over weed control costs at Mower County, 1990.

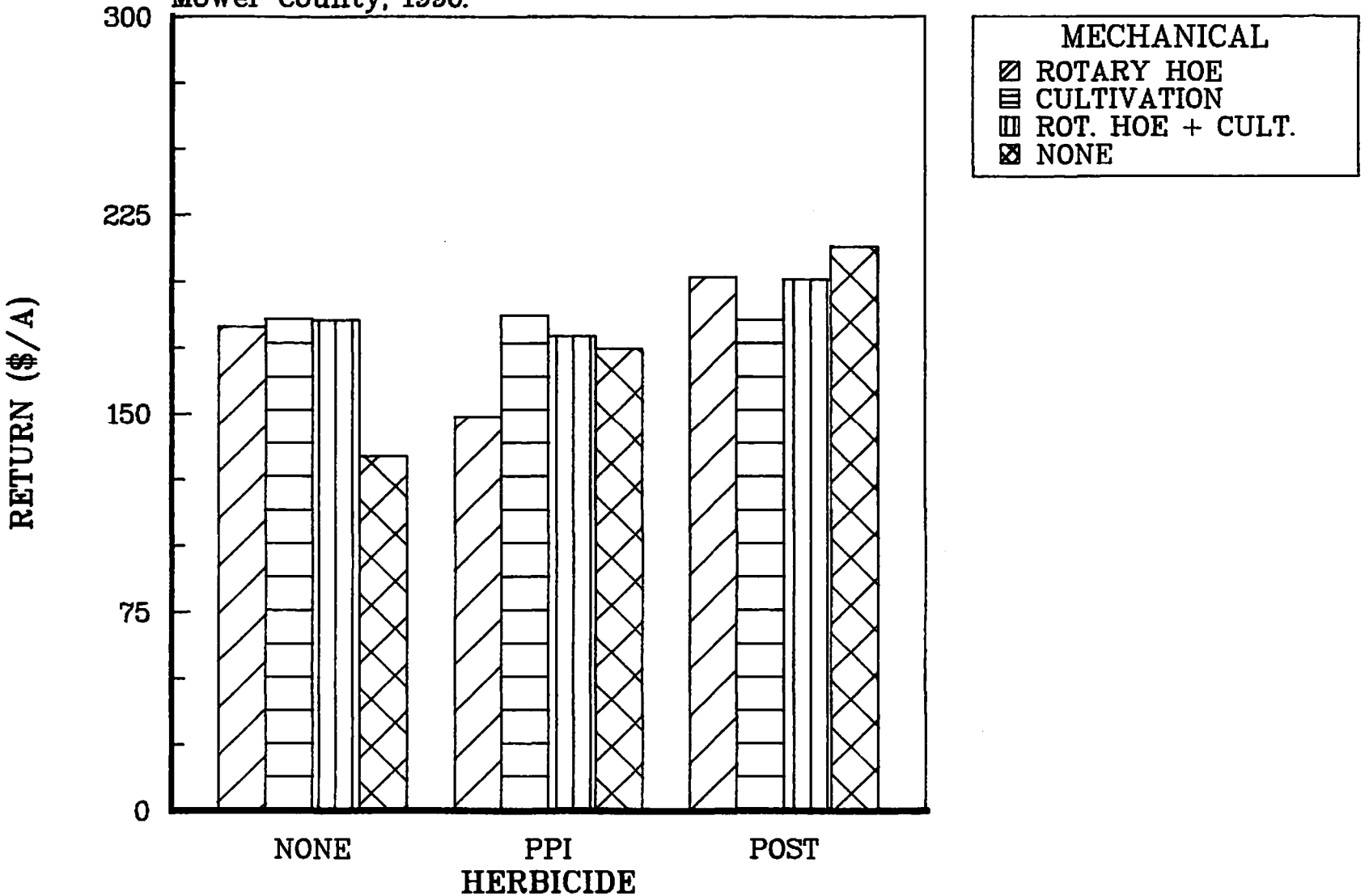
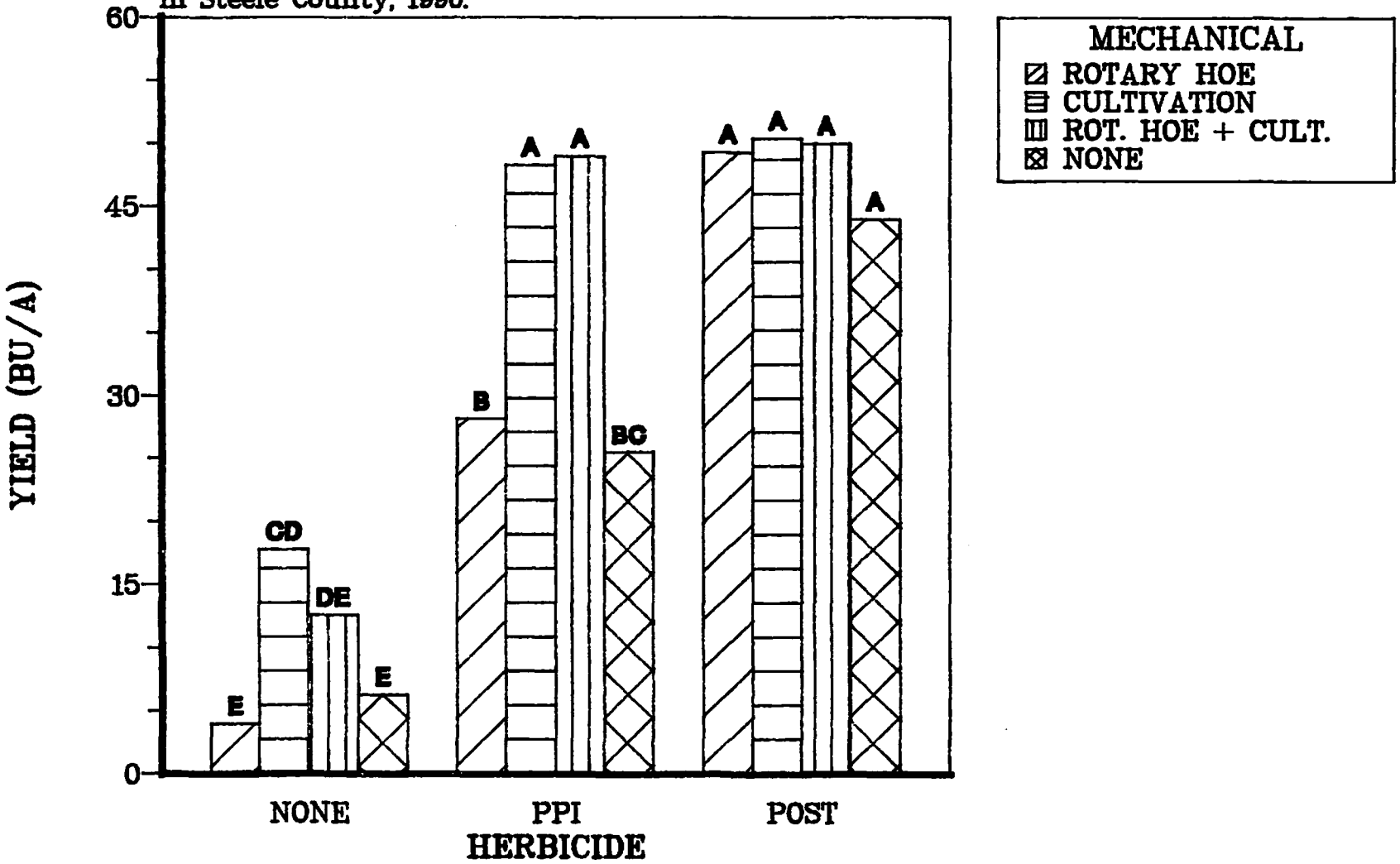
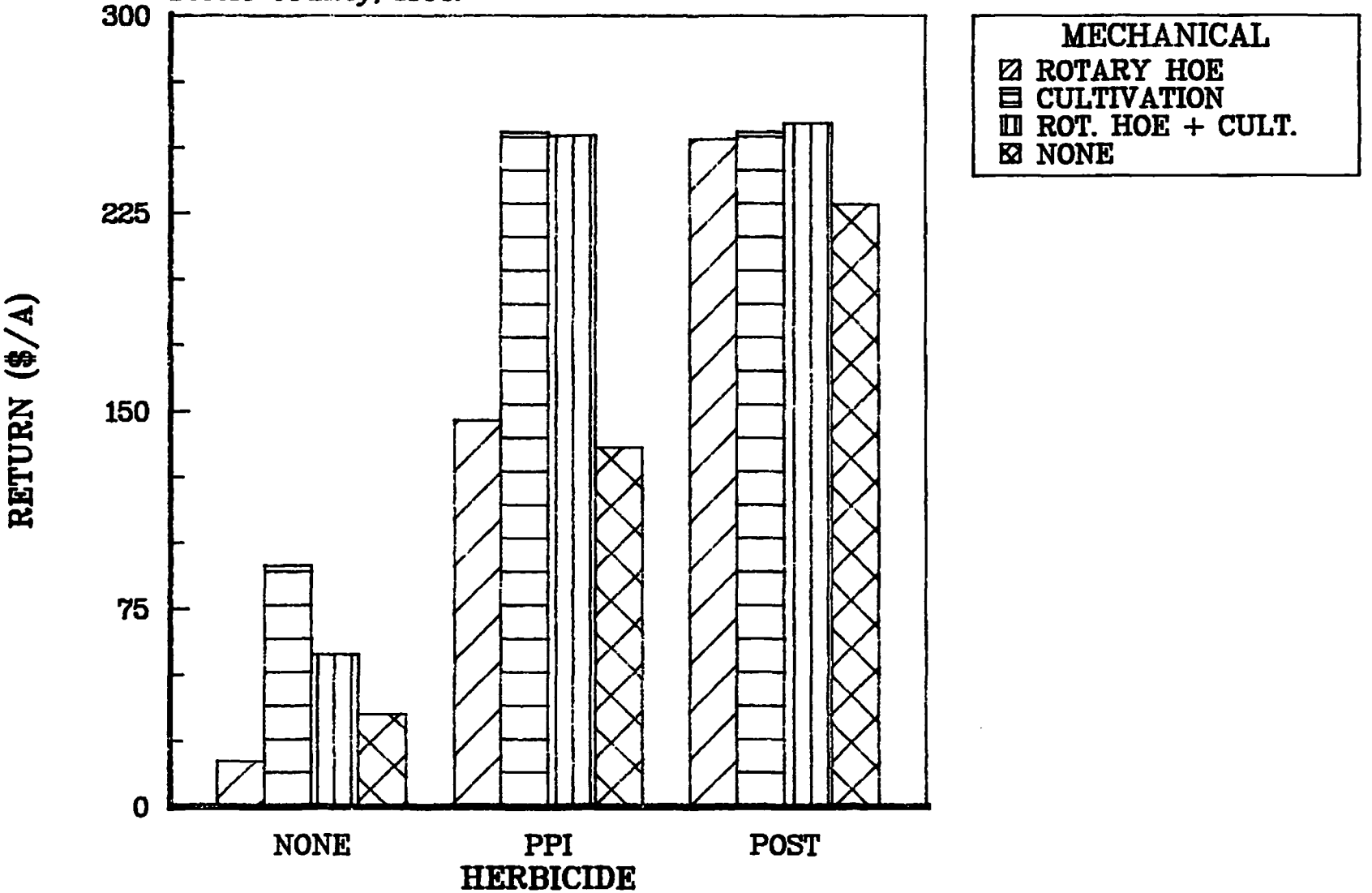


Figure 7. Soybean yields as affected by mechanical and chemical weed control practices in Steele County, 1990.



Yields identified by the same letter are not significantly different at the 0.05 level.

Figure 8. Returns over weed control costs at Steele County, 1990.



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

Carl Rosen, Dave Birong, and Louise America

ABSTRACT. Soil samples from 10 irrigated fields were collected to a depth of three feet during the 1990 growing season. Fields sampled included: 6 potato fields, 3 sweet corn fields, and, 1 field corn field. Soil nitrate-N and ammonium-N were determined in KCl extracts. In addition, soil water from all fields was collected weekly from suction tubes and analyzed for nitrate-N. Rainfall during the 1990 season was well above average with over 6 inches occurring during a one week span in mid-June. Significant nitrogen movement beyond the root zone corrsponding to the June rainfall was detected in all fields. Nitrogen distribution during the season in potato and corn fields differed due to differences in placement. At mid-season nitrate and ammonium were higher between the row in corn and higher within the row for potato. Dry matter and nitrogen accumulation in roots, vines, and tubers through the season for early harvested and late harvested potatoes are presented.

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 nitrate-N 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 fields under conditions defined by growers. The ultimate goal is to help improve N management practices for irrigated crops.

Experimental Procedures. Six potato fields, three sweet corn fields, one field corn field, one tomato field, and one gladiolus 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 flowering for the gladiolus 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. All soil samples were placed in plastic bags and kept moist at 40°F until analyzed (usually less than 3 days). 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 Sept. samples, total nitrate-N and ammonium-N in the 3' profile were calculated by assuming half the field was 'within row' and the other half was 'between row'.

In five of the six potato fields, recently mature leaf (leaflet plus petiole) and petiole alone samples were collected on June 29. Samples were dried and ground to pass through a 30 mesh seive. Water soluble nitrate-N was determined using conductimetric procedures. Other elements were determined in ashed samples dissolved in 1 N HCl using ICP methodology. In two potato fields, 3, 5 ft sections were harvested at 10 day intervals and seperated into roots, vines, and tubers and then dried and weighed. Nitrogen was determined using the salicylic acid method for total nitrogen. Suction tubes were installed in the rows of five of the six potato fields and all other fields at 2.5 and 4.5 foot depths. There were two tubes at each depth in each field. Nitrate in soil water was determined in samples collected weekly during the growing season and at 2-3 week intervals after harvest through mid-November.

