Table 8. Variable Input Crop Management System II Plot Management - CSOA rotation, Oats, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	None	None	None	None
LPI	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	MAP + Urea + KCl 50-50-50 lb/A (N-P_2O_5-K_2O) Broadcast 4/19	Buctril 1 pt/A 5/26	None	None
HPI	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	MAP + Urea + KCl 50-50-50 lb/A (N-P_2O_5-K_2O) Broadcast 4/19	Buctril 1 pt/A 6/1	None	None
ORG	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	None	None	None	None

Table 9. Variable Input Crop Management System II Plot Management - CSOA rotation, Alfalfa, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	None	None	With Oats	None	None	None	None
LPI	None	None	With Oats	TSP 0-40-0 lb/A Broadcast 6/13	None	None	None
HPI	None	None	With Oats	TSP 0-40-0 lb/A Broadcast 6/13	None	None	None
ORG	None	None	With Oats	None	None	None	None

Table 10. Variable Input Crop Management System II Plot Management - CSOA rotation, Corn, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/7 5/12	Pioneer 3769 29,000/A 5/13	None	None	5/17 5/19 5/27 5/31	6/10 6/20
LPI	Moldboard Fall 93	Digger 5/9	Pioneer 3769 29,000/A 5/9	Urea 25-0-0 lb/A Band 5/9	Buctril 1 pt/A Band 6/3	5/13 5/19 5/27	6/10 6/20
HPI	Moldboard Fall 93	Digger 4/23 5/7 5/9	Pioneer 3769 29,000/A 5/9	Urea + MAP 40-50-0 lb/A Broadcast 4/22	Eradicane 2.5 lb/A 5/7 Bladex 1.5 lb/A 5/7 Stinger 0.66 pt/A Broadcast 6/1	None	6/3 6/20
ORG	Moldboard Fall 93	Digger 5/7 5/12	Pioneer 3769 (untreated) 29,000/A 5/13	Beef Manure 59-25-42 lb/A (N-P_2O_5-K_2O) Fall 93	None	5/17 5/19 5/27 5/31	6/10 6/20

Table11. Variable Input Crop Management System II Plot Management - CS rotation, Soybean, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/24 7/12
LPI	Chisel Fall 93	Digger 5/12	Parker 158,000/A 5/12	None	Pursuit 3 oz/A Select 8 oz/A Band 6/3	5/17	6/10 6/13 6/28
HPI	Moldboard Fall 93	Digger 2 passes 5/12	Parker 158,000/A 5/12	None	Treflan 0.75 lb/A Sencor 0.25 lb/A Broadcast 5/12	None	6/10
ORG	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/28 7/12

Table12. Variable Input Crop Management System II Plot Management -CS rotation, Corn, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Chisel Fall 93	Digger 5/7 5/12	Pioneer 3769 29,000/A 5/13	None	None	5/19 5/27 5/31	6/10 6/20 7/12
LPI	None	Digger 5/9	Pioneer 3769 29,000/A 5/9	Urea 125-0-0 lb/A Band 5/9	Buctril 1 pt/A Band 6/3	5/13 5/19 5/27	6/10 6/20
HPI	Chisel Fall 93	Digger 4/23 5/7 5/9	Pioneer 3769 29,000/A 5/9	Urea + MAP 145-35-0 lb/A Broadcast 4/22	Eradicane 2.5 lb/A 5/7 Bladex 1.5lb/A Broadcast 5/7	None	6/3 6/20
ORG	Chisel Fall 93	Digger 4/23 5/7 5/12	Pioneer 3769 (untreated) 29,000/A 5/13	Liquid Hog Manure 339-125-104 lb/A (N-P_2O_5-K_2O) Spring 94	None	5/19 5/27	6/10 6/20 7/12

Table 13. 1994 Variable Input Crop Management Systems Yields

Rotation	Crop	Management Level				$LSD_{0.05}$
		MIN	LPI	HPI	ORG	
		bu/A				
CSOA	Corn	77.1	161.8	157.1	150.6	13.0
CS	Corn	79.4	152.0	182.2	133.7	15.3
SOAC	Soybeans	36.4	34.6	43.2	45.3	3.9
SC	Soybeans	29.9	40.9	41.3	37.8	3.7
ACSO	Alfalfa*	2.7	5.3	5.4	4.9	0.8
OACS	Oats	72.3	65.1	73.0	88.2	22.6

*Alfalfa yields are (T/A)

Table 14. 1994 Variable Input Crop Management Systems II Yields

Rotation	Crop	Management Level				$LSD_{0.05}$
		MIN	LPI	HPI	ORG	
		bu/A				
CSOA	Corn	137.9	150.3	162.4	147.2	13.5
CS	Corn	86.3	158.3	138.7	87.3	32.0
SOAC	Soybeans	40.1	46.7	50.7	42.0	4.7
SC	Soybeans	28.9	36.5	41.2	28.4	6.9
ACSO	Alfalfa*	5.2	5.9	5.9	6.2	0.6
OACS	Oats	107.1	102.5	118.3	121.8	41.7

*Alfalfa yields are (T/A)

Organic Crop Rotation Study

S.R. Quiring, D.R. Huggins, D.J. Fuchs, J.H. Ford[1]

ABSTRACT

Crop rotations can increase crop yields and improve weed control, and are considered to be fundamental to organic production systems. Crop rotations consisting of continuous corn, corn-soybean, corn-soybean-oat, and corn-soybean-oat-alfalfa, with and without composted poultry manure, were established in 1990. Corn yields were greater when other crops were added to the rotation , as compared to continuous corn. Manure applications increased corn yield in all rotations. Oat yields were low and variable due to poor stands and high weed pressure and, no significant response to crop rotation or manure application occurred. Soybean yields were increased with crop rotation, but, manure had little effect on yield. Alfalfa yields were doubled where manure was applied. The reported results are preliminary, and the value and meaning of the study will increase with time

INTRODUCTION

This study was designed to evaluate the effects of crop rotation, with and without fertilizer (poultry manure), on plant growth, crop yield, and weed control. Crop rotations consist of 1 to 4 years with continuous corn, corn/soybean, corn/soybean/oat, corn/soybean/oat/alfalfa. The site, located on the Koch farm next to the Southwest Experiment Station, has a history of low synthetic fertilizer and herbicide use, and high weed pressure. Soil tests from the fall of 1988 showed Bray 1 phosphorus at 10 ppm and potassium tests of 171 ppm. This study was started in 1990 following soybeans with the first yields taken in the fall of 1990. There are no chemical weed control practices used, only mechanical weed control methods.

METHODS and MATERIALS

The study is a randomized complete block, split plot design, with four replications. Main plots (60' x 155'), consist of crop rotation, with each crop represented in each year, and subplots (30' x 155') consist of control (no manure) and composted poultry manure applications. The manure rate is based on soil test results from the previous fall sampling and University of Minnesota Extension recommendations. Soil samples for phosphorus and potassium were taken to a depth of 1 foot with 8 composite cores per plot. Soil nitrate samples were taken in 1 foot increment down to 5 feet with 2 cores per plot.

Composted poultry manure with an N-P_2O_5-K_2O analyses of 5.4-3.66-4.31 was used (Table 1). The rate was selected to meet the crop requirement of the most limiting nutrient (P or N). The manure was broadcast on the plot and incorporated prior to secondary tillage in the spring.

After planting oats, and oats under seeded with alfalfa, plots were harrowed and packed (Table 1). This was done to increase weed control and soil to seed contact. The corn and soybean plots were rotary-hoed as often as needed to increase weed control (Table 1). Cultivations of corn and soybean were done as necessary to obtain maximum weed control. Tillage and rotary hoeing in like crops in all rotations were treated the same, but cultivation in corn varied from manure to no manure treatments. All treatments except oat under seeded with alfalfa were moldboard plowed in the fall.

Total weed counts were taken in all plots. All weed species were identified and counted in each sample. Three samples four feet long and 2.5 feet wide were taken in corn and soybean for grassy weeds. In oats and alfalfa five 1 foot squares per plot were collected for both grassy weeds and broadleaf weeds. Three samples, 150 feet by 2.5 feet, were taken for broadleaf weeds in corn and soybean plots.

RESULTS

In 1994, corn yields were significantly increased with the addition of manure across all rotations, however, the only significant increase in yield due to rotation effects was comparing continuous corn to the three year rotation (Table 2). The three year crop rotation with manure increased soybean yields significantly over the two year rotation (Table 3). There was a decrease in soybean yield when manure was applied across all rotations. This could be due to greater weed numbers from increased fertility (Table 3). Low oat yields were caused by a low population of oat and a high density of weeds. Yields were not taken with a plot combine due to early harvest of oat to prevent weed seed from reaching physiological maturity. Yields were taken using three, one meter squares per plots. Oat seed was separated from the biomass, weighed and calculated accordingly (Table 4). Adding manure to alfalfa more than doubled the yield in 1994 (Table 5).

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[1] S.R. Quiring, D.R. Huggins, D.J. Fuchs, and J.H. Ford are Sr. Research Technician, Assistant Professor, Former Scientist, and Professor at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. Organic Rotation Plot management information

Rotation	Spring Tillage	Seed	Rotary Hoe	Cultivation	Fertilizer
Continuous Corn	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	2.86 tons/A ** 5.4-3.66-4.31 4/22
Corn/Soybean	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	4.02 tons/A ** 5.4-3.66-4.31 4/22
Corn/Soybean/ Oat	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	5.2 tons/A ** 5.4-3.66-4.31 4/22
Corn/Soybean/ Oat/Alfalfa	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	0.9 tons/A ** 5.4-3.66-4.31 4/22
Soybean/Corn	Digger 4/22 5/7 5/12 5/23 5/27	Parker 158000 Seeds/A 5/27	5/31	6/14 6/24	0.63 tons/A ** 5.4-3.66-4.31 4/22
Soybean/Oat/ Corn	Digger 4/22 5/7 5/12 5/23 5/27	Parker 158000 Seeds/A 5/27	5/31	6/14 6/24	0.63 tons/A ** 5.4-3.66-4.31 4/22
Soybean/Oat/ Alfalfa/Corn	Digger 4/22 5/7 5/12 5/23 5/27	Parker 158000 Seeds/A 5/27	5/31	6/14 6/24	0.9 tons/A ** 5.4-3.66-4.31 4/22
Oat/Corn/ Soybean	Digger 4/22 Harrow/Pack 4/23	Dane 80 lbs/A 4/22			0.5 tons/A ** 5.4-3.66-4.31 4/22
Oat/Alfalfa/ Corn/Soybean	Digger 4/22 Harrow/Pack 4/23	Dane 64 lbs/A 4/22 Pioneer 5262 12 lbs/A 4/22			0.5 tons/A ** 5.4-3.66-4.31 4/22
Alfalfa/Corn/ Soybean/Oat		Pioneer 5262			1.19 tons/A ** 5.4-3.66-4.31 4/22

* Cultivation on 6/24 was on no manure corn only.

** Split plot design where only half the plot received manure.

Table 2. Crop rotation and manure effects on corn yields

	1990		1991		1992		1993		1994	
	Manure		Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-	+	-
	bu/a									
CC	84.6	74.5	85.4	55.7	93.3	63.7	42.5	11.2	149.5	57.3
CS	85.7	73.1	112.7	70.8	123.3	75.1	57.7	23.8	168.2	91.8
CSO	101.7	78.0	90.8	57.9	133.1	70.5	69.2	24.5	174.7	99.9
CSOA	82.9	70.9	116.2	69.1	140.4	98.7	69.5	46.2	156.6	93.3
$LSD_{0.05}$	22.4	28.5	23.8	19.8	16.3	40.6	19.9	12.5	18.9	37.4

Table 3. Crop rotation and manure effects on soybean yields

	1990		1991		1992		1993		1994	
	Manure		Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-	+	-
	bu/a									
SC	42.5	38.1	40.0	35.8	26.6	28.4	33.3	24.3	20.4	23.9
SOC	43.7	41.2	35.7	35.4	28.4	27.8	35.7	23.2	27.1	30.6
SOAC	43.7	40.7	36.3	33.8	28.5	28.3	33.6	21.3	26.7	29.1
$LSD_{0.05}$	7.9	9.0	9.6	11.8	6.6	10.6	7.4	7.2	6.3	6.3

Table 4. Crop rotation and manure effects on oat yields

	1990		1991		1992		1993		1994	
	Manure		Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-	+	-
	bu/a									
OCS	93.7	70.0	39.9	38.7	89.1	83.6	30.8	15.7	21.2	21.3
OACS	89.1	65.9	39.4	38.2	69.0	66.0	26.9	16.6	18.5	18.5
$LSD_{0.05}$	6.2	23.4	9.2	5.4	40.7	27.5	21.2	13.8	2.6	22.5

Table 5. Crop rotation and manure effects on alfalfa yields

	1991		1992		1993		1994	
	Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-
	ton/a							
ACSO	5.4	4.5	4.3	2.9	4.8	3.3	6.6	3.1

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1994

Month/ Period	Dates/ Period	Precipitation 1994	Precipitation 100-yr. average	Precipitation Dev. from av.	Air Temperature 1994	Air Temperature 100-yr. average	Air Temperature Dev. from av.	Soil Temperature (10 cm depth) 1994	Soil Temperature (10 cm depth) 10-yr. average
January	1-31	1.00	0.68	+ 0.32	- 2.5	8.0	-10.5	31.4	20.7
February	1-28	0.71	0.67	+ 0.04	5.1	12.8	- 7.7	28.6	23.9
March	1-31	0.78	1.13	- 0.35	29.5	26.7	+ 2.8	31.9	29.2
April	1-10	0.22	0.57	- 0.35	38.4	38.0	+ 0.4	38.5	
	11-20	0.67	0.64	+0.03	48.4	44.4	+ 4.0	44.5	
	21-30	4.68	1.05	+3.63	44.9	48.3	- 3.4	44.5	
Total/ av.		5.57	2.26	+3.31	43.9	43.6	+ 0.3	42.5	41.4
May	1-10	0.14	0.77	- 0.63	47.5	52.0	- 4.5	49.0	
	11-20	0.35	0.95	- 0.60	65.2	55.8	+ 9.4	63.9	
	21-31	0.63	1.25	- 0.62	67.1	60.0	+ 7.1	69.8	
Total/av.		1.12	2.97	- 1.85	60.1	56.1	+ 4.0	61.2	57.1
June	1-10	0.02	1.29	- 1.27	65.8	63.0	+ 2.8	71.4	
	11-20	1.23	1.30	- 0.07	68.4	66.3	+ 2.1	68.3	
	21-30	1.25	1.37	- 0.12	69.4	68.1	+ 1.3	72.1	
Total/av.		2.50	3.96	- 1.46	67.9	65.8	+ 2.1	70.6	69.3
July	1-10	5.29	1.44	+3.85	68.0	70.1	- 2.1	70.5	
	11-20	0.69	1.06	- 0.37	68.6	71.4	- 2.8	73.2	
	21-31	0.18	1.01	- 0.83	67.6	71.4	- 3.8	73.1	
Total/av.		6.16	3.51	+2.65	68.1	70.9	- 2.8	72.3	76.7
August	1-10	1.20	1.04	+0.16	66.8	70.4	- 3.6	73.7	
	11-20	0.28	0.93	- 0.65	65.2	69.0	- 3.8	68.0	
	21-31	0.68	1.04	- 0.36	66.6	66.9	- 0.3	71.4	
Total/av.		2.16	3.01	- 0.85	66.2	68.7	- 2.5	71.0	73.9
September	1-30	1.98	2.20	- 0.22	62.6	59.0	+ 3.6	64.0	61.5
October	1-31	3.13	1.74	+1.39	49.3	47.2	+ 2.1	49.1	47.8
November	1-30	0.73	0.97	- 0.24	34.6	29.7	+ 4.9	36.1	33.6
December	1-31	0.41	0.68	- 0.27	19.4	15.2	+ 4.2	29.4	23.4
Growing Season	4/1-8/31	17.51	15.71	+1.80	61.3	61.0	+ 0.3	63.6	63.8
Annual	1/1-12/31	26.25	23.78	+2.47	42.2	42.0	+ 0.2	49.2	46.7

CONTINUOUS CORN SILAGE[1]

S.D. Evans[2]

Abstract

This long-term study addresses the effects of removal of continuous corn silage and corn grain on soil properties and yield. In 1994 there were significant effects of fertilizer level only. The 28-year averages show no yield differences due to the removal of silage versus grain. A significant difference in yield does exist between the long-term high and low fertilizer rates.

Objective

This is the 28th year of a continuing study initiated in 1965 on a McIntosh silt loan soil. The study was initiated to determine the effects of removal of continuous corn silage and fertilizer rate on soil properties and yield. Half the plots receive a fertilizer rate of 74+48+48 ($N+P_2O_5+K_2O$) lb/A and the other half a rate of 148+96+96, fall applied. Silage and shelled corn samples were collected.

Experimental Procedure

The experiment is designed as a latin square with 4 treatments: (1) silage, low fertility (2) silage, high fertility (3) grain, low fertility (4) grain, high fertility. In 1993 the corn plants were severely stunted due to excessive rain and cool temperatures. The corn failed to reach maturity and was chopped down with a flail chopper and disked under on September 9 and moldboard plowed on October 28, 1993. The study was field cultivated on May 13 and again on May 16 and seeded to Pioneer 3751 corn at 30,000 seeds/A in 30-inch rows on May 17, 1994. Force 1.5G was band applied at seeding at 10 lb/A. Lasso @ 3 lb/A active ingredient (a.i.) + Bladex @ 2.2 lb/A a.i. were applied pre-emergence broadcast on May 20. The study was row cultivated on June 10 and again on June 22. Dates of tasseling and silking were recorded. Silage yields were obtained from chopping 3 10-foot rows on September 20 and grain yields were calculated from 2 45-foot rows harvested with a plot combine on October 14. Yields were also taken, as in past years, on an adjacent unfertilized (check) area where only the grain is removed.

Results and Discussion

Silage Yields

There were significant differences in silage yields between high and low fertility treatments in 1994 (Table 1). There were no significant differences in silage yields due to the continuous removal of grain or silage at the low fertility level or at the high fertility level in 1994. The 28-year average shows no effect on silage yields with regard to continuous grain or silage removal but does show significant differences between high and low fertility treatments.

Grain Yields

The 1994 grain yields (Table 2) show a significant difference in grain yield between the high and low fertility treatments of 52.1 bu/A. The long-term 28-year average also shows a significant grain yield advantage for high fertility over low fertility treatments of 7.0 bu/A.