Results and Interpretations. Rainfall during the 1990 growing season was excessive. There were at least 3 dates between June and August where more than 3 inches of rain fell over a 24 hour period (Fig. 1). Most growers attempted to supplement rainfall, when needed, to provide about 1.5" - 2" of water per week from June through mid-August. Potato yields varied from approximately 260 cwt/A to 530 cwt/A, and N fertilizer applications ranged from 180 lb N/A to 300 lb N/A. Sweet corn yields ranged from 5.5 T/A to 7.5 T/A, and N fertilizer applications ranged from 160 lb N/A to 200 lb N/A. The field corn yield was 156 bu/A with 250 lb N/A applied.

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

[2] Extension Soil Scientist, Junior Scientist, Research 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 29 lb/A nitrate-N in the top 3 feet before planting and fertilizer application, with a range of 18 to 34 lb/A. There was a gradual decrease in nitrate from the top foot to the bottom 2-3 foot depth. In contrast to previous years, the residual nitrate level in the soil was low, possibly due to higher amounts of fall and winter precipitation. The practice of hilling and placing fertilizer N in the row affected N distribution in the field. Levels of nitrate-N in the rows were over 2 times greater than levels between rows. The amount of nitrate-N in the top 3' in July was about 20 lbs lower than in previous years due to leaching rainfall that occurred in June and July. At harvest, the level of nitrate-N in the top 3 feet was about 10 lbs higher than the level recorded before planting.

Ammonium-N levels during the growing season over all potato fields are summarized in Table 2. One field had unusually high ammonium-N levels. This particular field had field corn as a previous crop where anhydrous ammonia was used as the N source. 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 most potato fields, large flushes of nitrate were detected at about day 175. This corresponds to a leaching rain on June 18-19 (calendar day 169-170). In most cases nitrate-N rapidy declined at the 2.5' depth after this date followed by a more gradual decline at the 4.5' depth. Management practices did have some influence on the relative levels of nitrate in the soil water. For example, late planted, low yielding potatoes (Figure 2) and potatoes receiving higher rates of N (Figures 3 and 4) generally had higher soil water nitrate concentrations during the season and after harvest compared to potatoes with higher yields and where lower nitrogen rates were used. Dry matter accumulation and nitrogen accumulation in roots, vines, and tubers through the season for early and late harvested potatoes are presented in Figures 11 and 12. For half the season, most of the dry matter and N accumulation was attributed to the vines. Tubers accounted for most of the dry matter and nitrogen during the latter part of the season. Roots were relatively minor contributors to dry matter and N accumulation. Early harvested potatoes accumulated a total of 100 lb N/A by the end of the season while late harvested potatoes accumulated 125 lb N/A.

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. Because of the later planting date, field 1 had higher levels of tissue N than the other fields. Based on established critical values for that sampling date, fields 2, 3, and 4 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, 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-N and ammonium-N were generally similar to those found in fields to be planted in potatoes. 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. At mid season there was significantly more ammonium-N in the corn than in the potato fields. Except for one field, most of the N fertilizer was applied after the heavy rainfall in June. Residual nitrate was higher in corn than in potato fields.

Soil water nitrate in the corn fields is presented in Figures 7 to 10. The early planted sweet corn (Fig. 10) had the highest nitrate-N concentrations in the soil water at both sampling depths following the leaching rain in June. The other corn fields sampled had relatively low nitrate-N concentrations. The lower concentrations were due to the later planting dates and delay in applying N fertilizer until later in the season.

In summary, the 6 inch rainfall occurring in June caused leaching in all fields. From a potato production standpoint, this rain occurred at a time when the potential for nitrate leaching was very high. All the sidedress N had been applied, any ammonium-N applied would have been nitrified, and plant growth was just begining the exponential phase. Therefore, 1990 would probably represent a worst case leaching potential for potatoes. This survey has also shown that N distribution during the growing season in potato and corn fields differed. Most N was within the row for potato and between the row for corn. Because of the later planting and N fertilizer application dates for corn, more nitrate moved beyond the root zone in potato than corn. Based on nitrate samples from suction tubes, timing of application, N rate, and final yield had an effect on nitrate-N movement through the soil profile for both crops.

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: 180 - 300 lb N/A
Ranges in total yield: 260 - 530 cwt/A

April 1990

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	11.1	5.7 - 15.0
1 - 2	10.6	6.9 - 14.1
2 - 3	7.3	5.7 - 8.8
Total	28.9	18.2 - 34.3

July 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	13.8	3.0 - 33.8	5.3	3.3 - 8.4
1 - 2	14.4	2.2 - 27.1	4.1	2.2 - 5.8
2 - 3	7.3	1.8 - 12.7	2.9	1.3 - 4.8
Total	35.4	6.9 - 64.2	12.3	8.3 - 17.2
Total lbs NO_3-N/A in field[2]			48.1	17.9 - 81.0

September 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	12.1	7.0 - 16.4	8.0	3.8 - 13.2
1 - 2	7.0	2.6 - 11.6	4.8	2.0 - 9.4
2 - 3	3.7	1.5 - 7.3	2.6	1.4 - 4.3
Total	22.8	11.0 - 30.2	15.3	8.3 - 21.7
Total lbs NO_3-N/A in field[2]			38.1	25.7 - 45.8

[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 1990

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	13.8	1.9 - 52.5
1 - 2	4.2	0.7 - 9.1
2 - 3	1.7	0.1 - 2.5
Total	19.5	5.2 - 63.2

July 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	7.6	3.7 - 20.5	3.1	1.2 - 9.3
1 - 2	5.7	1.9 - 14.4	3.2	1.3 - 6.8
2 - 3	3.9	1.3 - 13.2	2.3	1.4 - 3.5
Total	17.1	7.5 - 34.8	8.7	4.0 - 19.6
Total lbs NH_4-N/A in field[2]			26.2	14.4 - 45.5

September 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	1.6	0.5 - 2.5	1.1	0.4 - 2.9
1 - 2	1.2	0.2 - 2.4	1.3	0.4 - 2.3
2 - 3	1.0	0.2 - 2.9	0.7	0.2 - 1.3
Total	3.8	1.3 - 7.8	3.1	1.6 - 6.1
Total lbs NH_4-N/A in field[2]			6.9	2.9 - 11.2

[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. Nutrient concentrations of potato leaves sampled from N-Survey grower fields on June 29, 1990 (Means of 4 samples from each field).

Field Number	Nutrient: NO_3-N Leaf	NO_3-N Petiole	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Al	Na
	%						ppm						
1	0.87	2.68	0.51	5.18	0.48	0.27	388	269	38	7	41	454	103
2	0.32	1.46	0.63	3.58	0.62	0.53	84	271	17	5	24	54	26
3	0.37	1.45	0.40	5.07	0.34	0.31	114	487	46	27	31	82	76
4	0.73	1.98	0.44	5.59	0.73	0.30	88	598	31	6	32	55	26
5	0.10	0.57	0.54	4.97	0.66	0.42	101	273	31	7	30	79	40

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

Ranges in total N fertilizer applied: 160 - 250 lb N/A
Ranges in total yield (sweet corn): 5.5 - 7.5 T/A
(field corn): 156 bu/A

April 1990

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	15.9	14.6 - 16.9
1 - 2	10.7	5.1 - 16.7
2 - 3	8.5	4.1 - 15.8
Total	33.6	23.7 - 49.5

July 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	4.0	2.4 - 5.8	19.5	15.0 - 23.4
1 - 2	2.4	1.9 - 2.9	16.1	10.0 - 24.6
2 - 3	2.9	1.0 - 5.3	7.0	4.9 - 9.6
Total	9.3	8.2 - 10.2	42.4	33.6 - 52.5
Total lbs NO_3-N/A in field[2]			51.7	41.7 - 62.7

September 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NO_3-N/half acre[1]			
0 - 1	3.5	1.0 - 6.6	11.8	1.1 - 19.5
1 - 2	1.9	0.6 - 5.1	17.4	1.1 - 50.2
2 - 3	1.5	0.6 - 2.5	8.4	0.7 - 19.8
Total	6.9	3.2 - 14.2	37.5	3.0 - 89.2
Total lbs NO_3-N/A in field[2]			44.4	6.1 - 103.4

[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 fields.

April 1990

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	3.6	1.1 - 6.7
1 - 2	2.7	2.0 - 3.3
2 - 3	2.5	1.8 - 3.3
Total	8.7	4.9 - 12.9

July 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	2.3	0.7 - 4.0	80.4	16.7 - 234.1
1 - 2	2.1	0.4 - 3.3	16.6	1.3 - 44.0
2 - 3	2.0	0.4 - 3.4	4.5	0.8 - 9.3
Total	6.4	1.5 - 10.6	99.5	32.2 - 281.3
Total lbs NH_4-N/A in field[2]			105.9	39.4 - 291.9

September 1990

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
	lb NH_4-N/half acre[1]			
0 - 1	0.9	0.4 - 1.2	7.3	0.7 - 23.9
1 - 2	1.0	0.6 - 1.4	5.7	0.3 - 19.5
2 - 3	0.8	0.4 - 1.6	1.4	0.6 - 2.5
Total	2.7	1.8 - 4.2	14.2	2.8 - 45.0
Total lbs NH_4-N/A in field[2]			16.9	4.6 - 47.7

[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.

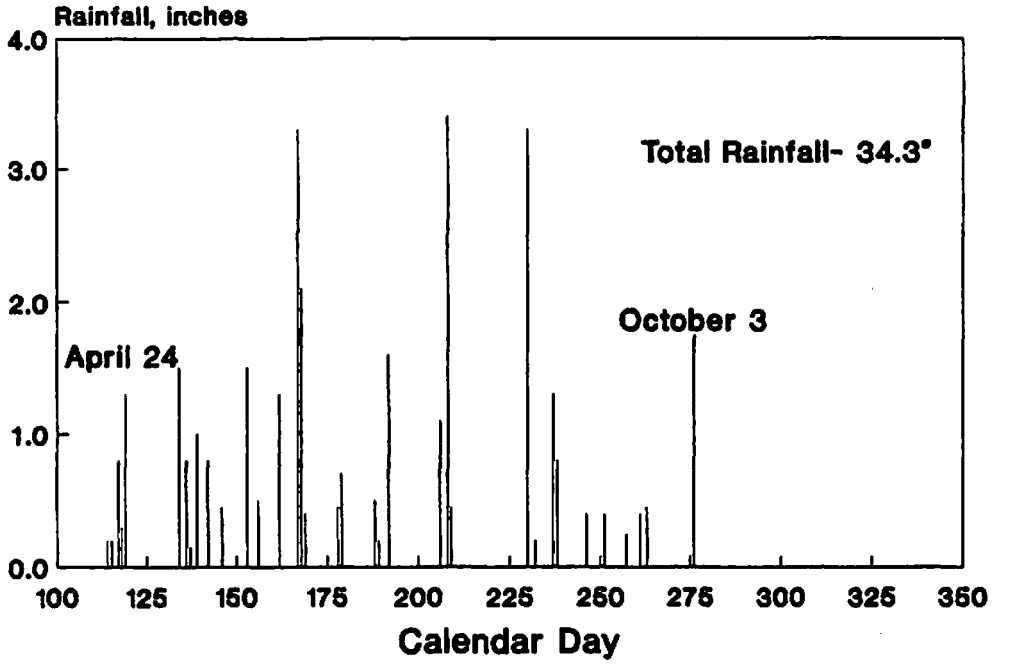
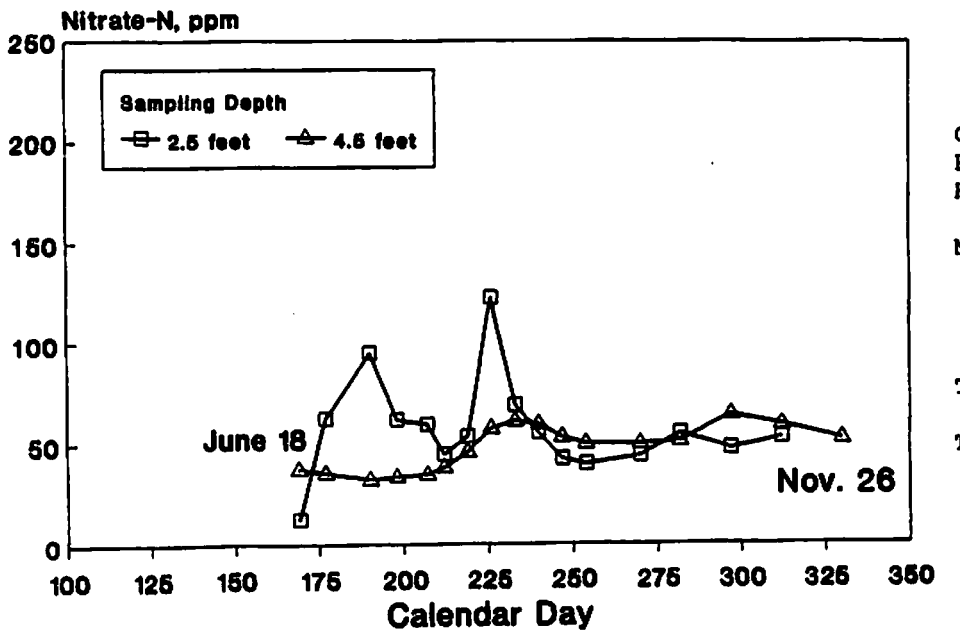


Figure 1. Rainfall distribution during the 1990 growing season at Big Lake, MN. This location was within a 15 mile radius of all fields sampled. April 24 indicates beginning of rainfall measurements, Oct. 3 indicates final rainfall measurement.

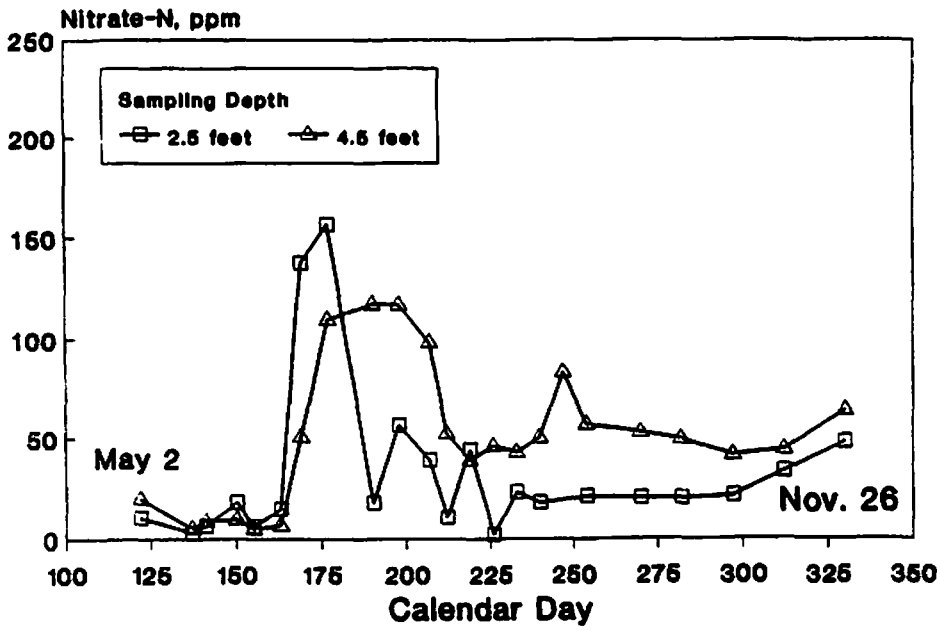


Cultivar - Norkota
Planting Date - May 29
Harvest Date - Sept. 20

N rate and mgmt. -
80 lb N/A starter
60 lb N/A June 15
60 lb N/A July 5
30 lb N/A late July
Total 230 lb N/A

Total Yield - 260 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. June 18 indicates the first sampling date and Nov. 26 indicates the last sampling date.

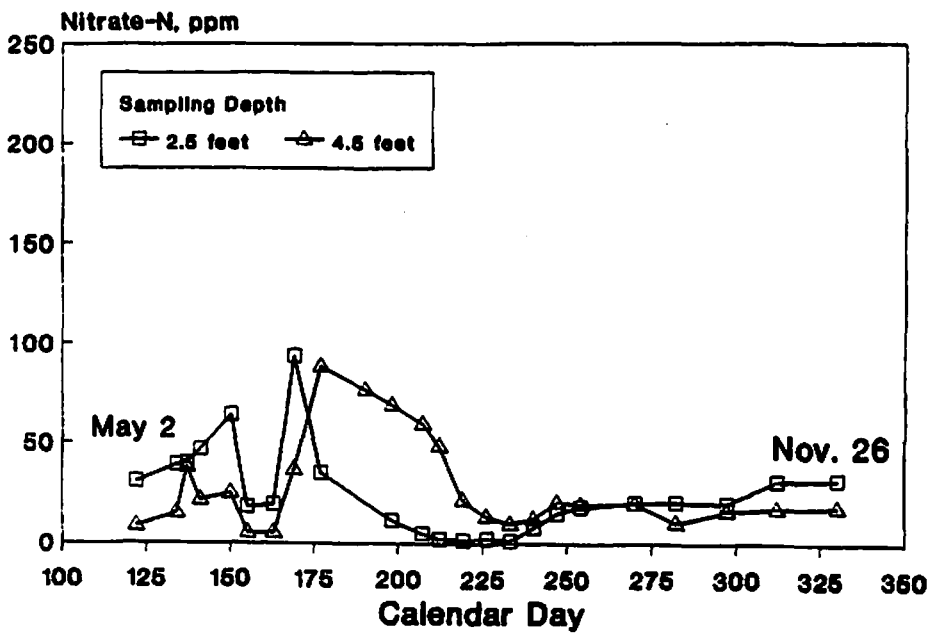


Cultivar - Russet Burbank
Planting Date - April 16
Harvest Date - Sept. 20

N rate and mgmt. -
70 lb N/A starter
180 lb N/A emergence (82-0-0)
50 lb N/A hilling
Total 300 lb N/A

Total Yield - 480 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 2 indicates the first sampling date and Nov. 26 indicates the last sampling date.

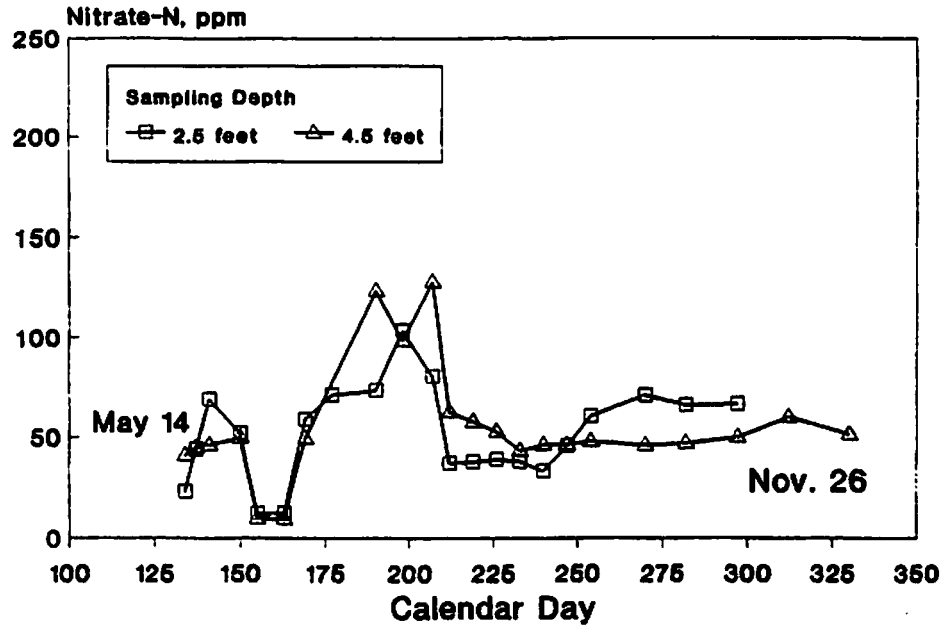


Cultivar - Russet Burbank
Planting Date - April 20
Harvest Date - Sept. 25

N rate and mgmt. -
80 lb N/A starter
46 lb N/A May 7
33 lb N/A May 25
46 lb N/A June 1
15 lb N/A June 15
15 lb N/A July 1
15 lb N/A July 15
Total 250 lb N/A

Total Yield - 530 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 2 indicates the first sampling date and Nov. 26 indicates the last sampling date.

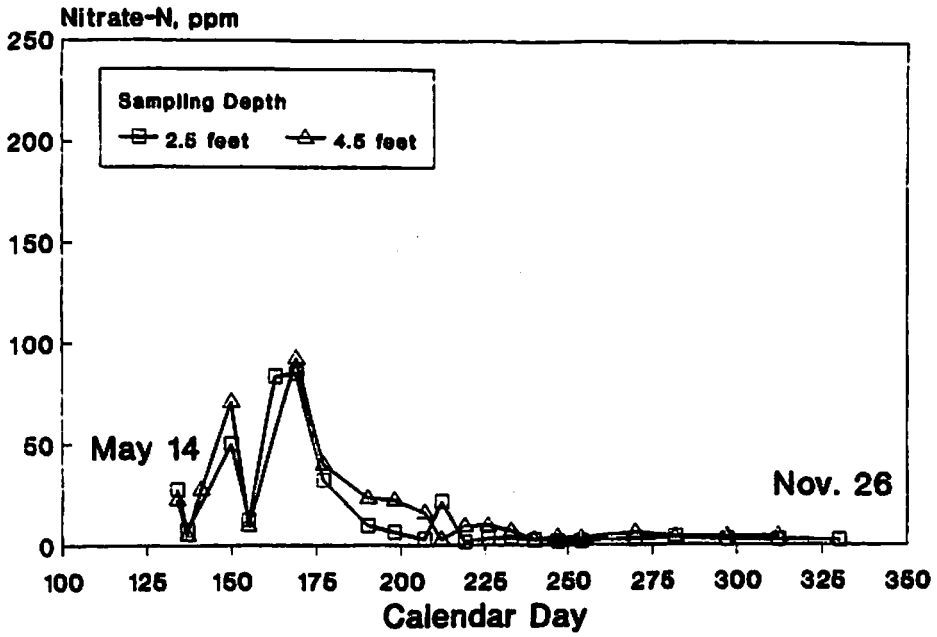


Cultivar - Norland
Planting Date - April 15
Harvest Date - August 25

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

Total Yield - 350 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 14 indicates the first sampling date and Nov. 26 indicates the last sampling date.

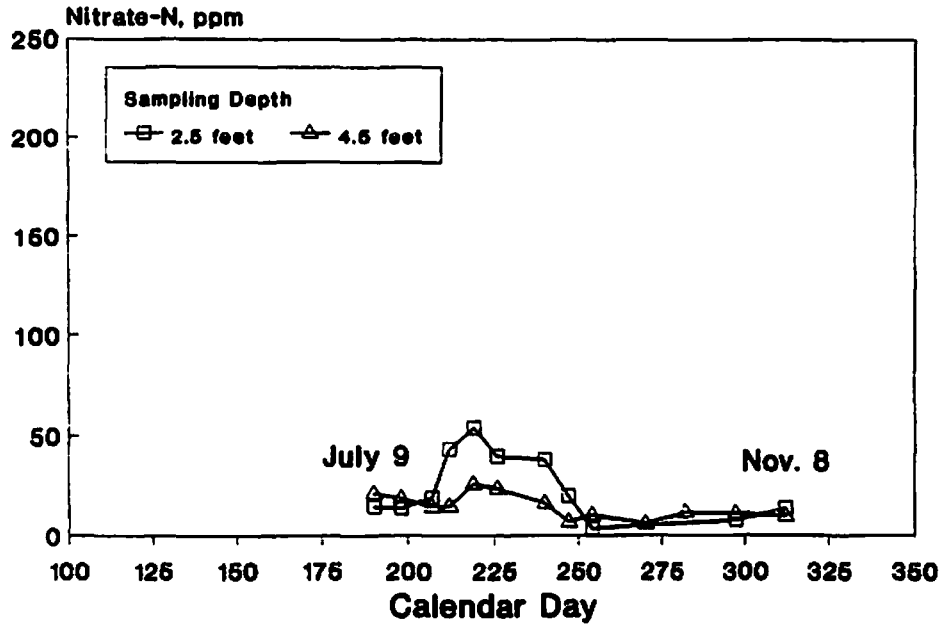


Cultivar - Norchip
Planting Date - April 13
Harvest Date - August 29

N rate and mgmt. -
84 lb N/A starter
100 lb N/A emergence
Total 184 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. May 14 indicates the first sampling date and Nov. 26 indicates the last sampling date.

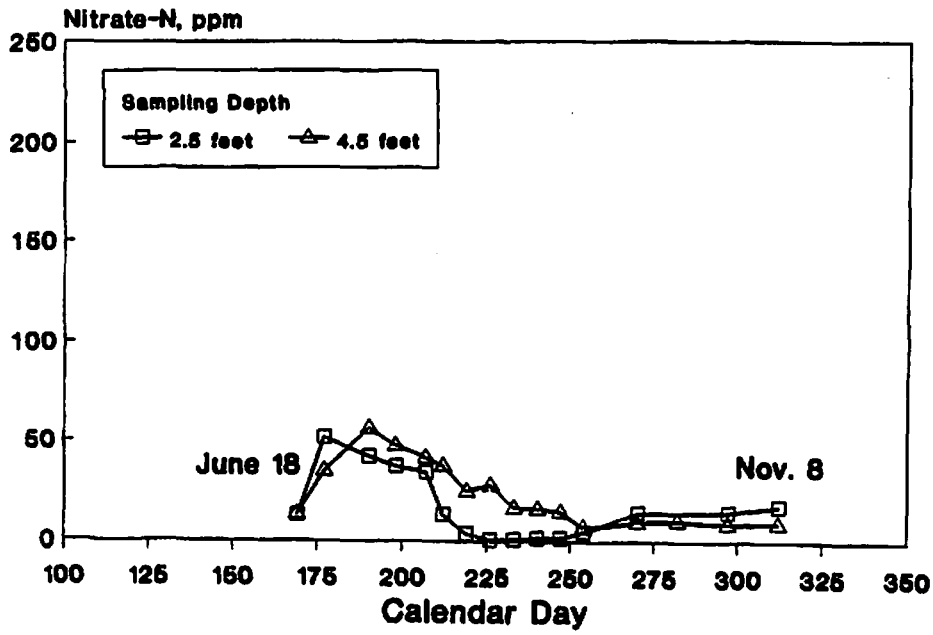


Hybrid - Sweet Jubilee
Planting Date - June 18
Harvest Date - August 25

N rate and mgmt. -
10 lb N/A starter
160 lb N/A July 4
Total 170 lb N/A

Total Yield - 4.5 T/A

Figure 7. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 6 (Sweet Corn). July 9 indicates the first sampling date and Nov. 8 indicates the last sampling date.