This study will be continued in 1995.

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[1] Funding provided by the West Cent. Expt. Sta., Univ. of Minnesota.

[2] Professor, West Cent. Expt. Sta., Univ. of Minnesota.

Table 1. Effect of removal of continuous silage or grain only on silage yields.

Treatment	1994 Yield	1966-1994 Yield
	dry matter, tons/A	dry matter, tons/A
Silage, low fertility	5.47	5.59
Silage, high fertility	8.06	6.19
Grain, low fertility	6.33	5.69
Grain, high fertility	7.66	6.10
Signif. Levels (%)		
Treatment	96	>99
Year	--	>99
Treatment x Year	--	>99
LSD, Treatment (.05)	1.95	0.16

Table 2. Effect of fertilizer level on grain and silage yields.

Treatment	1994 Yield	1966-1994 Yield
	bu/A @ 15.5% Moist	bu/A @ 15.5% Moist
Grain, low fertility	127.3	91.3
Grain, high fertility	179.4	98.3
Signif. Levels		
Treatment	98	>99
Year	--	>99
Treatment x Year	--	>99
LSD, Treatment (.05)	33.5	2.9
Grain, check (bu/A)	63.8	47.8
Silage, check (D.M. tons/A)	2.81	3.47

ANHYDROUS AMMONIA KNIFE SPACING STUDY[1]

S.D. Evans and G.A. Nelson[2]

Abstract

A field study was initiated at Morris, MN in 1994 to study the effect of sidedressed anhydrous ammonia knife spacing on corn yield. Additional treatments were included to evaluate urea application at sidedress stage with and without incorporation. There was an increase in corn yield up to 72 lb N/A as anhydrous ammonia, but no difference due to knife spacing. There was no influence of urea incorporation at the 72- and 108-lb N rates and no difference between the urea N source and anhydrous ammonia. This study will be continued for 1 or 2 more years.

Objectives

Anhydrous ammonia is the dominant source of inorganic nitrogen used in corn production. Normally anhydrous ammonia is injected into the soil through knives that run 6-10 inches deep. Horsepower requirements and fuel consumption are high during this process. It would be advantageous to space anhydrous ammonia knives 60 inches apart, rather than the conventional 30-inch spacing, to reduce horsepower and fuel requirements during the anhydrous ammonia application process. At the 60-inch spacing no ammonia is applied in the tractor wheel tracks. This study was designed to evaluate corn grain yield response due to spacing of anhydrous ammonia applicator knives at 30-inch intervals versus 60-inch intervals. The anhydrous ammonia was applied sidedress at the 5-leaf stage of corn with a conventional anhydrous ammonia applicator.

Experimental Procedures

An experiment was established in 1994 on a Nutley clay soil (2 reps) and Flom loam soil (2 reps). The individual plots were 6 rows (15 ft) wide and 45 ft long. The experimental design was a randomized complete block with 4 replications. The experimental site was in oats in 1993 and fall chisel plowed. The fall NO_3-N (0-2 ft) was 14 lb/A. Other initial soil tests are shown in Table 1. The study was field cultivated once and then seeded with a 6-row planter to Ciba-Geigy 4172 corn at 30,000 seeds/A in 30-inch rows on May 9. Force 1.5G was band applied at 10 lb/A at seeding. Lasso @ 3.0 lb/A active ingredient (a.i.) + Bladex @ 2.2 lb/A a.i. was applied preemergence on May 16. Anhydrous ammonia was sidedress applied with 30 and 60 inches between knives on June 8. Nitrogen was applied at rates of 32, 72, 108, and 144 lb/A at 30- and 60-inch knife spacings. A check treatment (no N) was also included by running knives at 30- and 60-inch spacings through the check plots without applying any nitrogen. Corn was in the 5-leaf, 3-collar stage at the time of nitrogen application. The study was cultivated with 6-row equipment on June 8, prior to nitrogen application and again on June 27. Four urea treatments were also included into the study for comparative purposes. Urea applications of 72 and 108 lb N/A were broadcast applied prior to cultivation on June 8, and thus incorporated via row cultivation. The unincorporated urea treatments of 72 and 108 lb N/A were broadcast applied after row cultivation on June 8. The urea treatments were also cultivated on June 27. Tasseling and silking dates were recorded. The study was harvested for grain on September 28 with a plot combine.

Results

The check treatments tasseled and silked about 1 day later than all other treatments. There were significant differences in grain yield due to nitrogen rate (Table 2.). There were no significant effects on grain yield due to knife spacing or the knife spacing x treatment interaction. Yield was maximized at about 72 lb N/A. The comparison of urea incorporated, urea unincorporated, and ammonia at 2 N rates showed no siginficant differences (Table 3). The surface applied urea was probably incorporated by rainfall that fell soon after application. On days 3 and 4 following application a total of 0.28 inch was recorded and an additional 0.61 inch on days 6 through 9 after application.

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[1] Funding provided by the West Cent. Expt. Sta., Univ. of Minnesota.

[2] Professor and Assistant Scientist, West Cent. Expt. Sta., Univ. of Minnesota.

Table 1. Analysis of initial soil samples.

	Organic Matter	pH	Olsen P	Bray P	K	Zn
	%		ppm	ppm	ppm	ppm
Average	5.7	- -	- -	34	227	2.6
Range	4.9-7.2	7.0-7.8	30-43[a]	21-50	200-250	1.5-4.3

[a] Values from only 2 reps with pH <7.4.

Table 2. Effect of anhydrous ammonia applicator knife spacing on corn grain yield.

Nitrogen Rate	30-in. Knife Spacing	60-in. Knife Spacing	Mean
lb/A	- - - - - - - - - bu/A @ 15.5% M - - - - - - - -		
0	80.5	80.5	80.5
32	106.9	113.5	110.2
72	150.3	148.9	149.6
108	142.7	153.3	148.0
144	159.3	159.8	159.5
Signif. Levels (%)			
Rep			62
Knife Spacing (KS)			34
N Treatment (N)			>99
LSD, Trt. (.05)			28.5
KS x N.			2

Table 3. Effect of incorporation, knife spacing, and N source on corn grain yield.

N Source	Nitrogen Rate	Knife Spacing	Incorporated	Yield
	lb/A			bu/A @15.5% M
NH_3	72	30	Yes	150.3
NH_3	72	60	Yes	148.9
NH_3	108	30	Yes	142.7
NH_3	108	60	Yes	153.3
Urea	72	- -	No	127.5
Urea	72	- -	Yes	133.8
Urea	108	- -	No	139.6
Urea	108	- -	Yes	124.9
Signif. Levels (%)				
Rep				89
Trt.				74
LSD (.05)				NS

ESTIMATION OF DIRECT AND RESIDUAL N AVAILABILITY FROM APPLIED LIQUID SWINE AND DAIRY MANURE[1]

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Abstract

The effects of liquid swine and liquid dairy manure applied at four rates on soil NO_3-N content and various crop parameters were evaluated for one and two years following fall manure injection and compared to four rates of urea and a check. The first year following application, all but the lowest manure rates increased soil NO_3-N levels at emergence, V5, and post-harvest over the check treatment. Soil NO_3-N levels from the 2nd year following manure application were significantly higher than the check treatment at emergence and V5 only with the highest manure rate from both sources. Post-harvest soil NO_3-N levels of the two highest rates of both manures were higher than the check in the 2-5 ft depth zone. Differences in chlorophyll meter readings on the residual manure study were significant only on July 11, the pre-tassel stage. On the study the first year after manure application, chlorophyll meter readings were affected by treatment at both V5 and pre-tassel stages. On both studies the range in readings was wider at pre-tassel than at V5. Plant height, total N upake, grain N removal, silage yield, and grain yield were all significantly affected by treatment on both studies. The effects were much larger on the 1st year following manure application as compared to the 2nd year. There was a positive relationship between soil NO_3-N to a 2-ft depth at corn stage V5 and corn grain yield. This study will be continued for one more crop year.

Introduction

Animal agriculture is an important part of the farm economy in west central Minnesota. Most manure is used as a nutrient source on cropland, but most farmers tend to give less credit to manure than suggested because 1) N fertilizer is cheap and 2) a little extra N gives them a cushion in case of unexpected N losses or reduced N availability from manure. It would be helpful if farmers had some technique to determine the N status and predicted N need before the period of maximum N uptake and early enough so that supplemental N could be applied. This is particularly important for slow release N sources such as manure. Early season soil and plant tests will be used to evaluate the apparent N mineralization rate and N status of the corn crop. Climatic variables will also be measured on a limited number of plots in another phase of the overall nutrient recycling effort so that apparent N mineralization can be modeled. Corn grain yields and N uptake will be used as the final measure of N availability over a growing season.

Experimental Procedures

The experimental site was established in the fall of 1992 on a predominately Aastad clay loam (Pachic Udic Haploboroll, fine loamy, mixed) located on the West Central Experiment Station, Morris, MN. The 1992 crop was corn and was harvested as corn silage on October 1-2, 1992. Two trial sites were established; one to commence with manure and fertilizer applications in the fall of 1992 (Site 1) and the other to commence with manure and fertilizer applications in the fall of 1993 (Site 2).

Treatment areas were staked out on both sites on October 5. The design for each site was a randomized complete block with 4 replications. Plot size was 15 ft wide (6 rows) by 47.5 ft long. Thirteen treatments included a check, 4 rates of urea, 4 rates of liquid swine manure, and 4 rates of liquid dairy manure (Table 2). Site 1 was grid sampled on October 6, 1992 on the corners of every second plot to determine the depth of topsoil, soil drainage characteristics, soil pH, soil organic matter content, and depth to carbonates. The same measurements

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were made on Site 2 on September 1, 1994. Samples were air dried and saved for analysis. Fertilizer was applied broadcast to Sites 1 and 2 on October 14, 1992 to provide 75 lb/A P_2O_5 and 75 lb/A K_2O.

Manure treatments were applied to Site 1 on October 19-20, 1992 and to Site 2 on October 21-22, 1993. Target application rates were 80, 160, 240, and 320 lb N/A. All manure treatments were applied with an experimental Agricultural Engineering Department manure applicator. Samples of each manure were taken directly from the applicator in the field for subsequent analysis. The N contents of the manures are given in Table 1. The applicator was weighed using portable load cells before and after each application treatment to calculate actual application rates. The applied manure rates were calculated from these weights (Table 2). The manure was metered through 4 hydraulically driven pumps, one for each injector, to provide an accurate uniform application. The applicator was outfitted with 4 18-inch sweeps, 24 inches on center, for a total applicator width of 7.5 feet. Two passes were required for each plot. Manure was applied at a 4-5 inch depth for all manures and rates except for the 320-lb dairy rate in 1992 which was applied at 5-6 inches on the first pass and 3-4 inches on the second pass. Inorganic fertilizer as urea was applied to provide 40, 80, 120, and 160 lb N/A. Urea was applied to Site 1 on October 22, 1992 and then field cultivated to incorporate the urea and remove wheel tracks from the manure applicator. Urea was applied to Site 2 on October 18, 1993 and then field cultivated to incorporate the urea and remove wheel tracks from the manure applicator on October 22, 1993. Urea was also applied to urea treatments in Site 1 in the fall of 1993 and to both sites in the fall of 1994. This study will be continued for one more crop year with only residual manure as compared to annual urea treatments.

2nd Year Residual Availability - Site 1 (1993-1994)

For the second year of the study on Site 1 the site was field cultivated for seedbed preparation on May 9, 1994 Ciba-Geigy 4172 corn was seeded at 30,000 seeds/A on May 9. Force 1.5G was applied at seeding at 10 lb/A. A tank mix of Lasso @ 3 lb/A active ingredient (a. i.) + Bladex @ 2.2 lb/A a. i. was applied broadcast preemergence on May 16.

The plots were soil sampled at the emergence stage (2-leaf) of corn on May 24-25. Plots consisted of 6 rows and were sampled to a depth of 2 ft in 1-ft increments. Each soil sample was a composite of 6 subsample probes (two in the corn row, two 7.5 inches from the row to the north, and two 15 inches from the row to the north). Soil samples were dried at 95°F for 24 hours, ground, and analyzed for NH_4-N and NO_3-N.

On June 1 Accent @ 2/3 ounce/A was applied broadcast for grass control. On June 8 the plots were row cultivated. The plots were soil sampled at the V5 stage of corn of corn in the same manner as the emergence sampling on June 13-14. On June 16 chlorophyll meter readings were taken on 10 plants/plot. Plant heights were measured on June 28 (10 plants/plot, extended leaf) and a plant population count was taken on June 29. Chlorophyll meter readings were taken a 2nd time on July 11 just prior to tasseling. Corn tasseling and silking dates were recorded.

Corn was hand harvested for silage yields from 45 ft of row on September 14-15. Silage samples were dried at 150°F for 48 hours and saved for N analysis. On September 22, 10 basal stalk samples were collected from each plot, each stalk was an 8-inch section located 6 to 14 inches from the soil surface. Corn grain was harvested from 2 45-ft rows using an Almaco combine on September 27. The plots were soil sampled using the same method as at the emergence sampling except they were sampled to a depth of 5 ft in 1-ft increments on October 10-11. Corn stalks were chopped on October 21 and urea fertilizer was applied on October 24 to the same plots and rates as in the fall of 1993. The study was chisel plowed on October 25.

1st Year Availability - Site 2 (1994-95)

For the first year of the study in Site 2 the field procedures, planting dates, hybrids, herbicides, plant and soil sampling procedures and dates were the same as in Site 1 with the following exceptions: emergence soil samples were taken on May 25-26, corn silage was harvested on September 15, and fall soil samples were taken on October 11-13.

Results and Discussion

2nd Year Residual Availability - Site 1 (1993-1994)

Soil N Content: There were significant effects of treatment on soil NO_3-N for emergence and V5 sampling dates and depth combinations shown in Table 3 for Site 1. The fall harvest date was only significant at the 0-5 ft depth indicating that 2 years after manure application the mineralized N had either been used up or leached out of the 0-1 and 1-2 ft increments. There were no significant effects of treatment on soil NH_4-N values on Site 1.

Plant Measurement: Relative chlorophyll meter readings, grain yield, silage yield, and plant height were significantly affected by treatment at Site 1 shown in Table 5. Relative chlorophyll meter readings were significant on July 11 but not on June 16. July 11 readings gave a good indication of yield range but were not precise enough to indicate yield levels and July 11 is too late to apply additional N. Grain yield and silage yields behaved similarly with treatments F3, F4, and D4 yielding the most. Due to heavy rainfall and/or low soil NO_3-N it is possible maximum yield was not reached at this site. Treatment effects for plant height, taken on June 27, were significant with taller plants generally yielding more than shorter plants but no close correlation was evident. There were no differences in grain moisture and grain bushel weight (Table 5) or in stover total N, grain total N, and basal stalk NO_3-N (Table 7). There were highly significant differences in total N uptake and N removed in the grain (Table 8). The C.V.'s were very high in the residual manure study indicating the extreme variability in the N availability. All basal stalk NO_3-N values were less that 20 ppm indicating very little available N in the soil at the end of the season (Table 7).

1st Year Availability - Site 2 (1994-95)

Soil N Content: Treatments affected soil NO_3-N for all sample dates and depth combinations shown in Table 4 for Site 2. V5 nitrates were lesser than those at emergence but there were still significant treatment effects. Greatest grain yields were associated with V5 0-2 ft NO_3-N soil tests of 9.8 ppm or greater. There were no effects of treatment on soil NH_4-N values on Site 2.

Plant Measurements: Relative chlorophyll meter readings, grain yield and moisture, silage yield, and plant height were significantly affected by treatment at Site 2 (Table 6). Relative chlorophyll meter readings were significant for both June 16 and July 11 and generally reflect greater yields associated with higher readings but not accurately for purposes of determining N status of the plant. Grain yield and silage yield responded in a similar manner with greatest yields at treatments F3, F4, S2, S3, S4, D3, and D4. Plant height on June 27 generally corresponded well with final yield. Stover total N, grain total N, and basal stalk NO_3-N were significantly affected by treatment at Site 2 (Table 7). In 1993 grain N and stover N were also significant for differentiating high yielding from low yielding treatments in 1993 but did not correlate with 1994 yields from manure treatments. Basal stalk NO_3-N was excellent for indicating excess inorganic N in the soil profile during the growing season as shown in S2, S3, and S4. There were highly significant effects of treatment on total N uptake on N removed in the grain from 1st year manure and urea applications (Table 8). The C.V.'s of the 1st year data were much lower than in the residual manure data. Basal stalk NO_3-N values of three of the swine manure treatments were above 200 ppm (Table 7) indicating substantial available N in the soil at the end of the growing season. This was also shown in the soil NO_3-N measurements (Table 4).

Yield - Soil Nitrate-N Relationship

In 1993 we found a close relationship between corn grain yield and soil NO_3-N (0-2 ft) at leaf stage V5. Similar data for 1994 is plotted in Fig. 1. With all treatments included (both sites) the $r^2 = 0.79$. A slightly better relation was found when including only the organic plots ($r^2 = 0.85$). It appears that a soil NO_3-N (0-2 ft) of about 10 ppm for corn leaf stage V5 was sufficient to reach about 95% of maximum yield.

Table 1. Nitrogen content of manure used.

Manure Source[a]	Site 1, N Applied fall 1992 Total	Org.	NH_4-N	Avail (93)[b]	Avail. (94)[c]	Site 2, N Applied fall 1993 Total	Org.	NH_4-N	Avail. (94)[b]
	lb/1000 gallons								
Swine	31.6	18.2	13.4	18.9	1.91	54.0	9.6	44.4	47.3
Dairy	35.6	17.4	18.3	23.5	1.83	31.4	13.2	18.2	22.2

[a] Sampled from the manure applicator just prior to application.
[b] Available N 1st year = NH_4-N + 30% of organic N.
[c] Available N 2nd year = 15%(remaining 70% of organic N).

Table 2. Treatments, target N rates, manure applied, and actual N applied, 1992 & 1993.

Trt.	N Source	Site 1, N Applied fall 1992 Manure Applied	93 Avail. Rates[a](	94 Avail. Rates[b](	Site 2, N Applied fall 1993 Target Rates	Manure Applied	94 Avail. Rates[a]
		-gal/A-	-lb/A-			-gal/A-	-lb/A-
CK	None	0	0	0	0	0	0
F1	Urea	0	40	40	40	0	40
F2	Urea	0	80	80	80	0	80
F3	Urea	0	120	120	120	0	120
F4	Urea	0	160	160	160	0	160
S1	Swine manure	2440	46	5	80	1740	82
S2	Swine manure	4880	92	9	160	5070	240
S3	Swine manure	7180	136	14	240	7400	350
S4	Swine manure	9740	184	19	320	9860	466
D1	Dairy manure	3880	91	7	80	2290	51
D2	Dairy manure	7860	185	14	160	4906	109
D3	Dairy manure	11300	266	21	240	6830	151
D4	Dairy manure	15700	370	29	320	8680	192

[a] Based on actual weight of manure applied and available N values from Table 1.
[b] Based on actual weight of manure applied and residual N values from Table 1.

Table 3. Effect of N source and rate on nitrate-N in the soil profile at emergence and V5 stage of corn growth, Site 1, 1994.

N Source	Avail. N Rate	Emergence NO_3-N 0-1 ft	Emergence NO_3-N 0-2 ft	V5 NO_3-N 0-1 ft	V5 NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-1 ft	Post Fall Harvest NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-5 ft
	lb/A	ppm						
Check	0	5.2	3.9	4.9	3.6	2.3	1.2	1.1
Urea[a]	40	6.2	5.5	5.1	4.5	1.3	0.9	1.5
Urea	80	12.4	9.5	7.9	7.4	2.2	1.2	1.8
Urea	120	7.9	8.7	7.5	8.6	1.2	0.8	3.4
Urea	160	12.5	12.4	9.6	9.1	2.3	1.5	3.1
Swine[a]	5	4.6	3.5	4.4	3.6	1.9	1.1	1.4
Swine	9	4.9	3.8	4.5	3.4	1.6	1.0	1.8
Swine	14	6.7	5.4	5.1	4.1	3.2	1.8	2.4
Swine	19	5.6	4.4	4.1	4.0	2.4	1.3	4.4
Dairy[a]	7	6.1	4.7	5.3	4.2	1.8	1.0	1.5
Dairy	14	6.0	4.5	4.9	3.7	2.4	1.3	2.6
Dairy	21	6.0	4.9	4.7	3.8	2.5	1.4	3.3
Dairy	29	7.4	6.5	7.0	6.6	2.1	1.2	4.8
Pr > F		.0001	.0001	.0019	.0001	.1019	.1406	.0001
BLSD(.05)		2.9	2.0	2.6	1.9	NS	NS	1.1
C.V. (%)		24.8	20.8	25.2	23.1	32.1	30.6	24.5

[a] Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.

Table 4. Effect of N source and rate on nitrate-N in the soil profile at emergence and V5 stage of corn growth, Site 2, 1994.

N Source	Avail. N Rate	Emergence NO_3-N 0-1 ft	Emergence NO_3-N 0-2 ft	V5 NO_3-N 0-1 ft	V5 NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-1 ft	Post Fall Harvest NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-5 ft
	lb/A	ppm						
Check	0	6.0	4.8	4.3	4.1	2.3	1.3	2.0
Urea[a]	40	7.2	6.2	6.2	5.8	2.0	1.2	2.6
Urea	80	9.9	9.1	8.2	8.3	2.2	1.4	2.3
Urea	120	13.0	11.2	10.3	9.8	2.0	1.3	1.9
Urea	160	19.1	16.6	14.8	12.9	3.4	2.0	3.4
Swine[a]	82	7.4	7.2	5.9	6.4	2.6	1.6	2.8
Swine	240	15.8	15.9	13.7	12.7	4.2	2.6	3.6
Swine	350	23.9	20.4	19.9	17.8	6.1	5.4	5.9
Swine	466	33.7	29.0	30.2	25.1	13.2	11.9	8.2
Dairy[a]	51	6.2	6.0	5.2	5.2	2.0	1.1	1.7
Dairy	109	10.2	9.7	8.3	8.2	2.1	1.2	2.7
Dairy	151	10.1	9.9	10.2	9.9	3.1	1.8	3.2
Dairy	192	13.2	12.1	11.9	10.8	2.9	1.7	2.9
Pr > F		.0001	.0001	.0001	.0001	.0001	.0001	.0001
BLSD(.05)		5.9	3.5	7.6	4.9	3.8	2.2	1.6
C.V. (%)		32.6	22.0	47.4	34.4	71.5	59.2	34.2

[a] Manure and inorganic N were applied in the fall of 1993.

Table 5. Influence of nitrogen source and rate on plant measurements: chlorophyll meter readings, grain yield, grain moisture, grain bushel weight, plant height, and silage yield, Site 1, 1994.

N Source	Avail. N Rate	Relative Chlorophyll[b] Jun 16	Jly 11	Grain Yield	Moisture	Weight	Plant Height Jun 27	Silage Yield
	lb/A			-bu/A-	--%--	-lb/bu-	- - in - -	-lb/A-
Check	0	0.90	0.73	75.8	27.7	53.1	42.5	8050
Urea[a]	40	0.98	0.86	101.2	25.4	52.9	45.2	9600
Urea	80	0.97	0.96	122.2	24.0	53.7	51.9	11700
Urea	120	1.02	0.96	127.4	25.3	53.7	48.7	13000
Urea	160	1.00	1.00	139.5	25.2	53.8	50.4	13400
Swine[a]	5	0.88	0.79	70.7	26.1	53.8	42.8	8570
Swine	9	0.89	0.76	92.6	25.9	53.6	44.7	9600
Swine	14	0.93	0.85	94.1	24.8	53.9	47.4	10100
Swine	19	0.93	0.85	98.1	24.4	53.8	46.7	10400
Dairy[a]	7	0.88	0.80	75.3	25.2	53.1	45.0	8830
Dairy	14	0.93	0.93	108.4	23.7	54.3	50.8	11100
Dairy	21	0.95	0.95	104.8	24.5	53.9	49.4	11600
Dairy	29	0.97	0.94	132.1	26.1	53.3	50.4	12600
Pr > F		.1150	.0023	.0100	.6720	.4609	.0001	.0006
BLSD(.05)		------	0.14	42.4	-------	------	5.5	2394
C.V. (%)		6.5	8.7	21.4	8.3	1.3	4.5	12.9

[a] Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.
[b] Actual chlorophyll meter readings for each rep were divided by the reading on treatment F4 for that rep.

Table 6. Influence of nitrogen source and rate on plant measurements: chlorophyll meter readings, grain yield, grain moisture, grain bushel weight, plant height, and silage yield, Site 2, 1994.

N Source	Avail. N Rate	Relative Chlorophyll[b] Jun 16	Jly 11	Grain Yield	Moisture	weight	Plant Height Jun 27	Silage Yield
	lb/A			-bu/A-	--%--	-lb/bu-	- - in - -	-lb/A-
Check	0	0.89	0.76	108.5	27.7	53.2	47.8	11000
Urea[a]	40	0.89	0.80	117.4	25.6	52.6	50.7	11500
Urea	80	0.98	0.92	142.4	24.7	53.2	55.6	14000
Urea	120	0.99	0.91	160.0	22.8	53.6	59.0	15700
Urea	160	1.00	1.00	171.4	24.9	52.9	59.9	16500
Swine[a]	82	0.97	0.88	128.3	24.6	53.5	55.7	13700
Swine	240	0.97	0.94	180.6	24.8	53.0	62.3	17300
Swine	350	1.02	0.98	188.4	25.8	52.1	65.4	17800
Swine	466	1.00	0.99	187.2	26.6	52.8	64.4	19200
Dairy[a]	51	0.88	0.79	116.3	26.9	52.5	50.8	12000
Dairy	109	0.97	0.90	147.2	26.3	53.4	58.6	15000
Dairy	151	0.94	0.92	166.6	25.9	52.9	59.9	16500
Dairy	192	0.99	0.98	174.2	23.6	53.5	62.9	16300
Pr > F		.0015	.0001	.0001	.0413	.1322	.0001	.0001
BLSD(.05)		0.07	0.05	14.9	3.3	------	3.1	1780
C.V. (%)		5.0	4.0	7.5	7.2	1.3	4.1	8.9

[a] Manure and inorganic N were applied fall of 1993.
[b] Actual chlorophyll meter readings for each rep were divided by the reading on treatment F4 for that rep.

Table 7. Influence of nitrogen source and rate on total N content of stover, total N content of grain, and NO3-N concentration of plant basal stalk, 1994, Site 1 and 2.

1994 Site 1					1994 Site 2				
N Source[a]	Avail. N Rate	Stover Total N	Grain Total N	Basal Stalk NO_3-N	N Source[b]	Avail. N Rate	Stover Total N	Grain Total N	Basal Stalk NO_3-N
	lb/A	- - - % - - - -		-ppm-		lb/A	-%-	-%-	-ppm-
Check	0	0.36	0.85	1.14	Check	0	0.30	0.85	7.06
Urea	40	0.38	0.89	0.75	Urea	40	0.32	0.90	1.78
Urea	80	0.47	0.93	5.57	Urea	80	0.36	1.02	1.58
Urea	120	0.39	0.95	12.90	Urea	120	0.42	1.05	2.41
Urea	160	0.39	1.05	18.10	Urea	160	0.44	1.20	11.70
Swine	5	0.33	0.89	0.96	Swine	82	0.38	0.98	0.81
Swine	9	0.33	0.90	0.81	Swine	240	0.50	1.18	215.00
Swine	14	0.38	0.94	1.43	Swine	350	0.47	1.30	512.00
Swine	19	0.41	1.00	4.22	Swine	466	0.55	1.24	976.63
Dairy	7	0.37	0.87	0.70	Dairy	51	0.37	0.88	0.83
Dairy	14	0.35	0.84	1.94	Dairy	109	0.33	1.04	1.91
Dairy	21	0.37	0.98	1.76	Dairy	151	0.36	1.07	1.35
Dairy	29	0.41	1.07	5.63	Dairy	192	0.47	1.25	22.30
Pr>F		.7244	.1052	.1666			.0001	.0001	.0001
BLSD .05		NS	NS	NS			0.09	0.12	180.3
C.V. (%)		20.4	10.0	172.5			15.7	8.6	101.9

[a] Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.
[b] Manure and inorganic N were applied in the fall of 1993.

Table 8. Influence of nitrogen source and rate on total N uptake and total N removed in the grain, 1994.

1994 - Site 1				1994 - Site 2			
N Source[a]	Avail. N Rate[b]	Total N Uptake	Total N Removed in Grain	N Source[c]	Avail. N Rate[d]	Total N Uptake	Total N Removed in Grain
	- - - - - - - lb/A - - - - - -				- - - - - - - lb/A - - - - - - -		
Check	0	49	37	Check	0	67	52
Urea	40	66	51	Urea	40	75	60
Urea	80	87	64	Urea	80	103	82
Urea	120	89	67	Urea	120	121	95
Urea	160	105	82	Urea	160	146	115
Swine	5	48	36	Swine	82	92	70
Swine	9	60	47	Swine	240	154	119
Swine	14	66	49	Swine	350	171	138
Swine	19	74	57	Swine	466	175	130
Dairy	7	51	36	Dairy	51	77	57
Dairy	14	68	51	Dairy	109	107	86
Dairy	21	76	58	Dairy	151	123	100
Dairy	29	103	81	Dairy	192	153	122
Pr>F		.0080	.0141			.0001	.0001
BLSD .05		35	31			18	16
C.V. (%)		25.7	28.6			11.5	13.2

[a]Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.
[b]Available N 1st year = NH4-N + 30% of organic N.
[c]Manure and inorganic N were applied in the fall of 1993.
[d]Available N 2nd year = 15%(remaining 70% of organic N).

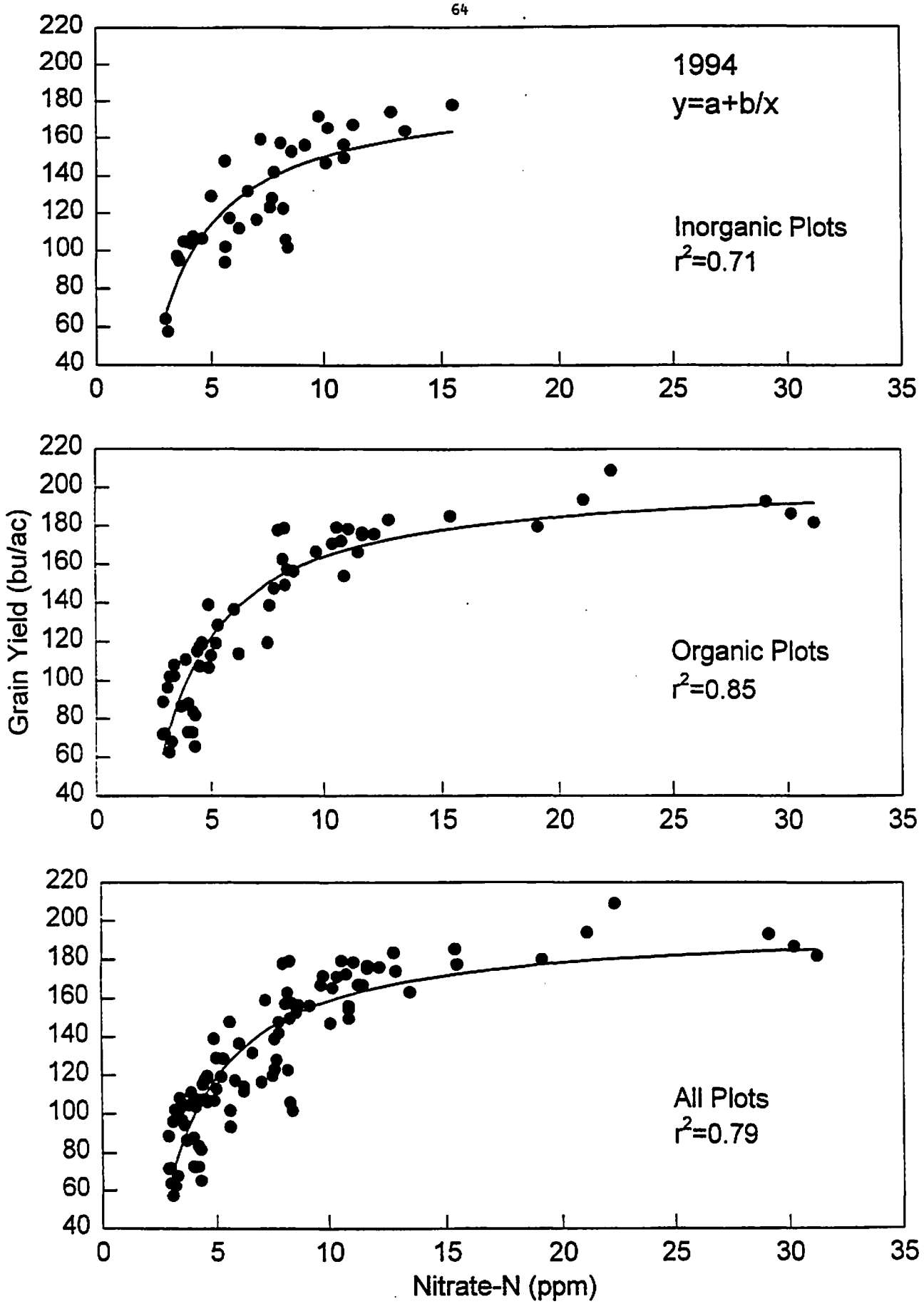

Figure 1. Relationship between soil nitrate-N (0-2 ft. at corn stage V-5) and grain yield.

ASSESSMENT OF THE EFFECTS OF TILLAGE AND MANURE APPLICATION ON SEDIMENT AND P LOSS DUE TO RUNOFF IN 1994[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, S.D. Evans, G.A. Nelson, B.J. Johnson and A. Ranaivoson[2]

Abstract

In the RT system, snowmelt-runoff was the predominant source of the annual runoff and phosphorus loss; On the contrary, in the PL system, rainfall-runoff was the predominant source of the annual runoff and phosphorus loss. Sediment loss in snowmelt-runoff was a negligible contribution to the annual sediment loss. Therefore the annual sediment loss was mainly from rainfall-runoff. The PL systems resulted in 11.8 times higher sediment loss compared to RT system. The annual TP loss in the PL systems was 1.9 times higher than TP from RT systems. Particulate-P from PL plots was 3.9 times higher than that of the RT systems. The RT system resulted in 3.7 times higher DMRP loss compared to the PL system. One time manure application in 1992 did not significantly influence the annual runoff, PP, DMRP and TP loss. Manure application significantly reduced rainfall-runoff and sediment loss.

Tillage had no significant influence on grain yield, number of ears, and number of plants at harvest. The RT system resulted in a significantly higher grain moisture content. Manure application significantly influenced grain yield although did not significantly influence grain moisture, number of ears, or number of plants at harvest. There was no significant difference in earleaf-P concentration.
In Rt plots, manure application resulted in increased yield of 1.1 Mg ha-1, whereas in the PL system, manure application resulted in no grain yield increase. Tillage systems were not significantly different in grain-P uptake and grain-P concentration. Manure application significantly resulted in greater grain-P uptake, grain P concentration and grain yield. Differences in grain-P Uptake and concentration was in part due to the increase of soil-P with manure application.

Introduction

Importance of agriculture as non-point source of pollutants lies in the significant association between sediment or total phosphorus increases in natural water bodies and various measures of agricultural land use. Sediment is the most visible of agriculturally derived pollutants. Sediments not only contribute to costly dredging requirements at lake, ports and marinas but also carry sediment-bound pollutants, such as particulate P, to surface waters such as lakes. Researchers indicated that for water quality management adoption of conservation tillage reduces sediment and P loading to surface water. There is considerable concern regarding the contamination of surface waters from land applied manure phosphorus. The concern over phosphorus with respect to water quality is focused with stimulation of algae and other aquatic plant growth due to phosphorus eutrophication. For most water bodies, phosphorus is the key limiting nutrient for aquatic plant growth. Since, focusing only on total phosphorus for eutrophication control could result in no improvement in water quality, It is recommended that eutrophication control measures be directed toward controlling algal available P. Long term studies showed that reducing sediments will not necessarily lead to a reduction in phosphorus eutrophication.

In Minnesota, the problem of non-point source pollution in the Minnesota River Basin is confounded by the extensive hog, dairy and poultry farming in the area. Manure application to land is a regular management practice for crop production in the Minnesota River Basin. However to get the nutrient benefits from manure, it needs to be incorporated in the soil. The dilemma is: to what degree of soil cultivation is necessary to incorporate manure while maintaining enough residue to prevent excessive erosive losses of sediment and phosphorus. The objectives of the study are:

1. To evaluate the effects of moldboard vs. ridge tillage in combination with and without manure application on phosphorus and sediment loss in surface runoff both during frozen and unfrozen periods.