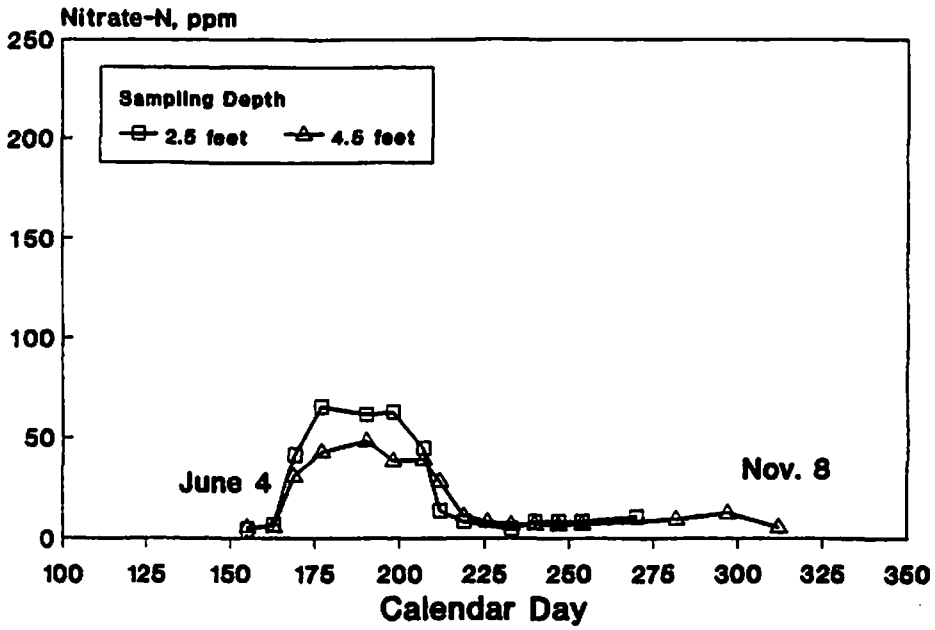


Hybrid - Silver Queen
Planting Date - June 4
Harvest Date - August 15

N rate and mgmt. -
30 lb N/A starter
140 lb N/A June 26
30 lb N/A late July
30 lb N/A early August
Total 230 lb N/A

Total Yield - 7.5 T/A

Figure 8. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 7 (Sweet Corn). June 18 indicates the first sampling date and Nov. 8 indicates the last sampling date.

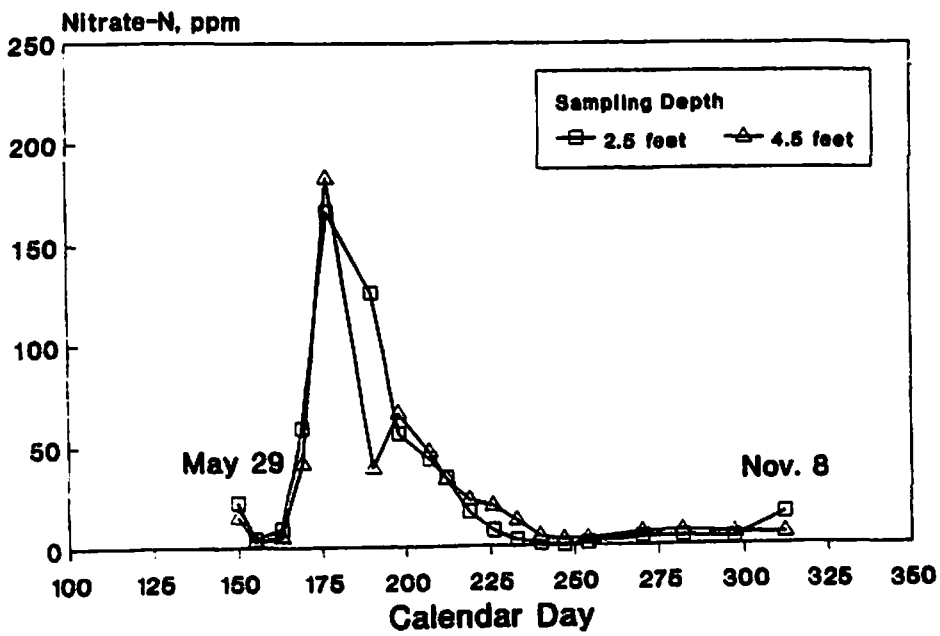


Hybrid - Field Corn
Planting Date - May 2
Harvest Date - Sept. 30

N rate and mgmt. -
18 lb N/A starter
32 lb N/A June 8
200 lb N/A June 19
Total 250 lb N/A

Total Yield - 156 bu/A

Figure 9. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 8 (Field Corn). June 4 indicates the first sampling date and Nov. 8 indicates the last sampling date.



Hybrid - Yukon
Planting Date - May 2
Harvest Date - July 30

N rate and mgmt. -
20 lb N/A starter
140 lb N/A June 7
Total 160 lb N/A

Total Yield - 7.0 T/A

Figure 10. Nitrate-N in soil water at the 2.5 and 4.5 ft. depths as a function of time for Field 9 (Sweet Corn). May 29 indicates the first sampling date and Nov. 8 indicates the last sampling date.

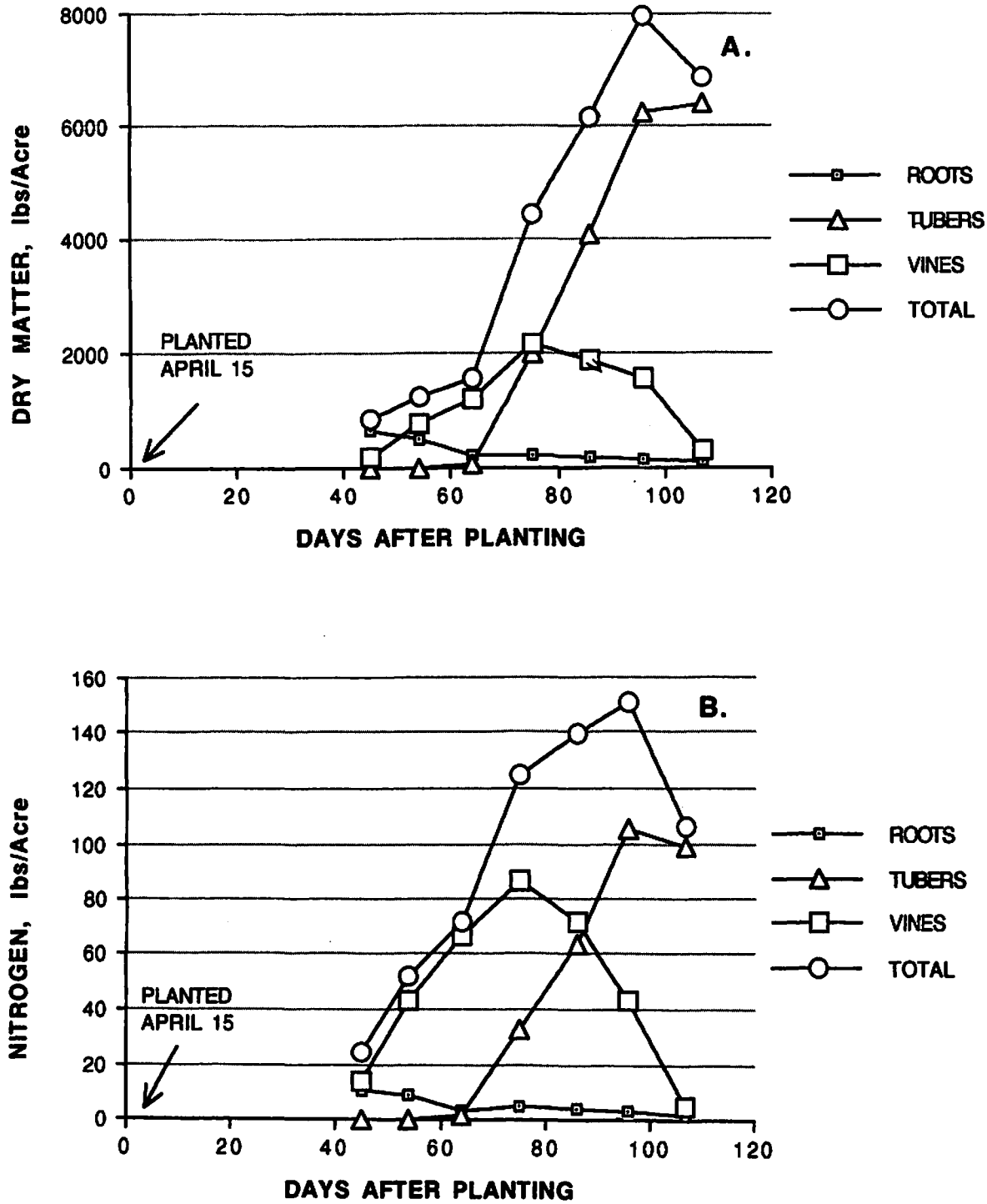
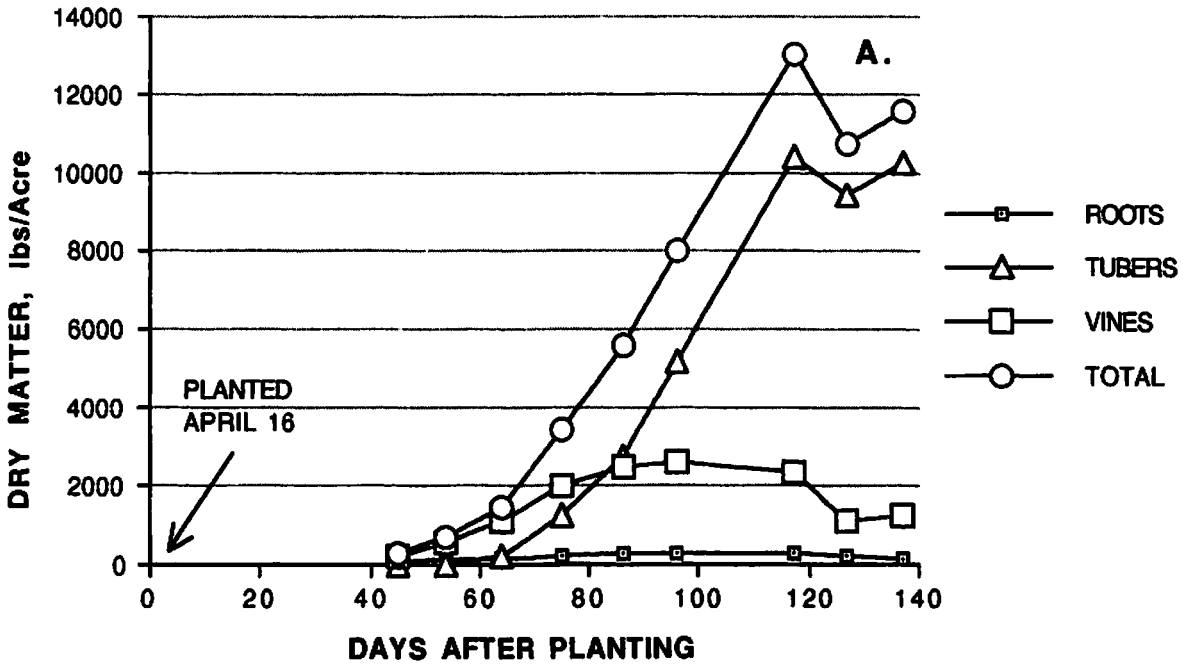


Figure 11. Dry Matter (A) and Nitrogen (B) accumulation in potato root vines and tubers through the season for early harvest Norland. Management practices for this field are presented in Figure 5.



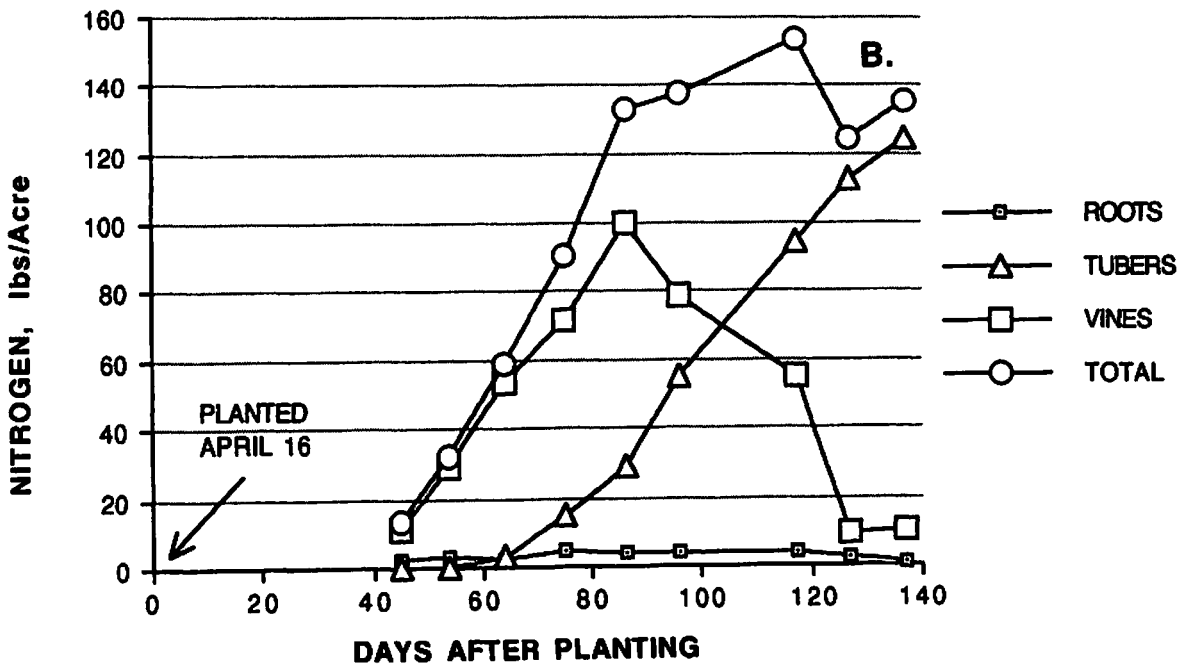


Figure 12. Dry Matter (A) and Nitrogen (B) accumulation in potato root vines and tubers through the season for late harvest Russet Burbank. Management practices for this field are presented in Figure 3.

EFFECT OF N-HIB AND N-FIX ON POTATO YIELD[1]

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

Objective: To determine the effects of N-hib (Stoller Chemical, Houston, TX) and N-fix (BioCorp Global, Inc., Springfield, MO) on potato yield and quality and to compare the effects with standard fertilizer practices.

Location: Potato Research Farm, Grand Forks, ND

Cultivars: Norchip for the N-Hib trial - Planted 5/10/90, Russet Burbank for the N-Fix trial - Planted 6/1/90

Treatments:
N-hib trial:
1. Control, no fertilizer applied
2. Conventional, 25 lbs N/A as urea broadcast and incorporated prior to 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 prior to emergence banded near the row
5. Conventional plus 70 lbs N/A plus 30 lbs Ca/A as N-Hib prior to 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 30 lb P_2O_5/A as a broadcast application prior to planting. The experimental design was a randomized complete block with 6 replications.

N-Fix trial:
1. Control, No fertilizer applied
2. Conventional fertilizer, 44 lb N/A and 44 lb P_2O_5/A
3. N-Fix at the rate of 0.1 gal/A applied 6/90
4. Conventional fertilizer plus N-fix

Results: As in 1989, yields were low due to the extremely dry weather conditions (Tables 1 and 2). There was a significant yield response in the N-hib trial to applied fertilizer either from the conventional source or from N-hib. There was no difference due to source of fertilizer (ie. N-hib was the same as conventional fertilizer) indicating that the cheapest source would be the most economical to use. There were no significant differences in the N-Fix trial due to applied fertilizer and/or N-fix. Yields were extremely low due to the dry weather and the late planting date.

Table 1. Effect of N-hib, supplemental N, and foliar B on Norchip tuber yield and specific gravity.

Treatment	Tuber Size					
	<1.5"	1.5-2.5"	2.5-3.5"	>3.5"	TOTAL	SPECIFIC GRAVITY
	cwt/A					
Control	1.5	42.8	79.7	8.4	132.4	1.093
Conventional	1.6	47.7	83.4	9.0	141.7	1.093
Conventional + Urea	1.7	48.7	89.9	12.0	152.3	1.094
Conventional + N-hib	1.3	49.6	81.5	7.0	139.3	1.093
Conventional + N-hib + B	1.5	52.9	79.4	7.5	141.2	1.092
Significance	NS	*	NS	NS	*	NS
LSD (5% level)	--	6.2	--	--	13.9	--

NS = Not significant, * = significant at the 5% level.

Table 2. Effect of N-fix and fertilizer on Russet Burbank tuber yield and specific gravity.

Treatment	Tuber Size				
	<1.5"	1.5-2.5"	2.5-3.5"	TOTAL	SPECIFIC GRAVITY
	cwt/A				
Control	1.9	41.8	30.6	74.3	1.093
Fertilizer alone	4.6	41.5	24.4	70.2	1.093
N-Fix alone	2.2	43.1	24.4	69.8	1.094
Fertilizer + N-Fix	2.3	43.2	32.6	78.3	1.093
Significance	NS	NS	NS	NS	NS

NS = Not significant.

[1]Supported by the Grand Forks Potato Research Station and the U of M Agricultural Experiment Station.
[2]Extension Soil Scientist, Associate Professor, Dept. Soil Sci., U of M, Area Agent and Potato Research Station Supervisor, Grand Forks, ND.

IMPACT OF AG-LIME ON SOYBEAN AND POTATO PRODUCTION ON IRRIGATED SANDY SOILS[1]

George Rehm and Carl Rosen[2]

Abstract: The sandy soils of the Anoka Sand Plain typically have an acid pH. This is satisfactory for potato production, but may limit yields of soybean in the rotation. This study was conducted to evaluate the effect of ag-lime on the production of soybeans and potatoes. In 1989, soybean yield was not affected by the ag-lime use at rates of 1, 2, and 3 ton per acre. In 1990, potato yield was not affected by ag-lime application; however, scab incidence increased significantly with ag-lime application.

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. Little data in Minnesota could be found that examined the effect of lime on the incidence of scab in potatoes. The objective of this study, therefore, was to determine the effects of ag-lime applications in a soybean/potato rotation.

Experimental Procedure:

The study was conducted at Big Lake, Minnesota on a Hubbard loamy sand soil. Agricultural limestone was broadcast and incorporated before planting in 1989 at the rates of 0, 1, 2 and 3 tons per acre. Each treatment was replicated 4 times in a randomized complete block design. The potato cultivar used was the scab sensitive, Norkota Russet. Soil pH (1:1 soil:water) was determined in samples collected from the top six inches in the row at harvest. Potato yields were determined by measuring 2, 10 ft rows from each plot. Twenty-five tubers from each plot were washed and evaluated for total scab incidence and deep scab incidence.

Results:

Soil pH, potato yield, and scab incidence are presented in Table 1. Soil pH increased with increasing rate of lime application. All plots dropped in pH from 1989 to 1990. The reasons for this drop are not clear, but may be due to the heavy rainfall occurring in 1990 compared to 1989. Because of the frequent rains in 1990, little high pH irrigation water was applied in that year. Potato yields were not significantly affected by lime application; however, scab incidence increased with lime application. Deep pitted scab increased with lime indicating a decrease in marketable potatoes. These results suggest that lime should be used cautiously in a potato/soybean rotation. If lime is used, then a scab resistent potato cultivar should be selected for the rotation. An additional experiment should be conducted on a soil with an initial pH of less than 5.0 to see if low rates of lime might be more beneficial than in this study where initial pH was already higher than needed for potato/soybean production.

Table 1. Effect of ag-lime on soil pH in 1989 and 1990, potato yield, and potato scab incidence.

Treatment	Soil pH 1989	Soil pH 1990	Potato Yield	Total Scab Incidence	Deep Pitted Scab Incidence
Tons lime/A			cwt/A	%	%
0	6.3	5.8	410	22	4
1	6.4	5.9	389	47	19
2	6.4	6.2	355	45	14
3	6.5	6.3	360	39	17
Significance	NS	*	NS	*	*

[1]This project was supported in part by the Minnesota Lime Producers Association.
[2]Extension Soil Scientists, Department of Soil Science.

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

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

ABSTRACT:

There are several liming materials that can be used for alfalfa production on acid soils. For this study, 4 liming materials were applied at 3 rates. All materials were broadcast and incorporated before the alfalfa was seeded. In the first year of production, yield was not affected by either lime source or rate of application. Soil pH was not influenced by lime source but increased curvilinearly with rate of application.

Introduction:

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

Experimental Procedures:

This study was established in an irrigated field in Wadena County in the spring of 1990. Four liming materials (normal ag lime, finely ground ag lime, sugarbeet lime, Pel Lime) were applied at 3 rates (4,321; 8,640; 12,960 lb. ECCE/acre). Treatments in the complete factorial were arranged in a randomized complete block design with 4 replications. To provide another comparison, Pel Lime was applied at a rate of 2,160 lb. ECCE per acre. A control treatment was established, but it was not part of the complete factorial design.

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

Soil samples (0-6 in.) were collected prior to treatment application and the results are listed in Table 1. Two cuttings were harvested. Soil samples (0-6 inches) were collected from each plot at the end of the growing season.

Results and Discussion:

In 1990, alfalfa yields were quite variable and this is to be expected in the seeding year. An excellent stand was established and yield differences due to treatment are anticipated in 1991 and succeeding years. In the first year of production, however, neither rate nor material had a significant effect on yield (Table 2).

Soil pH at the end of the 1990 growing season was affected by both lime source and rate of application. When averaged over all rates, pH values were high when the sugarbeet lime and finely ground ag lime were used. The use of "normal ag lime" and Pel Lime produced lower and equal values. When averaged over all sources, the pH increased as rate of application increased.

Summary:

An excellent stand of alfalfa was established at this experimental site. The treatments used had no significant on yield in the first year of production, but this is to be expected. Major differences due to lime use are anticipated for 1991.

[1/] Extension Specialist, Junior Scientist, Assistant Scientist, respectively.

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

pH	5.4
phosphorus (Bray #1), ppm	66
potassium (1 N $NH_4C_2H_3O_2$), ppm	144
exchangeable calcium, ppm	995
exchangeable magnesium, ppm	128
sulfur, ppm	5.8
organic matter, %	3.0

Table 2. The effect of lime source and rate of application on yield of irrigated alfalfa and soil pH in the fall of 1990.

Lime Source	Effective Calcium Carbonate Equivalent Applied	Yield	Soil pH
	lb./acre	ton D.M./acre	
control	-	1.45	5.6
normal ag lime	4,321	1.62	6.0
	8,640	1.62	6.1
	12,960	1.47	6.1
finely ground ag lime	4,321	1.75	6.2
	8,640	1.76	6.2
	12,960	1.39	6.5
sugarbeet lime	4,321	1.71	6.2
	8,640	1.54	6.4
	12,960	1.56	6.6
Pel Lime	2,160	1.39	5.8
	4,321	1.54	5.9
	8,640	1.53	6.2
	12,960	1.40	6.2

APPLICATION OF LIMING MATERIALS FOR ESTABLISHED ALFALFA

George Rehm, Andy Scobbie, Dan Schmitz[1/]

ABSTRACT: There have been many instances where alfalfa growers plant alfalfa and then realize that lime should have been applied before seeding. This project in Goodhue County is designed to evaluate liming materials and placement of these materials for established alfalfa on soils where pH values are low. Treatments used had variable effects on individual cuttings but none increased total yield for the growing season.

Introduction:

There is general agreement that lime, when needed, should be broadcast and incorporated before alfalfa is seeded. There are, however, situations where alfalfa is planted and, because soil samples were not collected, lime is not applied as needed. This study is designed to evaluate liming materials and methods of application that might be appropriate for alfalfa that has been established on acid soils.

Experimental Procedure:

This study was established in Goodhue County in August of 1989. Alfalfa had been seeded in the spring of 1989 in a field where the soil pH averaged 5.7. Seven treatments were applied and compared to a control (see Table 1).

For the treatments where the knife application was used, coulters were spaced 12 inches apart and knives designed to apply either dry or fluid materials were placed behind the coulters. The depth of application was approximately 5 inches. Rate of application was limited with this equipment. Consequently, there was no attempt to apply equal rates of all materials. Since the calcium carbonate equivalent varies with material, the pounds of effective calcium carbonate equivalent (ECCE) are reported. With the new Minnesota Lime Law, this will be reported at ENP (Effective Neutralizing Power).

Three cuttings were taken during the growing season. Alfalfa was in the bud to 1/10 bloom stage at each cutting. Soil samples (0-6 inches) were collected from each plot in September.

Results and Discussion:

The total alfalfa yield for the growing season as well as the pH values measured in September are summarized in Table 1. Statistical analysis of the yield data showed no significant differences among the treatments that were applied. There was some variability in the yields. This variability, however, was due to the growth of alfalfa in the field and not the treatment that was applied. It's also important to note that the use of coulters on 12 inch centers in an established alfalfa stand had no negative effect on yield.

Soil pH was increased by the broadcast application of the high rates of both ag lime and fluid lime. Otherwise, there was no change in soil pH when compared to the control.

Table 1. Effect of lime source and rate of application on the yield of established alfalfa and soil pH at the end of the growing season.

Lime Source	Placement	Rate Applied	Alfalfa* Yield	Soil pH
		lb. ECCE/acre	ton D.M/acre	
control	-	-	4.24 a	6.0 bc
Pel lime	knife	724	4.44 a	5.9 c
ag lime	broadcast	972	4.25 a	6.0 b
ag lime	broadcast	2.916	4.30 a	6.2 a
fluid lime	broadcast	2,000	4.72 a	6.1 b
fluid lime	broadcast	6,000	4.38 a	6.4 a
fluid lime	knife	681	4.17 a	6.1 b
fluid lime	knife	2,082	3.91 a	6.0 bc

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

[1/] Extension Specialist, Assistant Scientist, Junior Scientist, respectively.

Summary:

The data collected during the 1990 growing season would indicate that yield of established alfalfa was not affected by in-season application of limestone materials either topdressed or knifed in to the established stand. It is possible that the treatments used may have a significant effect on alfalfa production in the years ahead. This study will be continued in 1991 to monitor changes that might occur.

RECYCLING OF NITROGEN FROM TURFGRASS CLIPPINGS[1]

Carl Rosen, Paul Johnson, Dave Birong, Don White, and Karl Ruser[2]

ABSTRACT: Turfgrass managed during a typical Minnesota growing season produced 147 lbs/1000 sq. ft. of clippings on a fresh weight basis and 44 lbs/1000 sq. ft. on a dry weight basis. The nitrogen content of the clippings was approximately 1.4 lbs/1000 sq. ft.

During the summer months about 30% of the waste stream can be made up of grass clippings. Recent legislation banning the dumping of organic yard waste in landfills has led to the need for finding alternatives to collecting the clippings. An acceptable means of managing turfgrass clippings is simply to return them to the lawn to decompose. Leaving the clippings on the lawn will recycle most nutrients, particularly nitrogen. The objective of this study was to quantify the amount of clippings produced and the amount of nitrogen contained in clippings during a 'typical' Minnesota growing season. These data will provide background information on how best to manage nitrogen for Minnesota lawns.