2. To evaluate the effects of manure residue on the yield and plant P-uptake.

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Materials and Methods

Tillage and manure interactions on sediment and phosphorus transport in surface runoff are being evaluated in the field at Morris, MN. Soil at the experimental site is a Barnes loam (fine-loamy mixed Udic Haploboroll, 12 % slope with south-eastern aspect). The initial soil test in 1992 for pH, Olson-P, Bray-P and ammonium acetate extractable K were 8.0, 17 ppm, 23 ppm and 155 ppm respectively.

The experimental design is a randomized complete block with split plots three replications (tillage main plots and manure the subplots). Twelve erosion plots, 22 m by 3 m (to accommodate four rows of corn) were marked and isolated using corrugated steel plates. At the end of each plot the runoff was routed with a trough made of a polyvinyl chloride (PVC) sheet (3 m by .3 m) and then channeled through a PVC pipe to a collecting system. The collecting system consists of three barrels of 210 L each. The first barrel collects very coarse sediments. The overflow from the first barrel is channelled to the second barrel. At the second barrel, 9 adjacent holes of 3.8 cm diameter were drilled near the rim of the barrel. One of the holes was connected to a PVC pipe of 3.8 cm diameter which channelled the excess runoff to the third barrel. This setup allowed 1/9 of the overflow from the second barrel to be collected in the third barrel. The collector was designed for a runoff depth of 3.5 cm (10 year 24-hour rainfall of 9.7 cm considering the curve number of 71). Corrugated roofing was placed over the PVC sheet at the end of the plots to avoid direct precipitation getting into the collecting system.

Tillage treatments include ridge tillage and moldboard plowing systems. Moldboard plowing practically allows complete soil incorporation of manure. In the moldboard system, fall moldboard plowing was followed in the spring by a field cultivation prior to planting. Ridge tillage represents an intermediate level of soil incorporation. Plant residue were concentrated between plant rows during winter and spring. Ridging was done on 24 June. Detailed cultural practices are presented in Table 1.

Manure treatments are with and without. Solid beef manure was applied once at the rate of 56 ton/ha in the spring of 1992. The manure contained approximately 161 kg TP/ha which contained 64 kg inorganic P/ha.

The runoff volume in each barrel was measured using a calibrated dip stick. After volume measurement, the runoff suspension was thoroughly stirred and samples were taken for sediment and phosphorus measurements. Sediments were measured by evaporating 200 mL of suspension followed by drying at 105 C. For each treatment sediment measurements were done in duplicate.

Total phosphorus was measured using perchloric acid digestion as described in EPA standard procedure (US EPA, 1981). For total P analysis 20 mL of suspension was pipetted while magnetically stirred to obtain a well mixed sample.

Dissolved molybdate reactive soluble phosphorus (DMRP) was measured from the solution after separation of solid phase from the runoff suspension. Total phosphorus and DMRP were determined with ascorbic acid method of Murphy and Riley (1962). Phase separation in DMRP analysis was achieved with centrifugation at 15,000 rpm (22,700 x g) for 5 minutes (10 minutes total time) at 25 °C.

Corn was planted on the twelve erosion plots at the seeding rate of 79,000 seeds/ha. Seeding was done up and down the slope. After planting, soil sample for determination of soil-P soluble in sodium bicarbonate (Olson-P) was taken at 0-5, 5-10, 10-15 cm depth. Olson-P analytical procedures was described in Olsen and Sommer (1982). Chemicals used for weed control are listed in Table 1. Grain and stover yield was measured. Corn ears, grain yield (after drying at 60 °C) and corn stands at harvest were estimated from rows of 15 m long. Stover yield was estimated by harvesting randomly 10 corn plants. The plants were chopped above the ground, shredded and a sample was taken for moisture determination. Determination of TP concentration in grain and stover involved digesting sample with perchloric acid (Olsen and Sommers, 1982) and measuring the intensity of blue molybdate as a coloring agent at wave length of 882 nm after ascorbic acid addition (Murphy and Riley, 1962).

Table 1. Cultural practices at the West Central Agricultural Experimental Station, Morris, MN.

Tillage

1992 No-till
Ridge till (July 21, 1992)
Spring moldboard (May 6, 1992)
1993 Fall Moldboard (Oct 27, 1992)
Spring Moldboard(Apr. 28, 1993)
Ridge till (July 6, 1993)
1994 Fall Moldboard (Oct. 27, 1993)
Spring Moldboard (Apr. 28, 1994)
Ridge tillage (June 24, 1994)

Cropping History

1991-Alfalfa
1992-Corn Pioneer-3751
-Corn Pioneer-3617
-Corn Pioneer-3921
1993-Corn Pioneer-3751
1994-Corn Pioneer-3751

Planting and Harvest Dates

Corn - was planted with a Hiniker 4 row planter with 76 cm row spacing.
In 1992, corn was replanted due to plant damage from gophers, using an Almaco Planter

	Planting/Replanting		
Crop	Date	Rate	Harvested
Corn	May 7,1992	79,072 seeds/ha	Oct. 23, 1992 Corn was chopped, and left on field
	May 29, 1992	98,840 seeds/ha	
	June 15, 1992	148,260 seeds/ha	
	April 29, 1993	79,319 seeds/ha	Oct. 13, 1993 Two rows of 30 feet long each.
	May 5, 1994	79,000 seeds/ha	Oct. 11, 1994 Two rows of 25 feet long each.

1992 Applied-Manure Analysis

Manure		Date	NH4	NO3	Mineral	Organic	Total N	P	K	DMRP	Solids Total	Volatile	fixed
source	Rate	Applied	%										
Beef	56Mg/ha	May 6/92	.215	.005	.220	.64	.860	.289	.668	0.114	29.12	84	16

Rate of applied and available N, P_2O_5 and K_2O and DMRP

Manure		Date	NH4	NO3	Mineral	Organic	available N	Total N	P205	K20	DMRP
source	Rate	Applied	kg/ha								
Beef	56 Mg/ha	May 6/92	120.4	2.8	123.2	358.4	212.8	481.6	370.7	374.1	63.7

It is assumed that 25 % of organic N and all of mineral N is available in the year of application.

1993

No manure is applied.
Non-manure plots received a topdress application of 50.4 kg N/ha (NH_4NO_3) in 7/6/93.

1994

No manure was applied
The manured and non-manured moldboard plowed plots received 111 and 134 kg N/ha, respectively (6/6/94).
The manured and non-manured ridge tilled plots received 134 and 157 kg N/ha, respectively (6/6/94).

Soil

Barnes loam (fine-loamy mixed Udic Haploborolls, 12 % slope with southern aspect. Soil is high in organic matter, and pH is 8.0. Initial soil test on Olson-P, Bray-P and K
are 17, 23 and 155 mg/kg respectively.

Pest Control

1992
Lorsban 15G , 11.1 kg/ha (May 7, 1992)
Ranger 1.1 kg/ha+2,4-D ester 0.6 kg/ha+Banvel 0.3 lb/A+Lasso EC 4.5 kg/ha+Bladex DF (90%) 2.5 kg/ha (5/8/92)
Ranger 1.1 kg/ha only on no till plot to kill grasses and alfalfa (5/22/92)

1993
Round-up, 2.5 L/ha on ridge till for controlling volunteer alfalfa (4/21/93)
Counter 15 G 11.1 kg/ha over the furrow at seeding (4/29/93)
Lasso 4.5 kg/ha + Bladex 2.5 kg/ha to control volunteer alfalfa + Separate application of Round-up 2.47 L/ha (4/30/93)
Atrazine 0.84 lb/A for post emergence quack grass control (5/20/93)

1994
Round-up, 3.5 L/ha on ridge till for controlling quackgrass (4/22/94)
Force 15 G, 11 kg/ha for insect control (5 May, 1994)
Lasso 3.4 kg/ha + Bladex 2.5 kg/ha + Round-up (2.3 kg/ha) as tank mix for preemergent herbicide (May 6, 1994).
Atrazine 2.2 kg/ha + Buctril 1.2 L/ha and vegetable oil as tank mix for post-emergent weed control (June 1, 1994)

Results and Discussion-1994

I. Surface Runoff, Erosion and Phosphorus Loss.

Ridge Till (RT) vs. Moldboard Plow (PL)

The annual runoff was not different between RT or PL system (Table 2). For the RT system, snowmelt-runoff was the predominant source of the annual runoff; On the contrary, for the PL system, rainfall-runoff was the predominant source of the annual runoff (Figure 1). Greater snow runoff in RT system was due to greater snow depth trapped by standing corn residue and lack of surface depressional storage in RT system. Water depth equivalence of snow in RT and PL systems was 9.9 and 5.9 cm, respectively.

Contribution of snow sediment loss to the annual sediment loss was negligible (Figure 1). Therefore the annual sediment loss was mainly from rainfall-runoff. The PL systems resulted in 11.8 times higher sediment loss compared to RT system (Table 2). The rainfall-runoff sediment loss from two sequential rain events in early spring contributed the most to the annual sediment loss (Figure 1). At these events, no crop was grown, and surface residue cover was low in the PL system. In the RT system, the presence of residue cover increased infiltration, and protected the soil against soil detachment and thus reduced soil erosion significantly. Although a heavier rainfall (10.3 cm 24 hour rainfall) occurs in July 5, only a slight increase of sediment loss was observed both in RT and PL system. At this stage, corn canopy cover reduced rainfall impacts on soil erosion. In this particular event, the RT system resulted in significantly lower sediment loss compared to the PL system.

Total phoshorus (TP) in runoff suspension consists of sediment associated phosphorus, soluble organic phosphorus and soluble inorganic phosphorus. The soluble inorganic phosphorus that is usually detected with ammonium molybdate is referred to as dissolved molybdate reactive phosphorus (DMRP). The difference of TP and DMRP is called particulate phosphorus (PP). The DMRP is for the most part bioavailable for algal growth. Whereas the PP, which consisted of the sediment associated phosphorus and organic material in runoff, may constitute a long term source of potentially bioavailable in lakes (Sharpley et al., 1991).

Annual total phosphorus (TP) loss was higher in PL system compared to RT systems. The annual TP loss in the PL systems was 1.9 times higher than TP from RT systems (Table 2). For the RT system, TP from snowmelt-runoff was the predominant source of TP loss. On the contrary, for the PL system, erosion was the predominant source of TP loss, and the annual TP loss was solely due to the rain occurred in early spring (Figure 2).

Annual particulate-P (PP) was significantly influenced by tillage (Table 2). Particulate-P from PL plots was 3.9 times higher than that of the RT plots which was mainly due to the two rainfall events in early spring (Figure 2). In the RT system, snowmelt-runoff was the predominant source of PP loss, whereas in the PL plots, rainfall-runoff was the predominant source of PP loss. The significance of PP loss from snowmelt in RT system were over shadowed by two early spring rainfall-runoff events in the PL system (Figure 2).

Tillage significantly influence annual dissolved molybdate reactive P (DMRP) loss. The RT systems resulted in 3.7 times higher DMRP loss compared to PL system (Table 2). In RT system, 54 percent of TP was

DMRP. In PL system, 8 percent of TP was DMRP. This indicated that DMRP in RT system, which is mainly from snowmelt, was a significant portion of annual TP. For the RT system, the majority of the annual DMRP loss occurred during the snowmelt-runoff whereas for PL system, DMRP loss was similar during the snowmelt-runoff and rainfall-runoff events (Figure 2). This comparison showed that the DMRP from rainfall was not significant compared to snowmelts, regardless of the major rainfall-runoff and erosion in early spring.

No Manure vs. Manure

Manure application did not significantly influence the annual runoff, PP, DMRP and TP loss (Table 2). Manure application did not influence PP or TP loss in snowmelt-runoff or rainfall-runoff (Figure 4). The significance of manure application was observed mainly on individual rainfall-runoff events. Differences of snowmelt-runoff were overshadowed by two rainfall runoff events in non-manured plots (Figure 3). Manure application significantly reduced rainfall-runoff and sediment loss, although did not significantly reduced the annual sediment loss. However, during major runoff events, manured plots resulted significantly less erosion (Figure 3).

II. Corn Yield

In 1994 rainfall was better distributed during the growing season. Tillage had no significant influence on grain yield, number of ears, and number of plants at harvest. The RT systems resulted in a significantly higher grain moisture content. Manure application significantly influenced grain yield although it did not significantly influence grain moisture, number of ears, or number of plants at harvest. During the growing season, it was qualitatively observed that manured plots resulted in greater plant height. This observation encouraged an earleaf sampling for TP determination. However, there was no significant difference in earleaf-P concentration (Table 3).

There was a significant tillage by manure interaction on grain yield (Table 3). In Rt plots, manure application resulted in increased yield of 1.1 Mg ha-1, whereas in the PL system, manure application resulted in no grain yield increase. The tillage by manure interaction was also significant for stover yield. In the RT system, greater grain yield with manure application resulted in the 0.7 mg ha^{-1} reduction of stover yield whereas in the PL system, lower grain yield with manure application resulted in 0.5 Mg ha^{-1} increase of stover yield. Differences in grain yield due to manure application was in part due to soil-P. In both the RT and PL systems, manure application resulted in significantly soil-P test. Soil was sampled after planting, taken between plant rows in 0-5, 5-10 and 10-15 cm deep. The average soil test is presented in Table 4.

Phosphorus Uptake in Grain and Stover

Tillage systems were not significantly different in grain-P uptake and grain-P concentration (Table 3). Lack of significance in grain yield and grain P concentration due to tillage resulted in insignificant differences in grain P uptake. Stover-P uptake and stover P concentration, however, was significantly influenced by tillage, although stover yield was not influenced by tillage. Therefore greater stover-P uptake was mainly due to greater stover-P concentration in the RT system. Greater stover-P concentration was in part due to soil-P test. Tillage system significantly influenced soil test. Soil test in RT plots was 24.5 mg P kg^{-1} compare to 12.7 mg P kg^{-1} in PL plots.

Manure application significantly resulted in greater grain-P uptake, grain P concentration and grain yield. Both greater yield and greater P concentration in grain resulted in greater P uptake in manured plots (Table 3). However, there was no manure influence on stover-P uptake and stover P concentration. There was no tillage by manure interaction for P uptake in grain and stover.

Table 2. The effects of tillage and manure application on the geometric means† of snowmelt, rainfall, and the annual losses of runoff, sediment, and phosphorus (2/22/94 (spring thaw) to 8/24/94).

	RIDGE TILL			MOLDBOARD			Average		P>F Values		
	No Man	Man	Avg	No Man	Man	Avg	No Man	Man	Tillage (T)	Manure (M)	T by M
Snowmelt Runoff											
Runoff (mm)	23.9	32.9	28.0	10.1	17.8	13.4	15.5	24.2	0.310	0.561	0.868
Sediment (kg/ha)	43.6	46.5	45.0	22.7	36.6	28.4	31.4	40.7	0.091	0.686	0.759
Total-P (g/ha)	159	284	212	30	60	43	120	142	0.044	0.408	0.954
PP (g/ha)	69.6	62.2	71.6	13.8	20.7	17.2	30.9	37.2	0.094	0.323	0.528
DMRP (g/ha)	89	222	141	17	39	26	39	93	0.042	0.250	0.954
Rain-Runoff											
Runoff (mm)	8.5	7.6	8.0	30.1	21.8	25.6	16.0	12.8	0.008	0.061	0.294
Sediment (kg/ha)	107	90	98	2512	1238	1763	518	334	0.002	0.095	0.256
Total-P (g/ha)	99	117	108	818	564	680	285	260	0.016	0.709	0.355
PP (g/ha)	62	65	64	789	538	652	252	220	0.008	0.538	0.473
DMRP (g/ha)	36.7	51.7	43.6	29.1	25.8	27.4	32.7	36.5	0.286	0.648	0.359
Annual Runoff											
Runoff (mm)	39.4	42.2	40.8	41.2	39.9	40.7	40.3	41.1	0.988	0.970	0.919
Sediment (kg/ha)	162	142	152	2536	1275	1798	640	425	0.004	0.233	0.391
Total-P (g/ha)	307	458	375	850	627	730	511	536	0.105	0.915	0.450
PP (g/ha)	165	169	172	804	561	675	429	398	0.018	0.415	0.686
DMRP (g/ha)	142	290	203	47	65	55	82	138	0.065	0.345	0.715

† Logarithmic transformation on the data is done to meet the normal distribution in statistical analysis.

Table 3. The effects of tillage and manure application on corn yield and phosphorus concentration and uptake at the West Central Experiment Station, Morris, MN, 1994.

	RIDGE TILL			MOLDBOARD			Average		P>F Values		
	No Man	Man	Avg	No Man	Man	Avg	No Man	Man	Tillage (T)	Manure (M)	T by M
Yield											
Grain (Mg/ha)	9.2	10.2	9.7	9.5	9.3	9.4	9.3	9.8	0.217	0.061	0.017
Ears (1000/ha)	68.0	72.3	70.2	74.6	70.6	72.6	71.3	71.5	0.271	0.956	0.164
Plants (1000/ha)	67.2	70.9	69.0	72.3	70.6	71.5	69.8	70.8	0.432	0.802	0.508
Grain Moisture (%)	24.9	24.2	24.6	21.2	19.6	20.4	23.1	21.9	0.038	0.718	0.518
Stover (Mg/ha)	7.0	6.3	6.7	6.5	7.0	6.7	6.7	6.6	0.481	0.606	0.019
P- Concentration and Uptake											
Earleaf Conc. (g/kg)	0.88	1.00	0.94	0.99	1.10	1.04	0.93	1.05	0.610	0.357	0.937
Grain-P Uptake (kg/ha)	18.6	24.7	21.7	19.0	22.3	20.6	18.8	23.5	0.395	0.019	0.307
Grain-P Conc. (g/kg)	2.02	2.42	2.22	1.98	2.39	2.19	2.00	2.44	0.737	0.017	0.939
Stover-P Uptake (kg/ha)	2.98	2.28	2.63	2.02	2.38	2.17	2.50	2.30	0.040	0.816	0.566
Stover-P Conc. (g/kg)	0.42	0.37	0.39	0.31	0.34	0.32	0.36	0.35	0.045	0.951	0.742

Table 4. The effects of manure application on soil Olson-P test (May 3, 1994), two years after manure application (May 6, 1992), at the West Central Agric. Exp. Sta. Morris, MN.

Year	Tillage	No Manure mg kg^{-1}	Manure mg kg^{-1}
1994	RT	18.3	30.8
	MB	7.0	16.5

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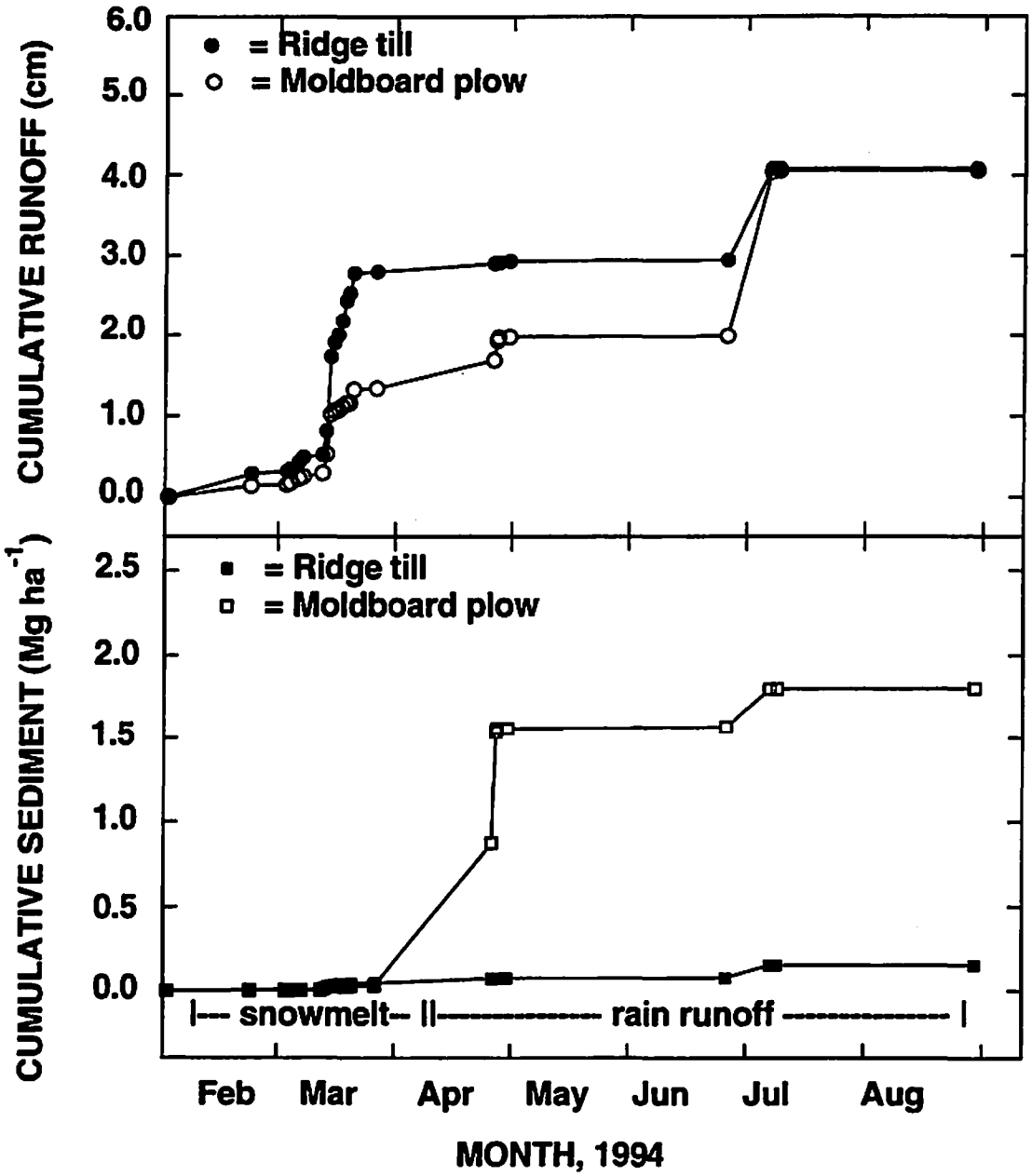

Figure 1. Tillage effects on runoff and sediment loss

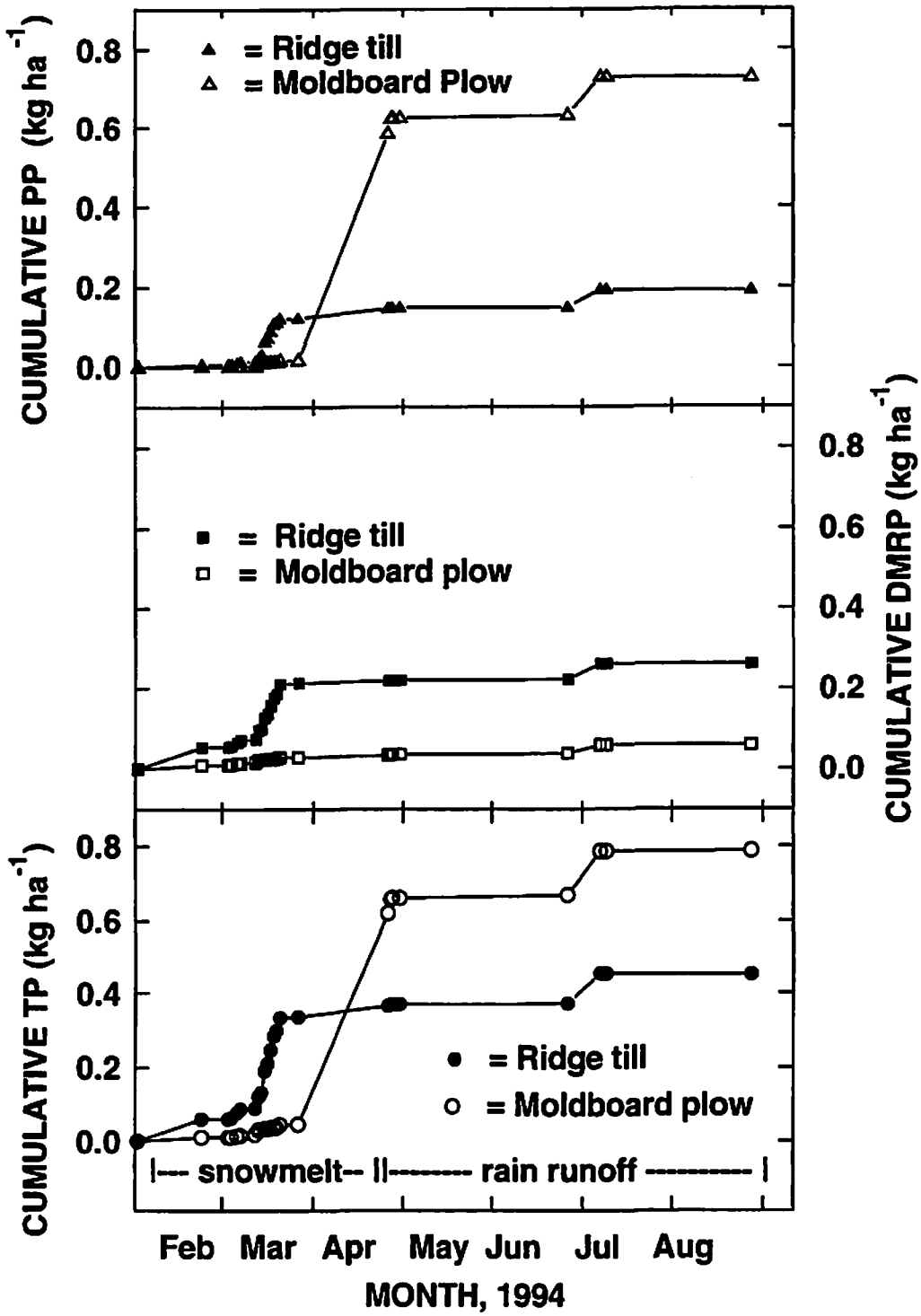

Figure 2. Tillage effects on PP, DMRP and TP

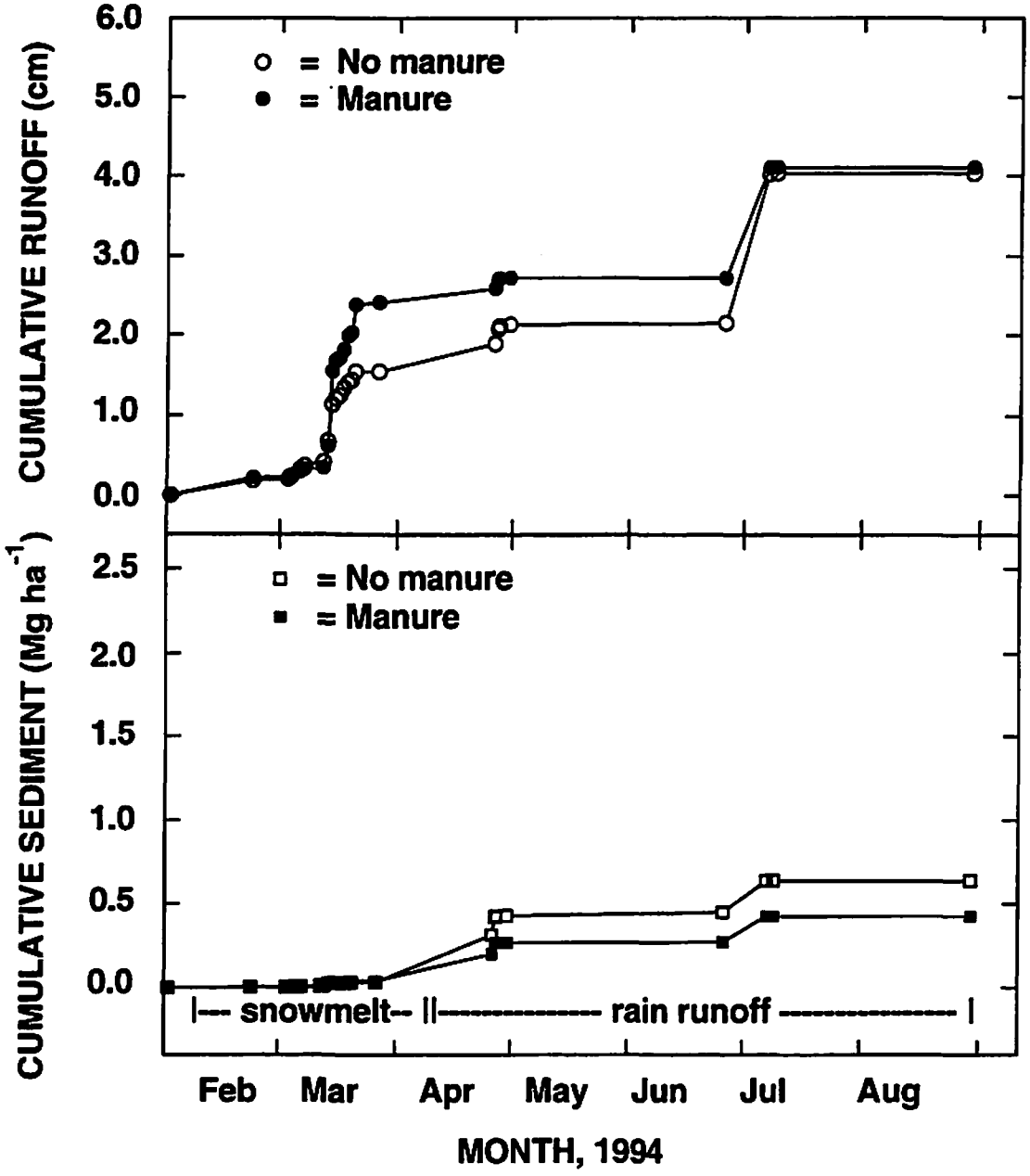

Figure 3. Manure effects on runoff and sediment

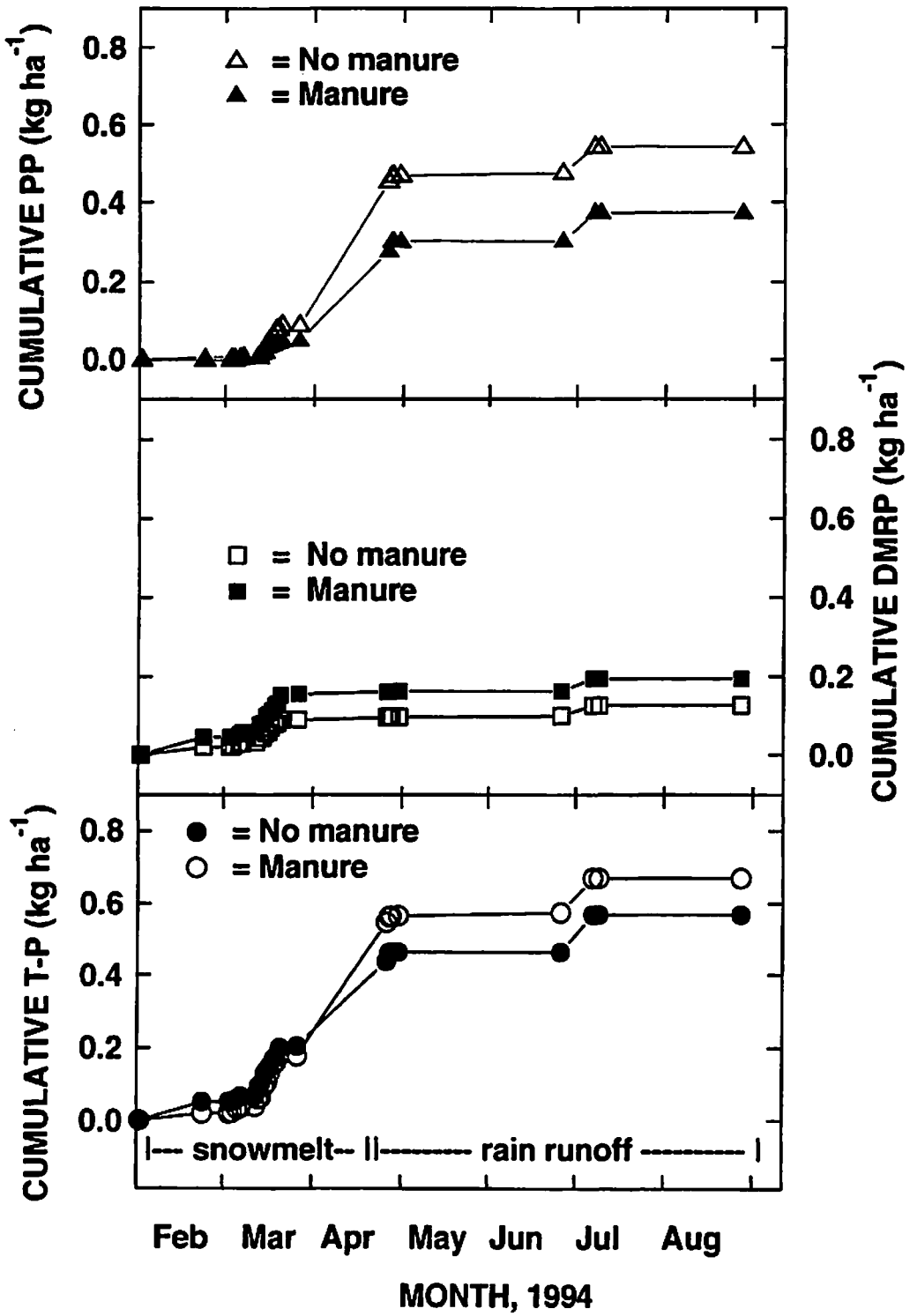

Figure 4. Manure effects on PP, DMRP and TP

CARROT RESPONSE TO FERTILIZER ON AN IRRIGATED SANDY SOIL[1]

Carl Rosen, Norman Krause, Mel Wiens, Gary McVey, Dave Birong, and Shelly Johnson[2]

Abstract: Two fertilizer studies were conducted at Staples to refine fertilizer recommendations for carrot production on sandy soils. Soil K was medium, P was high, B was low, and S was low. Nitrate-N before planting was less than 10 lb/A in the top two feet. Potassium applications of 60 to 120 lb K_2O/A increased carrot diameter, but did not significantly affect total yield. Nitrogen application did not affect total yield, but increasing N rate increased carrot diameter. Carrot dry matter percentage was not affected by K or N fertilizer. Final stand count decreased with increasing N and K fertilizer rates, suggesting that disk incorporation of fertilizer prior to planting is not adequate for fertilizer incorporation. Application of B, P and S fertilizers did not consistently affect carrot yield or quality. Nutrient concentrations in leaves during the growing season and in tops and roots at harvest are presented.

Carrot production in northern Minnesota has increased substantially in the past five years. In part, this increased production has occurred in response to an increased demand by a processing plant for dehydrated carrots. While dehydration has spurred interest in processing carrots, there is also interest in growing carrots for other types of processing, as well as for fresh market. The soils of central Minnesota tend to be coarse-textured and require irrigation for production of specialty crops such as carrot. The main advantage of these soils is that they tend to warm up faster in the spring, which enables earlier planting and an earlier maturing crop. Growing carrots on these soils would provide a longer season for processing and would also allow carrots to be marketed earlier. There has been very little research that defines the nutrient requirements of carrots grown on coarse-textured soils. Too little fertilizer applied will negatively affect yields, while excessive rates applied can potentially lead to poor carrot quality and environmental degradation. One of the fundamental needs for successful carrot production in central Minnesota is to determine nutrient input requirements for a high quality product. The objectives of this research were to: 1) Determine potassium (K) requirements of carrots on low to medium testing K soils. 2) Characterize carrot response to nitrogen (N) application in terms of quality and dry matter production. 3) Determine boron (B), phosphorus (P), and sulfur (S) needs for carrot production.

Procedures

Two carrot fertility experiments were conducted at Staples during the 1994 growing season. The soil is a Verndale sandy loam with an organic matter content of 2 to 3%. The first study evaluated carrot response to K fertilizer. A second study evaluated carrot response to N, P, S and B fertilizer. For the K experiment, the previous crop was corn and selected soil chemical properties were as follows: pH, 7.1; Bray P, 43 ppm; K, 61 ppm. For the N, P, B and S experiment, the previous crop was small grains and selected soil chemical properties (0-6") were as follows: pH, 6.9; Bray P, 52 ppm; K, 82 ppm; S, 2 ppm; B, 0.3 ppm. For the N,P,B,S study, extractable nitrate-N levels in the 0-1 and 1-2 ft depths were 7.8 and 2.3 lbs/A, respectively.