Procedures:

Established turf plots located on the St. Paul Campus were used for this study. The soil is classified as a Waukigen silt loam and the turf was predominantly Kentucky blue grass with some fescue and perennial ryegrass. On May 17, 1990, KCl extractable nitrate-N and ammonium-N in the top foot was 2.5 ppm and 2.4 ppm, respectively. Four, 15 X 30 ft. plots were measured and Scotts Turf Builder Plus (nitrogen plus pendimethalin) was applied at the rate of 1 lb N/1000 sq. ft. on May 24, 1990. On the same day, Trimec (2,4-D + dicamba, + mecoprop) was also applied at recommended rates to control broadleaf weeds. From May 30, 1990 through October 19, 1990, turfgrass was cut every 7-14 days to a height of 2 inches. On July 12, 1990, an additional 0.5 lb N/1000 sq. ft. was applied as ammonium nitrate. Plots were set up for irrigation; however, because of the timely and, on occasion, heavy rains during 1990, no irrigation was needed. Clippings were collected with a rear bag mower, weighed, and placed in a 55 gallon barrel compost bin (one bin for each plot). A small subsample of clippings was taken to determine moisture and Kjeldahl nitrogen content each time the turf was cut.

Results and Discussion:

An assumption made in this study was that clippings obtained for sampling were similar to those returned to a lawn where clippings were not removed. Since these plots had all clippings removed, the nutrients that would have been supplied by their degradation were not accounted for. Therefore, the data probably underestimates the amount of nutrient recycling that actually occurred.

Turfgrass fresh and dry weight, and nitrogen concentration and content at each mowing date and totals for the season are presented in Table 1. Nitrogen concentration in the clippings declined steadily until July and then increased with the July 12 nitrogen fertilizer application. Water extractable nitrate in the clippings was also determined; however, concentrations were less than 200 ppm nitrate-N (data not presented).

The total amount of clippings removed from the plots was equivalent to 147 lbs per 1000 sq. ft. on a fresh weight basis and 44 lbs per 1000 sq. ft. on a dry weight basis. The nitrogen content of the clippings was 1.4 lb N/1000 sq. ft. Thus, the clippings contained approximately the same amount of nitrogen that was applied. Had the clippings been left on the lawn, some of the nitrogen in the clippings would have been available for growth of the turfgrass. The exact amount of nitrogen available from the decaying clippings is not known, but the high nitrogen concentration of the clippings would render them susceptible to rapid microbial degradation. The amount of nitrogen found in the clippings in this study is about twice that reported in the literature from other areas of the country. Further studies need to be conducted to resolve these differences.

According the state demographers, there are approximately 1.3 millon residences in Minnesota. Assuming that each residence is about 0.2 acres in size, then there would be roughly 260,000 acres of lawn in the state. Based on these figures and the data obtained in this study, approximately 830,000 tons of fresh clippings and 249,000 tons of dry clippings are produced on home lawns each year in the state. Assuming a nitrogen content similar to that obtained in this study, the clippings would contain 8,100 tons of nitrogen. Based on these calculations, leaving clippings on the lawn can lead to significant nitrogen inputs into lawn fertilization in Minnesota.

[1]Funding for this study was provided by the Minnesota Extension Service and the Agricultural Experiment Station.

[2]Extension Soil Scientist, Research Assistant, Junior Scientist, Professor of Horticulture, and Associate

Table 1. Fresh weight, dry weight, nitrogen concentration, and nitrogen accumulation in turfgrass clippings. Mean ± one standard deviation.

DATE	FRESH WEIGHT lbs/1000 sq ft	DRY WEIGHT lbs/1000 sq ft	NITROGEN CONCENTRATION %	NITROGEN CONTENT lbs N/1000 sq ft
MAY 30	10.5 ± 2.5	3.2 ± 0.8	3.32 ± 0.11	0.11 ± 0.03
JUNE 6	13.0 ± 2.5	3.8 ± 0.7	3.16 ± 0.15	0.12 ± 0.03
JUNE 12	9.4 ± 2.1	2.7 ± 0.6	3.08 ± 0.10	0.08 ± 0.02
JUNE 21	12.7 ± 2.7	3.9 ± 0.8	2.91 ± 0.15	0.11 ± 0.03
JUNE 29	8.5 ± 1.9	2.5 ± 0.6	2.98 ± 0.17	0.07 ± 0.02
JULY 5	3.6 ± 0.8	1.3 ± 0.2	2.74 ± 0.13	0.03 ± 0.01
JULY 13	5.3 ± 1.0	1.7 ± 0.3	3.14 ± 0.23	0.05 ± 0.01
JULY 23	10.0 ± 1.5	3.3 ± 0.5	3.30 ± 0.12	0.11 ± 0.02
JULY 27	6.0 ± 1.3	1.7 ± 0.3	3.33 ± 0.10	0.06 ± 0.01
AUG 3	8.7 ± 1.1	2.5 ± 0.3	3.30 ± 0.21	0.08 ± 0.01
AUG 10	6.7 ± 1.1	1.8 ± 0.3	3.40 ± 0.14	0.06 ± 0.01
AUG 17	4.0 ± 1.0	1.3 ± 0.3	3.26 ± 0.17	0.04 ± 0.01
AUG 30	14.4 ± 2.4	3.9 ± 0.5	3.46 ± 0.14	0.14 ± 0.02
SEPT 11	17.5 ± 0.8	4.9 ± 0.3	3.59 ± 0.09	0.18 ± 0.01
SEPT 21	7.2 ± 1.1	2.3 ± 0.3	3.28 ± 0.03	0.08 ± 0.01
SEPT 28	5.4 ± 0.4	1.8 ± 0.1	3.12 ± 0.08	0.06 ± 0.00
OCT 19	4.5 ± 0.7	1.5 ± 0.2	3.09 ± 0.01	0.05 ± 0.01
TOTAL	147.3 ± 19.0	44.0 ± 5.7	---	1.43 ± 0.19

EFFECT OF TILLAGE AND FREQUENCY OF LIQUID DAIRY MANURE APPLICATION ON CORN PRODUCTION: A LONG TERM SUMMARY[1]

J. R. Joshi, J. B. Swan, J. F. Moncrief, and P. Burford[2]

Abstract: A summary of a long term study on tillage and liquid dairy manure for corn production are presented in this report. Liquid dairy manure was injected either annually, biennially or triennially on chisel-plowed treatments and annually or biennially on no-till treatments. Additional treatments included an annual application of chemical fertilizer, and a check.

The liquid dairy manure applied from an anaerobic pit during the study period (1982-90) contained an average of 0.33% N, 0.07% P, 0.23% K and 7.8% solids, and the variability over the years was small. Soil cover by corn residue was adequate (above 30%) in no tillage and marginal (around 30% or below) in chisel plowing systems across the treatments. Manure injection reduced residue by about half in no tillage but had little effect on chisel plowing. Yield obtained with fertilizer application were comparable to those of manure in the year of application. Tillage did not affect yield when manure was applied; however, chisel plowing did better in the years following manure application. Manure affected grain yields up to the third year after its application.

INTRODUCTION

The objective of the study is to determine the effects of tillage and frequency of manure application on corn yield, N uptake, and soil nitrogen levels. The site is located on a Seaton (Typic hapludalf, fine-silty, mixed, mesic) silt loam soil on the Dale Flueger Farm near Red Wing in Goodhue Co., MN. The study was initiated in 1982.

Liquid dairy manure is injected either annually, biennially or triennially on chisel-plowed treatments and annually or biennially on no-till treatments. A check treatment which does not receive any nitrogen and a fertilized check treatment which until 1988 received ammonium nitrate annually at the rate of 210 lbs N/A on no till plots and 170 lbs N/A on chisel plots are included in the study. In 1989 and 1990, the fertilized check received anhydrous ammonia , instead of ammonium nitrate, injected at the rate of 175 lbs N/A.

Between 1982-1986 the manure treatments were split with 0 and 200 lbs K_2O/A and the fertilizer treatments with 0, 200, and 400 lbs K_2O/A. The application of this extra potassium has been stopped since 1987. To evaluate residual effects of additional potassium, data in this report are presented on split basis with respect to K_2O whenever applicable.

The experiment is laid out in a randomized complete block split-split plot design with three replications. Tillage is the main plot and N source is the subplot. Manure as N source is further split by the year of N application as a sub-sub plot.

A long term (1982-90) summary of the data available on manure analysis, surface residue cover, and yield characteristics for fertilizer, triennial and biennial manure treatments is presented in this report. The cultural practices for individual years can be found in this and earlier issues of the 'bluebook'.

RESULTS AND DISCUSSION

Manure Composition. The amounts of liquid dairy manure applied and its nutrient composition during 1982-90 is given in Table 1. On an average, the manure contained 0.331% N, 0.069% P, 0.231% K, and 7.8% solids. About 56% of the total N was in mineral form. Standard deviation for the concentration of most elements from year to year was within 10% of the mean values. Actual amounts of the nutrients applied each year are given in Table 2.

[1] Support for this project in part was provided by a USDA-LISA (Low Input Sustainable Agriculture) grant, the Minnesota Department of Agriculture, the College of Agriculture Center for the Impacts of Agricultural Practices on Environmental Quality and the Soil Conservation Service. Their support is greatly appreciated.

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Residue Cover. Soil cover by corn residue left on the surface after planting in both tillages is summarized in Table 3.

Under no tillage conditions, the greatest amount of residue was left in the treatments which did not recei tillage associated with manure. These include fertilizer, check, and the second year of biennial manure treatments. The injection of manure reduced the residue by about half 'in' and 'between' the rows. Soil Conservation Service recommends at least 30% of residue cover to control erosion in conservation tillage practices. From that criteria, most treatments under no tillage had adequate amount of soil cover. Exception to this was treatment that received manure injection where the amount of residue was marginal.

Chisel plowing reduced the soil cover to below 30% in most treatments. The injection of manure did not cause any further reduction in soil cover.

Triennial Manure Study (1988-90). A table of significance of analysis of variance of various yield characteristics to evaluate the effects of N from manure applied triennially on chisel plowed corn for the period 1988-90 is given in Table 4. The year when N was applied during the triennial cycle had a significant effect on grain yield, stover yield, and N uptake characteristics in all three years. The response to the residual K from previous years was variable from year to year.

Compared to the manure application year, the grain and stover yield, on an average, declined by 16% in the second year and 35-38% in the third year of application (Table 5). The third year yields in this period were similar to the check plots. The response in terms of grain moisture, stover moisture, harvest index, and final stand at harvest was variable from year to year (Table 6 and 7). Nitrogen uptake as grain and stover N, and total N removal varied greatly depending upon when the manure applied (Table 7 and 8). Total N removal reduced by 26% in the second year and by 49% in the third year following the application of manure. The amount of N removed in the third year was similar to those of the check treatments.

Triennial Manure Study (1983-90). A summary of grain yields in fertilizer, manure (annual and triennial), and check treatments during a longer duration (1983-1990) is given in Table 9 and 10. As the effect of additional potassium has been variable during this period, the tables are prepared to compare fertilizer and check treatments (both 200 lb K_2O/A) with the average of manure treatments that received 0 and 200 lbs K_2O/A (Table 9) and with the manure treatments with 0 lb K_2O/A only (Table 10).

The long term averages reflect the following: (a) yields obtained with fertilizer and annual manu treatments were similar, (b) yield difference in the application year of manure on annual and triennial cycle was small (about 5%), (c) yield reduction in year following manure application was about 16-18%, (d) yield reduction in the third year after manure was applied is about 29 to 33%, the greater reduction when no K was added, and (e) there was a yield advantage of about 13-18 bu/A in the third year of triennial manure over check.

Biennial Manure Study (1983-90). A summary of grain yields in fertilizer, manure (annual and biennial), and check treatments on a longer term basis (1983-1990) is given in Table 11 and 12. Once again as the effect of additional potassium has been variable during this period, the tables are prepared to compare fertilizer and check treatments (both 200 lb K_2O/A) with the average of manure treatments that received 0 and 200 lbs K_2O/A (Table 11) and with the manure treatments with 0 lb K_2O/A only (Table 12).

The long term averages reflect the following: (a) tillage did not affect yields in the application year of N regardless of its source but chisel plowing was advantageous in the non-application year including check, (b) yield reduction in the year following manure application was 17% in no tillage and 10% in chisel plowing, and (c) yield after two years following manure application was higher than check by 82% under no tillage and 52% under chisel plowing.

Table 1. Rate of application and nutrient composition of liquid dairy manure (1982-1990)

NUTRIENT	1982S[1]	1983S	1983F	1985S	1986S	1987S	1988S	1989S	1990S	MEAN	STD
TOTAL-N (%)	.365	.306	.348	.34	.292	.398	.303	.298	.325	.331	.033
AMMON-N (%)	.185	.174	.177	.161	.237	.177	.205	.183	.156	.184	.023
P (%)	.062	.072	.067	.066	.062	.083	.	.	.	.0 69	.007
K (%)	.190	.244	.244	.235	.197	.297	.219	.219	.	.231	.315
SOLIDS (%)	7.21	6.99	7.35	8.86	.	9.15	7.6	7.6	.	7.8	.78
RATE(GAL/A)	12700	9100	10700	9200	9200	9200	8600	8300	8500	9500	1306

[1] S= spring-applied, F= fall-applied.