For the two experiments, the following fertilizer treatments were evaluated:

K_2O Experiment
Fertilizer Treatment

#	N	P_2O_5	K_2O
	----- lb/A -----		
1.	120	50	0
2.	120	50	60
3.	120	50	120
4.	120	50	180
5.	120	50	240

N, P_2O_5, B & S Experiment
Fertilizer Treatment

#	N	P_2O_5	K_2O	B	S
	---------- lb/A ----------				
1.	0	50	150	0	0
2.	60	50	150	0	0
3.	120	50	150	0	0
4.	180	50	150	0	0
5.	240	50	150	0	0
6.	120	0	150	0	0
7.	120	25	150	0	0
8.	120	50	150	2	0
9.	120	50	150	0	30
10.	120	50	150	2	30

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For the K experiment, half the N (urea) and all the P (0-46-0) and K (0-0-60) fertilizer were broadcast and incorporated by disking on May 3, 1994. The remainder of the N was sidedressed on June 27. For the N, P, B and S experiment, all phosphorus (0-46-0), potassium (0-0-60), boron (solubor) and sulfur (ammonium sulfate) applications were broadcast and incorporated by disking on May 3, 1994. Half the nitrogen (urea) was applied on May 3 and the remainder was sidedressed on June 27. Some urea was eliminated from the sulfur treatment to compensate for the N added with ammonium sulfate. Carrots were planted on May 4, 1994. Each plot consisted of 8 rows 22" apart. The population was originally set to be at 15 plants per foot; however, final plant population was measured at 4 to 7 plants per foot. The planting depth was 0.75". The variety used was 'Legend'. Each treatment was replicated four times. Recently matured leaf samples were collected on July 8 for nutrient analyses. For both experiments, two 10 foot sections of row were harvested from each plot (August 25 for N, P, B and S; September 1 for K). Top and root weight were recorded and subsamples were taken for dry matter determination and nutrient analyses. Soil samples were collected from the 0-1 and 1-2 ft depths in N treatments following harvest to determine residual soil nitrate.

Results

I. Potassium study

Yield and stand: Potassium fertilizer tended to increase yield of the larger diameter carrots (Table 1). Total yield was not significantly affected by K fertilizer application although there was a trend for increasing yield with 60 to 120 lb K_2O/A. Final stand count tended to decrease with increasing K application, suggesting that increased salt from the fertilizer damaged seed emergence. Disking of the fertilizer may not be adequate incorporation. Root dry matter percentage was not significantly affected by K fertilizer.

Tissue nutrient concentrations: Increasing K fertilizer increased K concentrations in leaves sampled in July (Table 2). Leaf concentrations N and Mg tended to decrease with K fertilizer application. At harvest, concentrations of K in root and tops increased with increasing K application (Tables 3 and 4). Approximately 0.37 lb/cwt is removed in the carrot root. A typical carrot harvest of 400 cwt/A would contain about 150 lb K/A and in the roots and 40 lb K/A in the tops. To convert to K_2O, these values should be multiplied by 1.2.

II. N, P, B and S study

Yield and stand: Increasing N fertilizer increased carrot size but had no effect on total yield (Table 5). As in the K study, fertilizer application tended to decrease final stand count, suggesting that disk incorporation is not adequate. Because of decreasing stand count with increasing N fertilizer, it is not possible to determine whether increased carrot size was due to N fertilizer or lower plant populations. Application of P, B, and S either had no effect or inconsistent effect on yield. Root dry matter percentage was also not consistently affected by fertilizer treatment.

Tissue nutrient concentrations: Increasing rates of N, P, B and S fertilizer had minimal effects on concentrations of these nutrients in carrot leaves sampled in July (Table 6). At harvest, however, concentrations N, P and S increased with corresponding increases in fertilizer application (Table 7). Increasing N rate increased N concentrations in carrot roots (Table 8). Application of P and K fertilizer had no effect on P and K concentrations in carrot roots. Boron at 2 lb B/A had no effect on B concentrations of tops or roots at harvest. A typical carrot harvest of 400 cwt/A would contain about 70 lb N/A in the roots and 40 lb N/A in the tops.

Table 1. Effect of potash fertility treatments on carrot yield and quality; harvested September 1, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	Forks, Culls	--- Root Diameter --- <⅞"	⅞ to 1¾"	>1¾"	Total Yield	Dry Matter Root	--- Dry Matter --- Roots	Tops	Total	Carrot population
	---- lb/A ----			---------- cwt/A ----------					%	--- Tons/Acre ---			plants/ft
1.	120	50	0	43.9	14.5	241.2	80.0	379.6	12.6	2.4	1.6	4.0	7.54
2.	120	50	60	48.1	11.2	219.8	132.4	411.5	13.2	2.7	1.2	3.9	6.63
3.	120	50	120	44.9	13.8	214.0	155.0	427.7	13.1	2.8	1.2	4.0	6.94
4.	120	50	180	58.0	13.7	228.4	129.8	429.9	12.5	2.7	1.2	3.9	6.74
5.	120	50	240	43.1	12.0	216.2	154.6	425.9	12.7	2.7	1.2	3.9	6.13
Significance				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)				--	--	--	--	--	--	--	--	--	--
Contrasts													
Lin Rate K				NS	NS	NS	++	NS	NS	NS	NS	NS	++
Quad Rate K				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant; ++ = significant at the 10% level.

Table 2. Effect of potash fertility treatments on the nutrient concentrations of carrot leaves; sampled July 8, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	Nutrient N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	---- lb/A ----			---------- % ----------					---------- ppm ----------				
1.	120	50	0	3.63	0.49	3.03	1.35	0.34	196	41	7	31	28
2.	120	50	60	3.46	0.50	3.58	1.27	0.31	190	40	7	30	28
3.	120	50	120	3.43	0.51	3.57	1.28	0.30	180	41	7	31	30
4.	120	50	180	3.43	0.52	3.75	1.30	0.30	172	39	7	32	28
5.	120	50	240	3.34	0.51	3.85	1.31	0.30	190	39	7	30	29
Significance				NS	NS	**	NS	*	NS	NS	NS	NS	NS
BLSD (5%)				--	--	0.38	--	0.03	--	--	--	--	--
Contrasts													
Lin Rate K				*	NS	**	NS	*	NS	NS	NS	NS	NS
Quad Rate K				NS	NS	NS	NS	++	NS	NS	NS	NS	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 3. Effect of potash fertility treatments on the nutrient concentrations of carrot tops; sampled September 1, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	Nutrient N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	---- lb/A ----			---------- % ----------					---------- ppm ----------				
1.	120	50	0	1.85	0.29	1.23	2.66	0.53	1266	129	5	21	28
2.	120	50	60	1.69	0.31	1.53	3.00	0.57	929	107	5	20	33
3.	120	50	120	1.90	0.30	1.70	3.23	0.55	867	106	5	20	31
4.	120	50	180	1.88	0.27	1.83	2.88	0.50	957	106	5	19	27
5.	120	50	240	1.71	0.29	2.01	2.76	0.46	1244	129	5	22	30
Significance				NS	NS	NS	++	NS	NS	NS	NS	NS	++
BLSD (5%)				--	--	--	0.48	--	--	--	--	--	4
Contrasts													
Lin Rate K				NS	NS	*	NS	++	NS	NS	NS	NS	NS
Quad Rate K				NS	NS	NS	*	NS	++	NS	NS	NS	NS

NS = Not significant; *, ++ = significant at the 5% and 10% level, respectively.

Table 4. Effect of potash fertility treatments on the nutrient concentrations of carrot roots; sampled September 1, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	Nutrient N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	---- lb/A ----			---------- % ----------					---------- ppm ----------				
1.	120	50	0	1.44	0.43	2.06	0.39	0.15	37	11	4	19	20
2.	120	50	60	1.29	0.40	2.31	0.39	0.15	57	10	4	17	19
3.	120	50	120	1.37	0.44	2.66	0.40	0.14	36	10	5	19	19
4.	120	50	180	1.35	0.42	2.72	0.41	0.15	40	11	4	18	19
5.	120	50	240	1.27	0.40	2.68	0.40	0.13	35	10	4	18	19
Significance				NS	NS	*	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)				--	--	0.55	--	--	--	--	--	--	--
Contrasts													
Lin Rate K				NS	NS	**	NS	NS	NS	NS	NS	NS	NS
Quad Rate K				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant; **, * = significant at the 1% and 5% level, respectively.

Table 5. Effect of various fertility treatments on carrot yield and quality; harvested August 25, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	Forks, Culls	Root Diameter <1⅝"	1⅝ to 2½"	>2½"	Total Yield	Dry Matter Root	Dry Matter Roots	Tops	Total	Carrot population
	--- lb/A ---			---------- cwt/A ----------					%	--- Tons/Acre ---			plants/ft
1.	0	50	150	29.2	135.7	176.0	0.0	340.8	12.1	2.1	0.8	2.9	6.28
2.	60	50	150	13.9	113.1	181.5	5.7	314.3	11.8	1.8	0.8	2.6	4.79
3.	120	50	150	34.2	94.6	203.0	2.2	334.0	11.5	1.9	0.9	2.8	5.11
4.	180	50	150	22.9	62.2	201.6	14.5	301.2	12.5	1.9	0.8	2.7	3.89
5.	240	50	150	27.6	90.6	225.3	8.4	351.9	12.2	2.2	1.0	3.2	4.80
6.	120	0	150	24.6	97.1	195.0	8.9	325.5	11.7	1.9	0.9	2.8	4.94
7.	120	25	150	27.3	89.0	234.7	14.2	365.2	12.0	2.2	1.1	3.3	4.65
8.	120	50	150 +B	33.0	95.9	213.6	9.1	351.7	12.5	2.2	1.0	3.2	4.85
9.	120	50	150 +S	39.6	90.6	242.2	8.7	381.1	12.1	2.3	1.2	3.5	5.36
10.	120	50	150 +B,S	17.9	103.2	203.1	8.6	332.8	13.1	2.1	0.9	3.0	4.76
Significance				++	NS	NS	NS	NS	NS	++	**	*	++
BLSD (5%)				18.9	--	--	--	--	--	0.4	0.2	0.5	1.47
Contrasts													
Lin Rate N (1,2,3,4,5)				NS	**	*	NS	NS	NS	NS	++	NS	**
Quad Rate N (1,2,3,4,5)				NS	NS	NS	NS	NS	NS	*	NS	NS	*
Lin Rate P (6,7,3)				++	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	NS	NS	++	NS	*	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
0 vs Boron (3,8)				NS	NS	NS	NS	NS	NS	++	NS	NS	NS
0 vs Sulfur (3,9)				NS	NS	NS	NS	++	NS	*	*	**	NS
0 vs B+S (3,10)				*	NS	NS	NS	NS	*	NS	NS	NS	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 6. Effect of various fertility treatments on nutrient concentrations of carrot leaves; sampled July 8, 1994.

Fertilizer Treatment				Nutrient										
#	N	P_2O_5	K_2O	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	--- lb/A ---			%						ppm				
1.	0	50	150	3.08	0.49	3.95	1.44	0.26	--	205	43	6	37	31
2.	60	50	150	3.21	0.46	3.81	1.38	0.25	--	195	49	5	36	27
3.	120	50	150	3.35	0.49	3.76	1.36	0.26	0.34	189	45	5	37	28
4.	180	50	150	3.23	0.47	4.04	1.33	0.25	--	185	45	5	38	29
5.	240	50	150	3.21	0.48	3.95	1.40	0.25	--	181	46	5	37	28
6.	120	0	150	3.28	0.48	3.96	1.32	0.24	--	173	44	5	38	28
7.	120	25	150	3.42	0.48	3.67	1.39	0.28	--	209	46	5	36	28
8.	120	50	150 +B	3.32	0.47	3.82	1.39	0.27	--	200	44	4	37	30
9.	120	50	150 +S	3.31	0.46	3.80	1.36	0.25	0.36	189	44	5	35	27
10.	120	50	150 +B,S	3.25	0.49	3.87	1.28	0.24	0.36	202	45	5	39	31
Significance				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
BLSD (5%)				--	--	--	--	--	--	--	--	--	--	3
Contrasts														
Lin Rate N (1,2,3,4,5)				NS	NS	NS	NS	NS	--	++	NS	NS	NS	++
Quad Rate N (1,2,3,4,5)				++	NS	NS	NS	NS	--	NS	NS	NS	NS	++
Lin Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	*	--	++	NS	NS	NS	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs Boron (3,8)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs Sulfur (3,9)				NS	NS	NS	NS	NS	++	NS	NS	NS	NS	NS
0 vs B+S (3,10)				NS	NS	NS	NS	NS	++	NS	NS	NS	NS	++

NS = Not significant; *, ++ = significant at the 5% and 10% level, respectively.

Table 7. Effect of various fertility treatments on nutrient concentrations of carrot tops; sampled August 25, 1994.

Fertilizer Treatment				Nutrient										
#	N	P_2O_5	K_2O	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	--- lb/A ---			%						ppm				
1.	0	50	150	1.64	0.29	2.91	3.59	0.37	--	811	106	5	27	37
2.	60	50	150	1.80	0.24	2.65	3.25	0.42	--	687	101	4	26	33
3.	120	50	150	1.98	0.27	2.66	3.20	0.44	0.26	655	90	5	22	33
4.	180	50	150	2.16	0.26	2.91	3.42	0.43	--	622	99	4	25	32
5.	240	50	150	2.07	0.25	2.85	3.28	0.38	--	595	105	4	25	32
6.	120	0	150	1.97	0.26	2.52	3.31	0.43	--	609	96	5	24	31
7.	120	25	150	2.04	0.27	2.52	3.30	0.45	--	602	89	5	21	32
8.	120	50	150 +B	2.03	0.28	2.61	3.56	0.47	--	540	92	4	26	36
9.	120	50	150 +S	1.98	0.28	2.48	2.94	0.45	0.37	597	84	5	25	31
10.	120	50	150 +B,S	1.94	0.23	2.55	3.26	0.42	0.39	750	109	4	27	34
Significance				*	NS	NS	NS	*	**	NS	NS	NS	NS	NS
BLSD (5%)				0.29	--	--	--	0.07	0.06	--	--	--	--	--
Contrasts														
Lin Rate N (1,2,3,4,5)				**	NS	NS	NS	NS	--	*	NS	NS	NS	*
Quad Rate N (1,2,3,4,5)				NS	NS	NS	NS	**	--	NS	NS	NS	NS	NS
Lin Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	--	NS	NS	++	NS	NS
0 vs Boron (3,8)				NS	NS	NS	NS	NS	--	NS	NS	*	NS	NS
0 vs Sulfur (3,9)				NS	NS	NS	NS	NS	**	NS	NS	++	NS	NS
0 vs B+S (3,10)				NS	++	NS	NS	NS	**	NS	++	*	++	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 8. Effect of various fertility treatments on nutrient concentrations of carrot roots; sampled August 25, 1994.

Fertilizer Treatment				Nutrient										
#	N	P_2O_5	K_2O	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	---	lb/A	---	%						ppm				
1.	0	50	150	1.19	0.42	3.21	0.41	0.13	--	56	15	4	23	20
2.	60	50	150	1.52	0.45	3.45	0.44	0.14	--	43	15	4	25	21
3.	120	50	150	1.48	0.46	3.27	0.44	0.14	0.13	61	15	4	22	20
4.	180	50	150	1.48	0.42	3.11	0.42	0.14	--	53	15	3	25	20
5.	240	50	150	1.61	0.45	3.21	0.42	0.14	--	57	16	4	26	19
6.	120	0	150	1.50	0.44	3.14	0.43	0.15	--	57	16	4	22	21
7.	120	25	150	1.48	0.44	2.95	0.41	0.14	--	59	13	4	21	20
8.	120	50	150 +B	1.37	0.42	2.95	0.38	0.13	--	45	13	3	21	20
9.	120	50	150 +S	1.45	0.42	2.89	0.40	0.14	0.14	43	14	3	23	19
10.	120	50	150 +B,S	1.42	0.41	3.18	0.41	0.14	0.15	49	13	3	22	21
Significance				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)				--	--	--	--	--	--	--	--	--	--	--
Contrasts														
Lin Rate N (1,2,3,4,5)				**	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Quad Rate N (1,2,3,4,5)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Lin Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	++	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	*	NS	NS	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs Boron (3,8)				NS	NS	NS	*	NS	--	++	NS	NS	NS	NS
0 vs Sulfur (3,9)				NS	NS	++	NS	NS	NS	++	NS	NS	NS	NS
0 vs B+S (3,10)				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 9. Effect of nitrogen treatment on residual soil nitrate-N (lbs/A) in the top two feet after carrot harvest.

Fertilizer Treatment				Sample depth (inches)		
#	N	P_2O_5	K_2O	0 - 12	12 - 24	Total
	---	lb/A	---	lbs nitrate-N/A		
1.	0	50	150	13.67	14.24	27.91
2.	60	50	150	18.16	51.96	70.12
3.	120	50	150	15.23	20.06	35.29
4.	180	50	150	21.84	49.07	70.91
5.	240	50	150	25.46	49.54	75.00
Significance				NS	NS	NS
BLSD (5%)				--	--	--
Contrasts						
Lin Rate N (1,2,3,4,5)				++	NS	NS
Quad Rate N (1,2,3,4,5)				NS	NS	NS

NS = Not significant; ++ = significant at the 10% level.

THE EFFECT OF INOCULATION, N RATE, AND SEED TREATMENT ON RED KIDNEY BEAN (*Phaseolus vulgaris*) YIELDS, STAPLES, MN, 1994[1]

J.F. Moncrief, C.J. Rosen, M.J. Wiens, B. Sheets, B.J. Johnson, and P.M. Bongard[2]

Abstract: Four N rates (27, 77, 127, and 177 pounds per acre) applied as broadcast urea at 3-4 trifoliates, two inoculation treatments (with and without Rhizobium) and two seed treatments (with and without streptomycin) were evaluated on red kidney beans (*Phaseolus vulgaris*) grown under irrigation on a sandy loam soil in north central MN. Yields were in the 3,000 pound per acre range. Bean yields responded over the range in applied N (392 pounds per acre). Inoculation with Rhizobium resulted in a 59 pound per acre yield response. Main effects of seed treatment with streptomycin were not significant although there were significant interactions with N rate and inoculation.