Table 2. The amounts in lbs/acre of nutrients applied as liquid dairy manure (1982-90)

NUTRIENT	1982S[1]	1983S	1983F	1985S	1986S	1987S	1988S	1989S	1990S	MEAN	STD
TOTAL-N	379	228	304	256	219	299	213	202	226	258	55
AMMON-N	192	129	155	121	178	133	144	124	108	143	26
P_2O_5	148	122	135	114	106	143	.	.	.	128	15
K_2O	236	218	256	212	178	268	184	178	.	216	33
SOLIDS (%)	7.2	7.0	7.4	8.9	.	9.2	7.6	7.6	.	7.8	.8

[1] S= spring-applied, F= fall-applied.

Table 3. Surface residue cover as affected by N source and frequency in Goodhue Co., MN.

NO TILL

N Source and Frequency	Surface Residue (%)										Mean	
	1984		1985		1988		1989		1990			
	IN	BET	IN	BET	IN	BET	IN	BET	IN	BET	IN	BET
Fertilizer	42	74	55	63	.	.	75	66	35	72	52	69
Manure (annual)	22	40	17	22	.	.	27	40	46	51	28	38
Manure (1st year)	30	33	21	20	5	18	27	34	24	41	21	29
Manure (2nd year)	31	66	49	60	67	60	44	56	57	62	50	61
Check	25	57	23	62	.	.	33	41	37	59	30	55

CHISEL PLOW

N Source and Frequency	Surface Residue (%)										Mean	
	1984		1985		1988		1989		1990			
	IN	BET	IN	BET	IN	BET	IN	BET	IN	BET	IN	BET
Fertilizer	17	24	13	23	.	.	24	44	20	36	19	32
Manure (annual)	13	14	22	21	.	.	40	42	20	50	24	32
Manure (1st year)	13	13	13	20	9	7	28	39	16	37	16	23
Manure (2nd year)	17	18	17	14	38	22	15	35	13	40	20	26
Check	16	16	6	15	.	.	35	36	20	25	19	23

Table 4. A table of significance of analysis of variance on various dependent variables on the effects of N from manure applied triennially on chisel-plowed corn in Goodhue Co., MN.

DEPENDABLE VARIABLE	1988			1989			1990		
	Year(Y)	K Rate(K)	Y*K	Year(Y)	K Rate(K)	Y*K	Year(Y)	K Rate(K)	Y*K
Grain Yield	**.000**	.173	.254	**.000**	.973	.792	**.000**	.514	.955
Plant Stand	**.007**	.192	**.082**	.377	.470	.318	.990	.978	.113
Grain Moisture	**.036**	.359	.556	.128	.507	.396	**.000**	.194	.877
Grain N	**.002**	**.080**	.762	**.000**	.304	.586	**.000**	.329	.183
Grain N Uptake	**.000**	**.065**	.203	**.000**	.128	.458	**.000**	.936	.919
Stover Yield	**.042**	.698	.373	.584	.876	**.084**	**.037**	.222	.663
Stover Moisture	.408	.431	.789	**.002**	.368	**.094**	**.019**	.589	.731
Total Dry Matter	**.005**	.440	.464	**.004**	.732	**.069**	**.006**	.414	.737
Harvest Index	.750	.567	.716	.151	.557	.218	.364	**.050**	.543
Stover N	**.009**	**.009**	.598	**.004**	.400	.323	**.000**	.123	**.079**
Stover N Uptake	**.000**	.300	.556	**.017**	.612	.104	**.000**	**.039**	.271
Total N Uptake	**.000**	**.065**	.195	**.000**	.365	.145	**.000**	.475	.682

Table 5. Effects of N from manure applied triennially to chisel-plowed corn on grain yield, stover yield, and total dry matter yield in Goodhue Co., MN.

Year of Application	K_2O (lbs/A)	GRAIN YIELD (bu/A)				STOVER YIELD (t/A)				TOTAL DRY MATTER (t/A)			
		1988	1989	1990	MEAN	1988	1989	1990	MEAN	1988	1989	1990	MEAN
First Yr	0	127	148	153	**143**	1.54	1.87	2.65	**2.02**	4.53	5.18	6.38	**5.36**
	200	134	148	158	**147**	1.81	2.77	3.36	**2.65**	4.97	6.38	7.25	**6.20**
	MEAN	**130**	**148**	**155**	**144**	**1.67**	**2.39**	**2.95**	**2.34**	**4.75**	**5.87**	**6.76**	**5.79**
Second Yr	0	120	125	117	**121**	1.40	1.98	2.34	**2.10**	4.24	5.10	5.24	**4.86**
	200	120	119	123	**121**	1.43	1.97	2.62	**2.01**	4.26	5.17	5.79	**5.07**
	MEAN	**120**	**122**	**120**	**121**	**1.42**	**1.97**	**2.48**	**2.06**	**4.25**	**5.12**	**5.52**	**4.96**
Third Yr	0	86	92	95	**91**	1.00	2.52	1.89	**1.80**	3.03	4.56	4.27	**3.95**
	200	69	97	96	**87**	1.06	1.48	1.96	**1.50**	2.69	3.62	4.14	**3.48**
	MEAN	**77**	**95**	**96**	**89**	**1.03**	**2.00**	**1.92**	**1.65**	**2.86**	**4.16**	**4.21**	**3.74**
Check	**200**	**79**	**82**	**87**	**83**	**1.08**	**2.04**	**1.77**	**1.69**	**2.95**	**4.20**	**3.84**	**3.66**

Table 6. Effects of N from manure applied triennially to chisel-plowed corn on grain moisture, stover moisture, and final stand count in Goodhue Co., MN.

Year of Application	K_2O (lbs/A)	GRAIN MOISTURE (%)				STOVER MOISTURE (%)				PLANT POPULATION			
		1988	1989	1990	MEAN	1988	1989	1990	MEAN	1988	1989	1990	MEAN
First Year	0	19.0	23.2	29.6	**23.9**	50.1	54.9	39.6	**48.2**	26.2	26.1	28.7	**27.0**
	200	19.3	21.4	28.7	**23.1**	48.1	52.8	41.3	**47.4**	27.6	24.6	30.6	**27.6**
	MEAN	**19.1**	**22.2**	**29.2**	**23.5**	**49.1**	**53.7**	**40.3**	**47.7**	**26.9**	**25.3**	**29.5**	**27.2**
Second Year	0	19.3	25.7	31.7	**25.6**	46.1	45.7	42.8	**44.9**	28.6	24.7	29.4	**27.6**
	200	18.4	23.6	30.2	**24.1**	45.5	50.4	41.4	**45.8**	27.9	22.1	29.5	**26.5**
	MEAN	**18.9**	**24.6**	**30.8**	**24.8**	**45.8**	**48.0**	**42.1**	**45.3**	**28.3**	**23.4**	**29.4**	**27.0**
Third Year	0	20.8	24.1	33.8	**26.2**	48.7	53.3	48.5	**50.2**	26.1	24.0	30.5	**26.9**
	200	20.0	25.5	33.2	**26.2**	45.6	54.4	52.5	**50.8**	25.2	25.5	28.2	**26.3**
	MEAN	**20.4**	**24.7**	**33.5**	**26.2**	**47.2**	**53.8**	**50.5**	**50.6**	**25.6**	**24.7**	**29.4**	**26.6**
Check	200	**20.6**	**23.2**	**32.3**	**25.4**	**46.3**	**54.4**	**47.5**	**49.4**	**28.2**	**25.4**	**30.7**	**28.1**

Table 7. Effects N of from manure applied triennially to chisel-plowed corn on harvest index, grain N, and stover N in Goodhue Co., MN.

Year of Applica-tion	K_2O (lbs/A)	HARVEST INDEX				GRAIN N (%)				STOVER N (%)			
		1988	1989	1990	MEAN	1988	1989	1990	MEAN	1988	1989	1990	MEAN
First Yr	0	0.66	0.64	0.60	**0.63**	1.44	1.27	1.30	**1.34**	0.61	0.65	0.45	**0.57**
	200	0.64	0.58	0.54	**0.59**	1.41	1.34	1.27	**1.34**	0.52	0.54	0.48	**0.51**
	MEAN	**0.65**	**0.60**	**0.57**	**0.61**	**1.42**	**1.31**	**1.28**	**1.34**	**0.56**	**0.59**	**0.46**	**0.54**
Second Yr	0	0.68	0.61	0.56	**0.62**	1.35	1.14	1.23	**1.24**	0.47	0.42	0.40	**0.43**
	200	0.66	0.62	0.54	**0.61**	1.26	1.18	1.05	**1.16**	0.42	0.47	0.38	**0.42**
	MEAN	**0.67**	**0.62**	**0.55**	**0.61**	**1.30**	**1.16**	**1.08**	**1.18**	**0.44**	**0.44**	**0.39**	**0.42**
Third Yr	0	0.66	0.46	0.56	**0.56**	1.30	1.04	1.03	**1.12**	0.53	0.42	0.33	**0.43**
	200	0.60	0.59	0.53	**0.57**	1.25	1.03	1.07	**1.12**	0.40	0.38	0.38	**0.39**
	MEAN	**0.63**	**0.52**	**0.54**	**0.56**	**1.28**	**1.03**	**1.05**	**1.12**	**0.47**	**0.40**	**0.36**	**0.41**
Check	200	**0.62**	**0.51**	**0.54**	**0.56**	**1.16**	**1.09**	**1.06**	**1.10**	**0.39**	**0.37**	**0.34**	**0.37**

Table 8. Effects of N from manure applied triennially to chisel-plowed corn on grain uptake, stover uptake, and N uptake in Goodhue Co., MN.

Year of Application	K_2O (lb/A)	GRAIN N UPTAKE (lbs/A)				STOVER N UPTAKE (lbs/A)				TOTAL N UPTAKE (lbs/A)			
		1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**	1988	1989	1990	**MEAN**
First Yr	0	86.5	84.3	93.9	**88.2**	18.2	24.1	24.0	**22.1**	104.7	108.4	118.0	**110.4**
	200	89.3	97.2	94.7	**93.7**	18.7	28.6	32.5	**26.6**	108.0	125.9	127.3	**120.4**
	MEAN	**87.9**	**91.7**	**94.3**	**91.3**	**18.5**	**26.7**	**27.7**	**24.3**	**106.4**	**118.4**	**121.9**	**115.6**
Second Yr	0	76.8	70.3	62.8	**70.0**	12.7	16.7	19.6	**16.3**	89.5	86.9	82.4	**86.3**
	200	71.2	75.3	60.8	**69.1**	12.2	18.3	20.8	**17.1**	83.4	93.6	80.1	**85.7**
	MEAN	**74.0**	**72.8**	**61.8**	**69.5**	**12.5**	**17.5**	**20.3**	**16.7**	**86.5**	**90.3**	**81.3**	**86.0**
3rd Yr	0	53.1	42.3	46.7	**47.4**	10.1	21.1	12.4	14.5	63.2	63.4	59.1	**61.9**
	200	40.8	43.3	48.7	**44.3**	8.3	11.0	15.1	11.5	49.0	54.3	63.8	**55.7**
	MEAN	**46.9**	**42.7**	**47.7**	**45.8**	**9.2**	**16.0**	**13.8**	**13.0**	**56.1**	**59.5**	**61.5**	**59.0**
Check	**200**	**43.5**	**48.7**	**43.7**	**45.3**	**8.4**	**14.7**	**12.0**	**11.7**	**51.9**	**63.4**	**55.8**	**57.0**

Table 9. Corn grain yields as affected by N from manure applied annually and triennially, and fertilizer applied annually in chisel plowing system in Goodhue Co., MN.

N Source and Frequency	Grain Yield (bu/A)								**1984-90**	
	1983	1984	1985	1986	1987	1988	1989	1990	**MEAN**	**ST.DEV.**
Fertilizer, 200 lbs K_2O/A	127	165	155	149	164	144	167	153	**157**	**8**
Manure (annual)[1]	132	165	151	150	162	136	163	166	**156**	**10**
Manure (1st year)	.	148	138	146	164	130	148	155	**147**	**10**
Manure (2nd year)	.	125	117	114	129	120	122	120	**121**	**5**
Manure (3rd year)	.	128	91	103	100	77	95	96	**99**	**14**
Check, 200 lbs K_2O/A	91	85	78	89	103	79	82	87	**86**	**8**

[1] Manure treatments were averaged over 0 and 200 lb K_2O/A treatments.

Table 10. Corn grain yields as affected by N from manure applied annually and triennially, and fertilizer applied annually in chisel plowing system in Goodhue Co., MN.

N Source and Frequency	Grain Yield (bu/A)								**1984-90**	
	1983	1984	1985	1986	1987	1988	1989	1990	**MEAN**	**ST DEV.**
Fertilizer, 200 lb K_2O/A	127	165	155	149	164	144	167	153	**157**	**8**
Manure (annual)	132	163	150	150	155	133	159	171	**154**	**11**
Manure (1st year)	.	149	139	147	158	127	148	153	**146**	**9**
Manure (2nd year)	.	129	108	120	137	120	125	117	**122**	**9**
Manure (3rd year)	.	132	102	113	109	86	92	95	**104**	**14**
Check, 200 lb K_2O/A	91	85	78	89	103	79	82	87	**86**	**8**

[2] Manure treatments with 0 lb K_2O/A only.

Table 11. Corn grain yields as affected by tillage, and N source and frequency of application in Goodhue Co., MN.

N Source and Frequency	GRAIN YIELDS (bu/A)																Mean	
	1983		1984		1985		1986		1987		1988		1989		1990		1983-90	
	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH
Fertilizer[1]	119	127	159	165	134	155	151	149	160	164	145	144	163	167	164	153	**149**	**153**
Manure (annual)	129	132	145	165	145	151	147	150	164	162	151	136	170	163	170	166	**153**	**153**
Manure (1st year)	114	112	156	160	138	150	147	151	169	163	144	137	154	150	144	153	**146**	**147**
Manure (2nd year)	108	122	101	134	109	117	106	122	133	140	125	126	143	135	140	144	**121**	**130**
Check	55	91	66	85	62	78	55	89	62	103	67	79	79	82	78	87	**66**	**87**

[1] Fertilizer and check treatments with 200 lb K_2O/A. Manure treatments were averaged over 0 and 200 lb K_2O/A treatments.

Table 12. Corn grain yields as affected by tillage, and N source and frequency of application in Goodhue Co., MN.

N Source and Frequency	GRAIN YIELDS (bu/A)																Mean	
	1983		1984		1985		1986		1987		1988		1989		1990		1983-90	
	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH
Fertilizer[1]	119	127	159	165	134	155	151	149	160	164	145	144	163	167	164	153	**149**	**153**
Manure (annual)	127	134	144	163	148	150	154	150	166	155	145	133	160	159	166	171	**151**	**152**
Manure (1st year)	125	114	155	153	132	146	146	154	168	159	149	131	141	155	146	155	**145**	**146**
Manure (2nd year)	104	125	98	138	115	121	104	134	150	145	111	126	151	136	128	129	**120**	**132**
Check	55	91	66	85	62	78	55	89	62	103	67	79	79	82	78	87	**66**	**87**

[1] Fertilizer and check treatments with 200 lb K_2O/A and manure treatments with 0 lb K_2O/A only.

EFFECT OF TILLAGE AND FREQUENCY OF LIQUID DAIRY MANURE APPLICATION ON THE AVAILABILITY OF N TO CORN, SOIL N DISTRIBUTION AND N CONCENTRATION IN SOIL WATER[1]

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Abstract: A summary of the results of the 1990 season of the study to determine the effects of tillage and frequency of liquid manure application on corn yield, N uptake, and soil N distribution initiated in 1982 is presented in this report. Despite late planting by about two weeks due to wet spring, the yields obtained in this season were comparable to those in the previous year. Annual application of manure produced greater grain yields and stover dry matter than anhydrous ammonia receiving equivalent amounts of N or biennial manure treatments receiving half as much N. The effects were not significant with respects to tillage treatments (no till and chisel plowing). The residual effect of additional K was reflected in higher plant stand at harvest, and lower grain moisture in manure treatments.

A significant amount of precipitation fell in April and May to raise the soil moisture levels to 22-26% by weight. The soil was uniformly wet throughout the profile. The amount of N in the soil profile dropped by 30 to 60 lbs/A from the levels in the previous fall. At the same time, soil water N at 5 ft. depth increased considerably suggesting the downward movement of water and N in the spring. The overall trends in soil water nitrate were similar in 1989 and 1990: no till yielded lower nitrate in soil water than chisel plowing, and there was more nitrate in soil water in anhydrous ammonia treatment than any of the manure treatments applied with equivalent or half the amount of N.

INTRODUCTION

The objective of the study is to determine the effects of tillage and frequency of manure application on corn yield, N uptake, and soil nitrogen levels. The site is located on a Seaton (Typic hapludalf, fine-silty, mixed, mesic) silt loam soil on the Dale Flueger Farm near Red Wing in Goodhue Co., MN. The study was initiated in 1982.

Liquid dairy manure is injected either annually, biennially or triennially on chisel-plowed treatments and annually or biennially on no-till treatments. A check treatment which does not receive any nitrogen and a fertilized check treatment which until 1988 received ammonium nitrate annually at the rate of 210 lbs N/A on no till plots and 170 lbs N/A on chisel plots are included in the study. In 1989 and 1990, the fertilized check received anhydrous ammonia , instead of ammonium nitrate, injected at the rate of 175 lbs N/A. Most cultural practices are similar to previous years (Table 1).

From 1982-1986 the manure treatments were split with 0 and 200 lbs K_2O/A and the fertilizer treatments with 0, 200, and 400 lbs K_2O/A. The application of this extra potassium has been stopped since 1987. To evaluate residual effects of additional potassium, data in this report are presented on split basis with respect to K_2O whenever applicable.

The experiment is laid out in a randomized complete block split-split plot design with three replications. Tillage is the main plot and N source is the subplot. Manure as N source is further split by the year of N application as a sub-sub plot.

The results of the analysis on yield and soil characteristics done for 1990 are included in this report.

RESULTS AND DISCUSSION

Residue Cover. Residue measurements were made both in and between the rows in duplicate in manure, fertilizer and check treatments in both tillages on June 18, 1990. A table of significance of treatment effects on residue cover is given in Table 2. There was about 18% more residue in between the rows than in the rows (Table 3). The difference in the amount of residue due to row position was small in no till when manure was applied but the amount increased in between rows by 17% in biennial manure treatment in the year following manure application, and by 37% in anhydrous ammonia treatments. In chisel plowed treatments, the amount of residue in between the rows exceeded the amount of residue in rows by 17-30% in all N treatments.

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Plant Population and Stover Yield. The effects of various treatments on plant population, stover dry matter, and stover moisture are given in Table 4. Although the plant population at harvest was not affected significantly by tillage or N treatments, no tillage had slightly lower population than chisel plowing. Previous K addition resulted in an increased stand (Table 5). Both stover dry matter yield and stover moisture at harvest were not affected significantly by treatments. The stover dry matter production response to N treatments was similar to grain yields: annual manure yielding highest followed by fertilizer, biennial manure in the year of application and biennial manure in the year following application. The stover moisture at harvest was lower in biennial manure in the year of application compared to the other N treatments (Table 6). Additional K in the previous years did not show any effect on stover yield or stover moisture content.

Grain Yields, Grain Moisture and Total Dry Matter. The treatment effects on grain yield, grain moisture, and total dry matter are summarized in Table 7. Tillage had no significant effect on grain yield, grain moisture, and total dry matter production at harvest. The source and frequency of N applied did have a significant effect on total grain yields, grain moisture, and total dry matter production at maturity. The grain yields ranged from an average high of 169 bu/A in treatments with manure applied annually to a low of 142 bu/A in the second year of biennial manure application. Grain yields were 10 bu/A lower with anhydrous ammonia treatment as compared to annual application of manure. A change from annual application of manure to biennial application resulted in a decrease in the yield by 20 bu/A in the year of application and by 26 bu/A in the year following the application of manure. The grain moisture content was generally 1-2% lower in manure applied treatments compared to the fertilizer treatment. The total dry matter yield at harvest ranged between 5.9 to 7.2 tons/A and showed similar response to N treatments as in grain yield: the highest yield associated with annual manure followed by anhydrous ammonia, biennial manure in the year of application and biennial manure in the year after application, respectively. The application of additional 200 lb/A of potassium in the previous years resulted in lower grain moisture in no till and higher grain moisture in chisel plowing compared to no addition of K (Table 8). Additional K also increased grain yields and decreased grain moisture at maturity at lower rates of N (Table 9).

Harvest Index. The harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover), was not affected by any tillage, N or K treatments (Table 10). The value of the index ranged from 0.52 to 0.57.

Soil Profile Moisture: Fall 1989. Gravimetric soil moisture determination were also made on soil samples taken to a depth of 5 ft. in the fall of 1989 during Oct. 24- Nov. 2. The soil samples were taken from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. The soil moisture was fairly uniform throughout the soil profile (Table 12): about 18% by weight in the upper 0-2 ft layer and about 17% in the depth below. The soil moisture was about 1% higher in between the rows than in the rows (Table 13). No till treatment had higher moisture in between the rows in all N treatments (Table 14); whereas, in chisel plowing, manure applied treatments had fairly uniform moisture in and between the rows while fertilizer and check treatments had higher moisture in between the rows than in the rows.

Soil Profile Nitrogen: Fall 1989. The soil samples taken in the fall were analyzed for total inorganic N and ammonium-N. A table of significance values using general linear means procedure of SAS is given in Table 11.

Of the N treatments sampled, anhydrous ammonia treatment had the highest total of 300 lbs N/A in the 5 ft. soil profile followed by 182 lb N/A in annual manure, 126 lb N/A in biennial manure in the year of application and 94 lb N/A in check treatments (Table 15). Of the total mineral N, the amount of ammonium N ranged from 60 to 75 lb N/A with a maximum difference of about 15 lb N/A among the N treatments. The major difference was in the amount of nitrate-N making up the difference in the amount of total mineral N. Most of the N in the profile was concentrated in the top 0-3 ft. layers (Table 16). Check treatments had fairly equal amount of N in and between the rows while N treatments had greater N in between the rows than in the rows (Table 17).

The amount of ammonium-N in the two row positions was more uniform in no till as compared to chisel plowed treatments (Table 18). In no till, most of the N in ammonium form was concentrated in the top 0-1 ft. depth segment; whereas, it was concentrated more in 1-2 ft. depth segment in chisel plowed treatments (Table 19). Most of the N in the nitrate form was still in the top 0-1 ft. depth segment in biennial manure and check treatments while a significant portion of nitrate N had moved down below up to 3 ft. depth in higher N treatments such as annual manure and fertilizer (Table 20). The amount of nitrate N was higher in between the rows than in the rows in all depth segments down to 3 ft. depth. In no till, the amount of nitrate-N was greatest in the top 1 ft. depth segment and decreased gradually down the profile; whereas, in chisel plowing most nitrate-N was concentrated in the 1-2 ft. depth segment of the profile.

Soil Profile Moisture: Spring 1990. Gravimetric soil moisture determination were made on soil samples taken to a depth of 5 ft. in the spring of 1990 on the 2nd of May. The soil samples were taken from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. A summary of significance for treatment effects on soil moisture is given in Table 21. The soil moisture ranged from 22% to 26% by weight, and was higher in manure applied treatments than the fertilizer and check treatments (Table 22). There was slightly higher moisture in the rows than in between the rows in biennial manure and check treatments; whereas, annual manure and fertilizer treatments had higher moisture in between the rows than in the rows. The 2-4 ft. depth segments were wetter than the depths above and below (Table 23). No till treatments were wetter in the top 4 ft. depth than the chisel-plowed treatments. The check was drier throughout the soil profile than any of the N treatments (Table 24).

Soil Profile Nitrogen:Spring 1990. Soil samples were taken to a depth of 5 ft. in 1 ft. increment were analyzed for total inorganic N and ammonium-N. A table of significance values using general linear means procedure of SAS is given in Table 21.

There was a decrease of about 30 to 60 lb N/A in total mineral N in the profile from the previous fall (Table 25). However, anhydrous ammonia treatments still contained highest amount of total mineral N in the top 5 ft. soil profile followed by annual manure, biennial manure and check treatments, respectively. The range in the amount of N among various treatments was between 45 to 53 lbs/A, and the most of the difference in the total amount of the mineral N was in the form of nitrate-N. Most of the ammonium N was in the surface 0-1 ft. layer while most of the nitrate-N was concentrated in the 2-4 ft. layer (Table 26). The nitrate-N was mostly concentrated to upper 2 ft. layer of the profile in biennial and check treatments showing little movement down below the profile (Table 27). In case of high N treatments such as annual manure and anhydrous ammonia, nitrate-N had moved down to 5 ft. depth.

Soil Water N. Suction water samplers were established on manure (annual and biennial) and fertilizer treatments to monitor nitrate-N in soil water at 5 ft. depth. Three samplers per plot were installed in corn row in two replications for each treatment. Water samples were drawn from each samplers at a weekly interval and were analyzed for nitrate-N in the laboratory.

The amount of N leached through the profile depends on the amount of water available in soil and the amount of recharge provided through precipitation after evapotranspiration and runoff losses. A summary of the monthly precipitation during 1988-90 growing seasons is illustrated in Fig. 1. The total amount of precipitation during April-September period was about 13 inches in 1988, 16 inches in 1989, and 31 inches in 1990. The soil profile was dry in a dry season of 1988, and hence there was difficulty in obtaining enough samples for nitrate analysis. In 1989, there was slightly higher precipitation and soil was recharged enough to obtain the water samples. Most significant rain fell in the spring of 1990 and the soil was fairly wet to cause the downward leaching of water and chemicals.

The effects of tillage treatments on soil water N at 5 ft. depth for the years 1989-90 are presented in Figure 2. In 1989 following a dry 1988 growing season, the initial concentration of nitrate-N in soil water for chisel plowed treatments was almost 80 ppm, about 4 times higher than the no till treatments. While the initial concentration dropped initially, and fluctuated in response to the precipitation events, the average concentration was fairly constant at about 70 ppm for chisel plowing and about 25 ppm for no tillage through the end of 1989 growing season.

In 1990, the concentration of nitrate-N in no till treatments increased to slightly below the level of chisel plowed treatments in May and June while the concentration of nitrate-N in chisel-plowed treatment remained at the level of previous year. There was a fluctuation in the concentration of nitrate-N in water in response to precipitation events in the succeeding weeks. However, the concentration of nitrate in water started declining with no tillage and started increasing towards the end of the season. The overall trends in water nitrate were similar: no till yielding lower nitrate at 5′ depth as compared to chisel plowing.

The effects of N treatments on soil water N at 5 ft. depth are illustrated in Fig. 3. The concentration of nitrates in water was fairly constant for anhydrous ammonia, annual manure, and biennial manure treatments throughout the 1989 season. The average nitrate content in water in anhydrous ammonia treatment was about 60 ppm followed by about 35 ppm in annual application of manure and less than 10 ppm in biennial application of manure.

The nitrate levels in 1990 increased in all the N treatments by about 5 to 35 ppm. There were fluctuations in nitrate levels in response to the precipitation events; however, overall nitrate levels remained fairly constant through the end of the season. The overall trend in 1989 and 1990 were similar: the fertilizer applied treatments yielding higher nitrate at 5 ft. depth followed by annual manure application and biennial manure application.