Introduction

Most of the dry edible beans in MN are grown on sandy soils overlying surficial aquifers vulnerable to contamination by nitrate nitrogen. The current N recommendation for kidney beans is 120 pounds per acre usually applied in split applications. One potential method of reducing the cost of production and potential environmental degradation by nitrate loss is by increasing the effectiveness of N fixation. This study was designed to evaluate the interactions between N rate; seed inoculation with Rhizobium; and seed treatment with streptomycin (an antibiotic).

Methods and Materials

The study design was a randomized complete block with two levels of split plots. Main plots were N rate (8 rows wide by 40 feet long), subplots were inoculation (four rows wide), and subsubplots were seed treatment with streptomycin (2 rows wide). There were six replications.

The previous crop was corn which was preceded by potatoes. Tillage was spring moldboard plowing with a plow packer. The soil is a Verndale sandy loam (coarse-loamy mixed, Udic Argiboroll) with a slope of 0 to 2 percent. Irrigation was based on the checkbook method and delivered through a solid set system.

Starter fertilizer (20-5-10-20; N,P,K,S) was applied at 135 pounds per acre with the planter on May 20, 1994. This resulted in 27 pounds N per acre. The main nitrogen application was broadcast applied as urea on 6/16/94 (3-4 trifoliate) at 0, 50, 100, 150 pounds per acre).

The red kidney bean variety was Montcalm (771 beans/pound, 90% germination, planted at 120,000 seeds per acre). An eight row planter with 30" row spacing was used. Four contiguous rows had seed treated with 400 gms of HiStick inoculant per 50 pounds of seed (2 x 10^9 Rhizobium leguminosarum Biovar. phaseoli per gram) and the other four contiguous rows did not (this treatment is referred to as"inoculation"). Within these four row subplots, two contiguous rows received seed treated with Captan fungicide (N-[(tichloromethyl)thio]-4cyclohexene-1,2-dicarboximide) and Lorsban insecticide (Chlorpyrifos [0,0-Diethyl 0-(3,5,6-Trichloro-2Pyridyl) Phosphorothioate]). This treatment is referred to "untreated seed". The other two rows were treated with Streptomycin Sulfate in addition to Captan and Lorsban. This is treatment is referred to as "seed treatment".

Treflan was applied at 1pt/acre preplant incorporated on 5/18/94. On 5/25 Dual at 2pt/acre was applied preemergence. No insecticides or fungicides were applied after planting. Weed control was excellent and there was very little white mold late in the season. Beans were knifed on 9/15/94 and threshed on 9/20/94. The harvest area was two 40 foot rows. Bean moisture levels were determined with an electrical resistance based meter and by oven drying at 120°F until there was no weight loss. The reported yields were calculated using the oven dry moisture determinations.

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Results and Discussion

The statistically significant main effects on bean moisture were for seed treatment with Streptomycin Sulfate only. Seed treatment reduced oven dried seed moisture by .4%.

Kidney bean yields were affected by N rate and inoculation. There were also interactions between seed treatment and N rate as well as seed treatment and inoculation although the main effects of seed treatment was not statistically significant. Kidney beans responded over the entire range of applied N (392 pounds per acre). There was a 59 pound per acre response to inoculation. It did not interact with N rate however.

The interaction between seed treatment and N rate and inoculation are shown at the bottom of table 1. The greatest response to seed treatment was at the 127 pounds N per acre rate. There was a response to inoculation and seed treatment alone or in combination. If neither seed treatment nor inoculation was not present, yields were reduced about 130 pounds per acre.

The comparison between the two moisture determination methods is shown in table 2. The bean moisture determined with the meter was 3.4% higher than when oven drying. Seed treatment affected bean moisture determination with oven drying but not using the moisture meter.

Table 1. Effect of nitrogen rate, inoculation, and seed treatment on harvest moisture and kidney bean yield at Staples, 1994.

N rate	Inocu-lation	Seed treatment	Harvest moisture[1]	Yield
			----%-----	--lb/A--
27	Yes	Yes	10.7abcd[2]	2916ef
		No	11.2ab	3076cdef
	No	Yes	10.6abcd	2886f
		No	10.6abcd	2993cf
77	Yes	Yes	10.05cd	3087cde
		No	10.6abcd	3036cdef
	No	Yes	10.5abcd	3114cde
		No	10.8abc	2932ef
127	Yes	Yes	10.1bcd	3162bcd
		No	10.8abcd	3108cde
	No	Yes	9.7d	3248abc
		No	11.0abc	2949def
177	Yes	Yes	11.0abc	3343ab
		No	11.1abc	3411a
	No	Yes	11.2ab	3362ab
		No	11.4a	3252abc
Main effects of N rate, inoculation, and seed treatment				
27			10.8a	2950c
77			10.5a	3042bc
127			10.4a	3117b
177			11.2a	3342a
	Inoc.		10.7a	3142a
	No inoc.		10.7a	3083b
		Seed trt.	10.5b	3140a
		No seed trt.	10.9a	3086a

Table 1. (cont.)

N rate	Inocu-lation	Seed treatment	Harvest moisture[1]	Yield
			----%-----	lb/A
N rate by seed treatment interaction				
27		Yes		2991d
		No		3000cd
77		Yes		3101bc
		No		2984cd
127		Yes		3205ab
		No		3029cd
177		Yes		3353a
		No		3331a
Inoculation by seed treatment interaction				
	Yes	Yes		3127a
		No		3158a
	No	Yes		3153a
		No		3014b

Pr>F	moisture	yield
N rate	0.27	0.002
Inoculation	0.82	0.09
N rate x inoculation	0.62	0.92
Seed treatment	0.04	0.17
Seed trt x N rate	0.46	0.08
Seed trt x inoculation	0.99	0.03
N rate x inoc x seed treatment	0.81	0.94

1. Bean moisture was determined by oven drying at 120°F until there was no longer weight loss.
2. Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 2. Effect of seed treatment and moisture testing method on kidney bean harvest moisture at Staples, 1994.

Treatment	Moisture Method	Harvest Moisture
		--%--
Seed trt.	oven dry	10.5
	meter	14.1
No seed trt	oven dry	10.9
	meter	14.2
Seed treatment		12.3b[1]
No seed treatment		12.5a
	oven dry	10.7b
	meter	14.1a
Pr>F		
N rate		0.26
Inoculation		0.89
N rate x Inoculation		0.69
Seed		0.06
N x Seed		0.71
Inoc. x Seed		0.92
N x Inoc x Seed		0.64
Method		0.001
N x Method		0.24
Inoc x Method		0.77
Seed x Method		0.03
N x Inoc x Method		0.61
N x Seed x Method		0.20
Inoc x Seed x Method		0.95
N x Inoc x Seed x Method		0.80

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Nitrogen Source Effects on Corn/Potato Yields and Nitrate Leaching, 1994[1]

J.T. Waddell, J.F. Moncrief, C.J. Rosen, S.C. Gupta, M.J. Weins, B. Sheets, and B.J. Johnson[2]

Abstract

Plots were established at Staples, MN to evaluate the following nitrogen sources: anhydrous ammonia, turkey manure, urea-ammonium nitrate (28%), granular urea and a control. An attempt was made to give each treatment (except the control) approximately 200 lbs N per acre, however the turkey manure treatment received 250 lbs N per acre. No differences in yield or moisture content was observed in corn grain supplied with different N sources. Potato tubers and vines did respond to different N sources. Measurement of N lost below the root zone indicates that turkey manure increased losses, however more N was applied in this treatment. Water use by corn was slightly lower during the early part of the growing season when percolation losses were highest. Except in the case of turkey manure, there was more nitrate leaching under corn.

Introduction

Crop production on sandy soils in Minnesota has been improved by the introduction of irrigation systems. Wright and Bergsrud (1991) produced an irrigation schedule termed 'the Checkbook Method' which predicts daily water use for several different crops in Minnesota using overhead sprinkler irrigation. It has been shown by Dylla et. Al. (1980) that these tables to predict water use are comparable to estimates obtained by more precise methods. While the checkbook method may be a valuable tool for predicting irrigation scheduling, the variability of climate from year to year plays a major role in assessing the risks of loosing nitrogen to sub-surface reservoirs.

It has been shown that varying the nitrogen source can have an effect on yields and contribute to contamination of groundwater (Nathan et al., 1992 and Sexton, 1993). Typically, growers in the central sands region of Minnesota have used urea as a nitrogen source. This source of nitrogen is readily available to plants once it is hydrolyzed. However, it may be rapidly leached into subsurface reservoirs during heavy rainfall events. Another nitrogen source is turkey manure. Minnesota is the second leading producer of turkeys in the United States. As a result, turkey manure is abundant and its disposal is of growing concern. Turkey manure is unique as a nitrogen source since its components include primarily ammonium and organic nitrogen compounds. The ammonium portion is readily available to plants while the organic N portion is more slowly made available for uptake throughout the growing season and into the next.

It was the purpose of this study to discern the effect of nitrogen sources on corn/potato yields. Another goal of this project is to quantitatively describe N movement below the root zone.

Materials and Methods

The test plots were located on a Verndale sandy loam soil. The site had a maximum slope of 2% with little or no runoff. Soils of the area are unique. An illuvial soil horizon of limiting hydraulic conductivity (0.54 in h^{-1}) exists with a clear upper boundary at approximately 10 inches and a gradual lower boundary at 16 inches below the surface (Sexton, 1993). Visual observations of the soil showed a limited number of preferential flow paths (macropores) due primarily to ant burrows. Earthworms are less common on soils of such a sandy nature.

Individual plots were 20 x 40 square feet. Corn (Pioneer 3921) was planted on 5 May in 30 inch rows at a rate of approximately 32,000 seeds per acre. A blended starter fertilizer was applied at rates of 30 N, 128 P_2O_5, 68 K_2O, 11 S (pounds per acre). On 6 May, the herbicides Bladex (cyanozine) and Dual (metalachlor) were applied at rates of 2.5 pounds and 2 pints per acre, respectively. No insect of fungus control procedures were needed in the corn. Weed control was good with a few weeds (quackgrass, lambsquarter and nightshade).

Potato (Russet Burbank) was planted on 26 April in 36 inch rows with a density of 17,424 seed pieces per acre. A blended starter fertilizer (7.5-32-17-3.1) was applied at a rate equivalent to 400 pounds per acre. Pre-plant and post-harvest knock down herbicide Diaquat was applied at rates of 1.5 pints per acre, otherwise weeds were controlled during the growing season by cultivation on 14 June. Furadan was applied on 27 July after noticing Colorado Potato Beetle infestation. Fungicide (Bravo) was applied weekly at rates of 1.5 pints per acre. Some Early Blight was detected during the growing season.

Nitrogen (approximately 170 pounds per acre) was applied preplant (anhydrous ammonia) or in two applications (urea and 28%) to both corn and potato plots totaling 200 pounds per acre except for the turkey manure treatment (Table 1). The plots were structured as a completely random design with four replications. This conservative rate of 200 lbs per acre was used in order to

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[1] *Support for this project was provided by the Legislative Commission on Minnesota Resources. Their support is greatly appreciated.*

[2] *J.T. Waddell, Graduate Research Assistant, J.F. Moncrief and C.J. Rosen, Extension Specialists, S.C. Gupta, Professor of Soil, Water, and Climate, University of Minnesota, St. Paul, Minnesota. M.J. Weins is the University of Minnesota Senior Plot Coordinator, Central Minnesota Economic Development, Research and Education Center, Staples, MN. B. Sheets and B.J. Johnson, Magnificent Technicians, CMEDREC and U of M, respectively.*

discern differences if any in the uptake and loss of nitrogen. Table 1 shows the application rates and schedules of the various treatments. Anhydrous ammonia was placed pre-plant below the row for potato and between the row for corn sidedress on 10 June.

Irrigation scheduling was based on the Checkbook Method (Wright and Bergsrud, 1991), with attempts to apply 0.75 inches (Figure 1). During the corn stages from planting to 12 leaf, irrigation was applied at a deficit of 60% of the available water (1.42 inches); from 12 leaf to first dent, the irrigation trigger was 0.95 inches (40%); and from first dent to maturity, irrigation was initiated at 66% (1.6 inches) depletion. For potatoes, an irrigation deficit of 50% was used from planting to tuberization and from tuberization to maturity a 40% deficit was used. Rainfall events which exceeded half of field capacity were followed by two days of cumulative soil water deficits at zero. Whenever the water deficit by the Checkbook Method became close to exceeding the water holding capacity, suction was applied to suction cup samplers. Also, suction was applied to samplers before irrigation events or when the chance of precipitation was 50% or greater.

Table 1. Nitrogen sources, application rates and dates.

Treatment	Potato			Corn		
	Rate	Date	Total§	Rate	Date	Total
Anhydrous Ammonia	206 (170)† lbs/ac	21 April	200 lbs/ac	206 (170) lbs/ac	10 June	200 lbs/ac
Urea	364 (85) lbs/ac	3 & 14 June	200 lbs/ac	364 (85) lbs/ac	3 & 14 June	200 lbs/ac
Urea Ammonium Nitrate (28%)	300 (85) gal/ac	7 & 24 June	200 lbs/ac	300 (85) gal/ac	7 & 24 June	200 lbs/ac
Turkey Manure	9.0 (245)‡ tons/ac	23 April	245 lbs/ac	9.2 (244) tons/ac	23 April	255 lbs/ac

§ Represents total nitrogen applied to individual plots including starter fertilizer.
† Values in parenthesis represent the calculated applied N (pounds per acre) for each source. Note that an additional 30 pounds N per acre was applied to potato and corn in starter application.
‡ Estimated available nitrogen = 100% mineral N(16.5 lbs/ton) + 30% organic N (34.9 lbs/ton). Moisture content was 32.9% by weight.

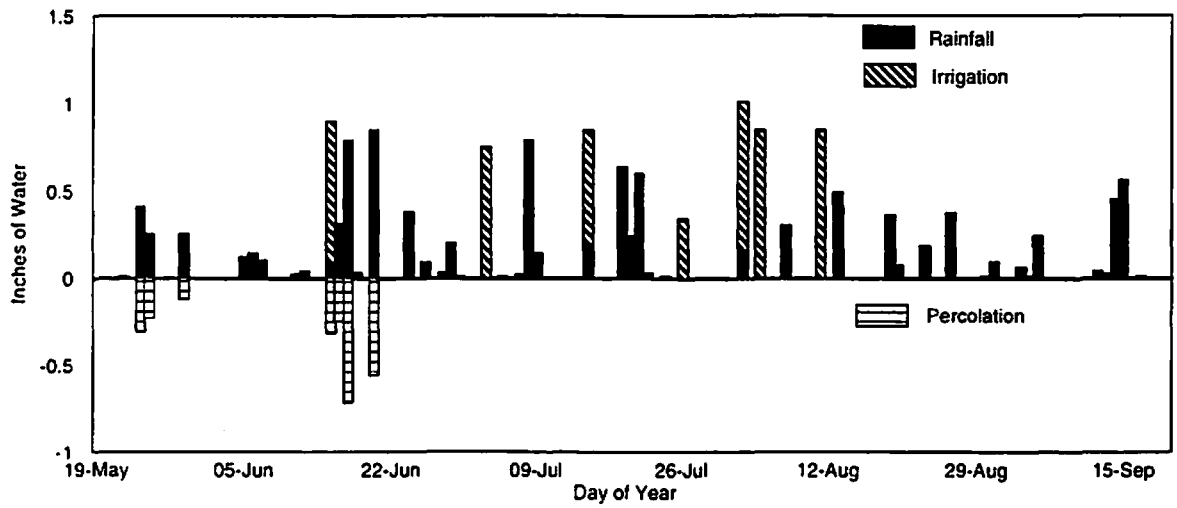

Figure 1 Rainfall and irrigation for the 1994 growing season. Percolation calculated by water budget approach using averaged values for water use for corn and potato.

Suction samplers were made from high flow (1 bar) porous ceramic cups (2 inch diameter) glued to poly vinyl chloride (PVC) pipe. Access tubes were inserted through a rubber stopper from which suction was used for collection of soil water percolate. Suction samplers were installed in plots amended with urea and turkey manure along with control plots. Suction samplers were installed at the 24 inch depth. Samples collected were quickly frozen and taken to the analytical lab where nitrate and ammonia concentrations were measured.

Corn was harvested by hand on 21 September. Stover and grain moisture content, yield and nitrogen content were determined. Potatoes were harvested on 16 September with biomass, N accumulation and quality parameters determined.

Results and Discussion

Rainfall and irrigation events are shown in Figure 1. Percolation values were calculated from a water budget using the equation:

$$Percolation = Rain + Irrigation - WaterUse - \Delta Storage$$

It is obvious that leaching losses below the root zone were prevalent early in the growing season just after fertilizer side dressing. Percolation losses in figure 1 were averaged from water use both for corn and potato. Water use (estimated from the Checkbook Method) for potato was greater than that of corn until day 200 (19 July) when uses were equal. After this time, corn water use was slightly greater than potato. During the latter portion of the growing season the center pivot irrigation device malfunctioned and corn may have been slightly stressed.

Corn

Corn yields are shown in table 2. All treatments yielded more grain than the control. The turkey manure treatment yielded highest with 232 bushels per acre. An explanation causing significantly higher yields with turkey manure include higher N fertilizer rates. Preliminary analysis of turkey manure indicated lower estimated available N than when we applied the manure to the plots. Other sources of nitrogen showed no significant difference in yield of corn grain (187 bu/ac). No difference in moisture content of the grain was observed. Stover yields for the 1994 growing season showed similar trends as did the grain. Turkey manure yielded the most stover producing over 2 tons per acre. The urea and turkey manure treatment yields were significantly higher than the control.

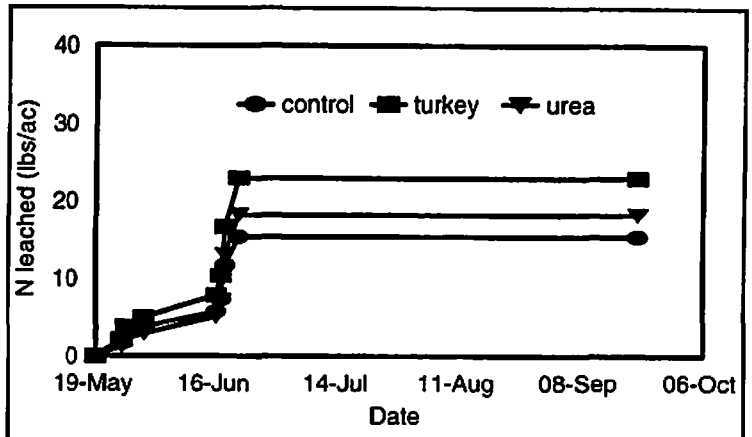

Figure 2 Cumulative nitrogen (principally nitrate) leached under corn plots instrumented with suction cup samplers during 1994 growing season.

Nitrogen uptake in corn grain had the exact trend as did the grain yield (table 2). Corn plots amended with turkey manure showed the highest N uptake, followed by plots ammended with the three chemical N forms, all yielding higher than the control. Similarly, nitrogen in stover was significantly higher in the turkey manure amended plots. Interestingly, the uptake of nitrogen from stover in the 28% plots was not significantly higher than than the control. One component of the nitrogen budget (N lost below the root zone) is shown in figure 2. Nitrogen leached was calculated by multiplying nitrogen concentrations obtained from suction cup samplers by the volume of water

Table 2. Response of corn to different nitrogen sources.

Nitrogen Source	Grain Yield	Grain Moisture	Stover Yield	Stover Moisture	Nitrogen Uptake		
					Grain	Stover	Total
	bu/ac	%	lbs/ac	%	-------lbs/ac-------		
Anhydrous Ammonia	185.9b	30.3a	3225bc	16.3b	118.6b	18.5b	137.1bc
Urea	197.8b	25.9a	3478b	20.1ab	131.5b	19.4b	150.9b
28%	177.9b	27.2a	2728c	18.5ab	114.0b	13.2bc	127.1c
Turkey Manure	232.3a	27.2a	4825a	27.8ab	158.2a	33.1a	191.4a
Control	112.2c	30.1a	3351bc	32.1a	44.5c	9.5c	45.0d

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

estimated from figure 1. Because only three treatments (turkey manure, urea, and control) were instrumented, some questions arise from leaching of the other sources and cannot be answered without further study. Because of the lack of leaching events occurring this year, not much N was leached in either treatments compared to the control. Still, the general trend of N leaching follows closely the amount of nitrogen applied with the turkey manure treatment being highest followed by urea as a nitrogen source and finally the control.

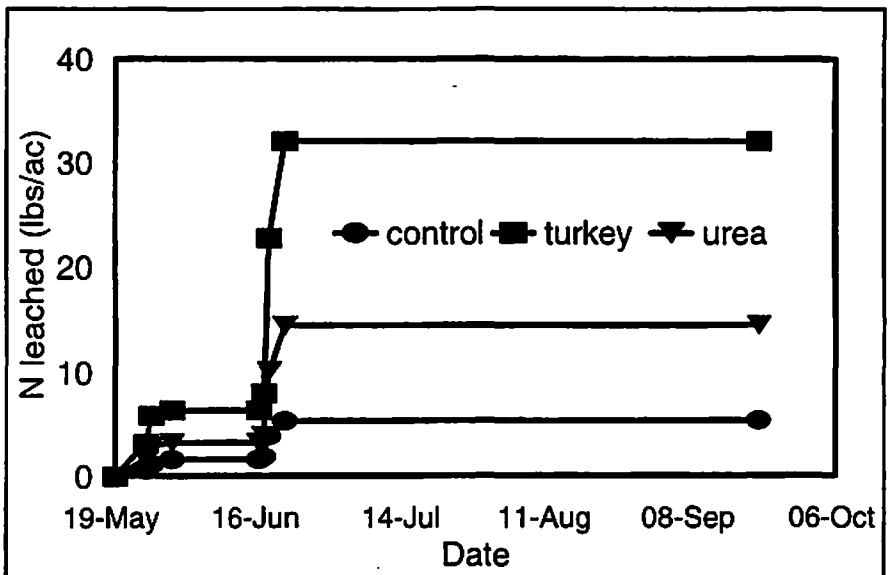

Figure 3 Cumulative nitrogen (principally nitrate) leached beyond the potato root zone during the 1994 growing season.

Potato

Potato yields are shown in table 3. Marketable tuber yields for the different nitrogen treatments were not significantly different while all were higher than the control. Total tuber yields were highest for the turkey manure, anhydrous ammonia and urea treatments leading to a conclusion that the extra N applied to potatos was not effective in increasing tuber yield. However, increased vine growth occurred with higher N rates supplied from turkey manure. Another interesting occurrence is the abundant quantity of knobs (misshappen tubers) for plots amended with urea. It is unknown why this occurred, except that this particular treatment had the highest standard deviation.

The quality of tubers was influenced by the different nitrogen sources for this particular growing season (table 4). Plots with turkey manure applied as the nitrogen source had the lowest density relative to water. This value was significantly lower than the other chemical N sources but not different than the control. The incidence of hollow heart determined from 25 tubers showed that the fewest occurred in nitrogen treatments other than anhydrous ammonia amended plots. While potato scab was qualitatively measured, no significant differences occurred in the treatments with maximum percantages less than 8%(data not shown).

Nitrogen uptake and tuber water contents are also shown in table 4. While water contents in the tubers were not significantly different, vine watter contents were different. It was evident at the time of harvest that vines in plots with turkey manure were actively growing, while the other treatments (especially the control) had begun to senesce. Nitrogen used by tubers indicates that all N treatments were similar and greater then the control. Vine uptake of nitrogen was highest in the turkey manure plots possibly as a result of luxury consumption. The chemical N sources all had similar uptake patterns at harvest and the control was least. Because of the increased uptake of nitrogen by the vines, total N uptake was greatest for the turkey manure treatment followed by the other N ammended treatments, all of which were significantly higher than the control. Nitrogen leached below the potato root zone was determined by multiplying the concentration of nitrogen from suction cup samplers by the percolation values obtained from the water budget. A plot of N leached throughout the growing season is shown in figure 3. The data indicates that highest leaching of N occurred under plots with turkey manure. This was probably due to the higher N rate as stated in the discussion section for corn.

Table 3. Response of potato tubers to different nitrogen sources.

Nitrogen Source	Culls	Ones	Twos	Jumbo	Knobs	Market‡	Total	Vine Yield
	cwt/ac							lbs/ac
Anhydrous Ammonia without N serve	35.4a†	157.2b	214.8a	24.3a	16.8b	372.0a	448.5ab	1775b
Urea	29.0a	185.1ab	188.8a	20.3a	46.0a	373.9a	469.1ab	1806b
28%	26.0a	183.9ab	189.3a	24.7a	16.0b	373.1a	439.9b	1505b
Turkey Manure	37.2a	208.6a	208.2a	21.3a	21.7b	372.0a	497.0a	2788a
Control	26.9a	72.7c	197.3a	2.5b	4.7b	269.9b	304.0c	628c

† Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

‡ Market refers to marketable tubers which is the sum of ones, twos and jumbos.

Table 4. Some quality parameters and nitrogen uptake values along with moisture content of tubers.

Nitrogen Source	Specific Gravity	Hollow Heart	Tuber N uptake	Tuber Water Content	Vine N uptake	Vine Water Content	Total N uptake
	g cm^{-1}	%	lbs / ac	%	lbs / ac	%	lbs / ac
Anhydrous Ammonia	1.0961a	12.5ab	153.9a	74.7a	26.4b	46.0cd	180.3b
Urea	1.0957a	8.3bc	170.8a	74.6a	26.3b	72.5ab	197.0b
28%	1.0948a	3.1c	160.0a	75.3a	24.0b	50.9bc	184.1b
Turkey Manure	1.0913b	6.3c	177.9a	75.9a	57.0a	87.2a	235.0a
Control	1.0934ab	15.6a	66.3b	75.0a	4.0c	27.7d	70.4c

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

Conclusions

The 1994 growing season was excellent with respect to potato/corn yield and nitrogen losses during the growing season. For corn, the amount of N (as seen in grain yields in table 2) may have been limiting as increased yields occurred in the turkey manure plots with 55 lbs/ac more N applied. The same is not true for potato yield since the increased N rates from turkey manure did not significantly increase tuber yield. Generalizations on the effectiveness or efficiency of turkey manure on yields and N leaching cannot be made since the N rate was much higher. Nitrogen forms other than turkey manure produced similar yields in corn grain and marketable tuber yield. However, as costs of nitrogen fertilizers are almost guaranteed to rise, the use of turkey manure may increase as a cheap effective source on nitrogen.

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WASECA, MINNESOTA 56093-4521

WEATHER DATA - 1994

Month	Period	Precipitation 1994	Precipitation Normal[1]	Avg. Air Temp. 1994	Avg. Air Temp. Normal[1]	Growing Degree Units 1994	Growing Degree Units Normal[1]
		---- inches ----		----- °F -----			
January	1 - 31	2.43	0.98	3.5	10.2		
February	1 - 28	0.89	0.97	8.9	16.1		
March	1 - 31	0.49	2.28	33.2	19.1		
April	1 - 30	5.59	2.97	45.0	43.1		
May	1 - 10	0.33		48.7		54.0	
	11 - 20	0.33		64.0		146.0	
	21 - 31	1.03		67.8		196.5	
	Total	1.69	3.65	60.4	57.7	396.5	327
June	1 - 10	2.05		64.8		153.0	
	11 - 20	0.84		75.4		245.0	
	21 - 30	0.43		70.3		203.0	
	Total	3.32	4.11	70.2	67.1	601.0	515
July	1 - 10	2.86		69.2		191.5	
	11 - 20	1.65		68.8		187.5	
	21 - 31	0.41		66.7		184.5	
	Total	4.92	4.21	68.2	71.3	563.5	646
August	1 - 10	3.75		66.7		170.5	
	11 - 20	0.54		65.3		160.0	
	21 - 31	0.68		67.7		195.5	
	Total	4.97	4.20	66.6	68.4	526.0	567
September	1 - 30	4.35	3.56	64.1	59.9	447.0	316
October	1 - 31	4.50	2.45	51.8	47.9	60.5	31
November	1 - 30	1.82	1.72	37.4	32.3		
December	1 - 31	0.70	1.35	24.0	16.2		
Year	Jan-Dec	35.67	32.45	44.6	43.4	2594.5[2]	2402
Growing Season	May-Sep	19.25	19.73	66.8	64.9	2534.0	2371

[1] 30-year normal from 1961 - 1990.
[2] 50 to 86° F base, May 1 until first fall frost.

Notes:
1) Highest 24-hour precipitation on August 10 - - - 3.21"
2) Growing degree units 8% above normal for season, 8th highest since 1950.
3) Highest temperature on May 31 and June 15 - - - 94°F.
4) Last spring frost - - - May 1.
5) First fall frost - - - October 10.
6) Solar radiation for May was 18% above normal and highest in 22 yrs of record keeping.

1994 Soil Moisture

0-5' Profile, Webster Clay Loam

Continuous Corn

Southern Experiment Station, Waseca, MN 56093

Depth	4/18	5/2	5/16	6/1	6/14	7/5	7/15	8/1	8/15	9/1	9/19	9/30	10/15	11/1
inches	inches available water in zone													
0 - 6[1]	0.93	1.15	0.73	0.87	1.21	0.69	0.99	0.60	0.93	0.66	0.99	0.92	1.01	0.92
6 - 12	0.60	0.86	0.78	0.70	0.87	0.43	0.57	0.26	0.62	0.33	0.66	0.83	0.71	0.78
12 - 18	0.87	0.93	0.88	0.81	1.01	0.64	0.67	0.50	0.79	0.44	0.78	0.88	0.79	0.86
18 - 24	0.64	0.80	0.73	0.72	0.82	0.55	0.50	0.44	0.59	0.39	0.60	0.72	0.66	0.72
24 - 36	1.96	1.93	1.92	1.63	2.02	1.32	1.33	1.50	1.67	1.42	1.43	1.79	1.50	1.81
36 - 48	2.74	2.60	2.24	2.00	2.64	2.24	2.26	2.31	2.45	2.26	2.11	2.83	2.57	2.51
48 - 60	2.39	2.24	1.77	1.28	2.32	1.70	1.85	1.78	1.76	1.66	1.67	1.94	2.46	1.84
Total available water in 0-5' profile (inches)	10.14	10.52	9.04	8.01	10.87	7.56	8.17	7.38	8.83	7.15	8.25	9.91	9.70	9.44
% of Capacity[2]	92	95	82	72	98	68	74	67	80	65	75	90	88	85

[1] All values obtained by gravimetric sampling using Waseca D_b and WP constants.

[2] Assuming 11.05" field moist capacity.

Above average rainfall resulted in plentiful soil moisture in the five-foot profile throughout the 1994 growing season. Lowest soil moisture levels occurred in July during peak use and again in early September. With soil moisture conditions at 85% of field capacity in November, soil moisture entering the 1995 growing season will likely be at field capacity.

NUTRIENT LOSSES TO TILE LINES AS INFLUENCED BY SOURCE OF N[1/]

Waseca, 1994

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ABSTRACT: A study was started in 1994 to compare the effects of liquid dairy manure and urea applied at similar N rates on N movement in the soil and into tile lines and corn production. Corn silage N uptake and grain N uptake were 17 and 14% greater, respectively, in the plots that received urea compared to those that received dairy manure. Nitrogen source had no effect on tile flow, NO_3-N concentration and loss in tile water, and NO_3-N content in the 0-8' profile in the fall. Nitrate-N concentrations in porous suction cup samplers installed at 4 and 6 ft depths tended to be slightly higher in urea fertilized plots compared to those that received dairy manure. In 106 water samples, ortho-phosphate was never detected while total P was detected in 15% of the samples. Total P concentrations averaged < .10 mg/L and were not different between manure and urea.

Nitrogen losses to tile lines have been documented in a number of research studies including some conducted at Lamberton and Waseca, Minnesota. These studies primarily showed that N losses were a function of the N application rate and amount of precipitation. Time of application and crop grown have also been shown to influence NO_3-N loss to tile lines. However, little information is available on N losses to tile lines when different sources of N are applied. The purpose of this study was to determine the effect of liquid dairy manure compared to urea on N movement in the soil and into tile lines and on corn production.

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into tile lines installed in plots measuring 45' x 50'. Each plot is enclosed with plastic sheeting to a 6-ft depth. Corn was grown from 1975-1981 with varying rates of fertilizer N. In the fall of 1981, the plot area was converted to a new study where two tillage treatments (fall moldboard plowing and no-tillage) were replicated four times. Corn was grown from 1982 through 1992 and was fertilized at an annual application rate of 180 lb N/A. In the fall of 1992, all 8 plots were moldboard plowed and corn was grown in the residual year (1993).

In the fall of 1993, the same 8 plots used in the previous study were converted to dairy manure and urea treatments. Liquid dairy manure was broadcast-applied on November 22 at a rate of 8000 gal per acre and the plots were moldboard plowed immediately. On May 4, urea was broadcast-applied by hand to 4 plots at a rate of 140 lb N/A before field cultivation. The nitrogen rate was selected to match the amount of N "available" from the manure based on calculations from the manure analysis (Table 1). "Available" N was calculated based on the assumption that all of the ammonium-N (109 lb) was available and 33% of the organic N (94 x 0.33 = 31 lb) was available for a total of 140 lb/A. Based on total N, this was 69% of the total applied N.

Corn (P3578) was planted on May 11 at a population of 32000 plants/A. Starter fertilizer was not used because of the high soil tests. Force was applied at 1 lb ai/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3.5 lb ai/A) and Bladex (3 lb ai/A) applied May 18. Weed and insect control were excellent.

In August 1994, porous suction cup (PSC) samplers and piezometers were installed at 4, 6, and 8 ft depths in the 8 plots that received either urea or dairy manure. The PSC and piezometers were installed 30-in. apart between the corn rows at a distance of 7 ft from the tile line.

Silage yields were taken at physiological maturity. Grain yields were taken by combine from 2-45' rows. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on a M-W-F basis thereafter for NO_3 analysis. Tile water samples of the first two sampling dates from all the plots and selected samples in the subsequent sampling dates were also analyzed for ortho-P and total P content. Water samples collected on a twice-monthly basis from PSC samplers and piezometers were also analyzed for NO_3. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on November 4, 1994.

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RESULTS

Corn grown in plots that received urea had significantly greater ($P \leq 0.05$) silage N uptake (17%) and grain N removal (14%) than those plots that received liquid dairy manure (Table 2). Although not statistically significant, silage yield, grain yield, and grain N concentration tended to be higher in the plots that received urea compared to those that received dairy manure. This suggests that we may have overestimated "available" N when we assumed 100% of the NH_4-N and 33% of the organic N would become available.

Table 1. Nutrient analyses and application rate of liquid dairy manure applied in November, 1993.

Dry matter	Total N	NH_4-N	Organic N	Total P_2O_5	Total K_2O
%	lb/1000 gal				
6.7	25.4	13.6	11.8	10.8	32.5
	lb/acre				
	203	109	94	86	260

Table 2. Influence of nitrogen source on corn production and N utilization at Waseca in 1994.

Nitrogen source	Final Population	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal	Grain H_2O
	x10³	T DM/A	lb N/A	bu/A	%	lb N/A	%
Urea	28.2	7.43	141.9	197.3	1.25	116.1	20.8
Dairy Manure	28.6	6.91	121.6	184.8	1.16	101.4	21.7
Check[1/]	29.6	3.66	53.3	102.5	0.94	45.6	22.5
CV (%)	0.4	3.9	3.4	5.1	3.8	2.6	3.1
LSD (0.05)	NS	NS	15.9	NS	NS	9.8	NS

[1/] The check plots (0 lb N/A) are not randomized within the replications and do not have the same plot history as the 8 main plots. Therefore, data from these plots are not included in the statistical analysis.

Precipitation in April was 2.6" above the normal while May rainfall was 2.0" below the normal. June through September rainfall was close to the normal and October rainfall was 2" above the normal. As a result, highest tile flow occurred in October followed by April (Table 3). Tile flow, flow-weighted NO_3-N concentration and nitrate-N losses did not differ between the two nitrogen sources.

Table 3. Influence of nitrogen source on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1994.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in.	mg/L	lb/A
		Urea	
April	3.09	10.5	7.4
May	0.86	10.8	2.1
June	-	-	-
July	-	-	-
August	0.71	9.2	1.5
September	-	-	-
October	4.37	8.5	8.3
Total	9.03	Avg = 9.5	19.3
		Dairy manure	
April	2.77	11.2	6.9
May	0.98	10.8	2.4
June	-	-	-
July	-	-	-
August	0.50	10.5	1.2
September	-	-	-
October	4.67	8.6	9.1
Total	8.92	Avg = 9.7	19.6