Table 3. Residual NO_3-N in the 0 to 5' soil profile of the cropping systems in April, 1993.

Depth	Cropping System in 1993		
	Cont. Corn	Corn-Sb	Soybean-C
feet	lb NO_3-N/A		
0 - 1	16.1	18.9	11.3
1 - 2	13.2	13.5	6.3
2 - 3	18.7	10.7	6.0
3 - 4	33.1	14.0	11.7
4 - 5	29.2	19.6	15.1
Total (0-5')			
Apr.'93	110.3	76.7	50.4
Oct. '92	95.3	44.1	59.2
% Change over winter	+16	+74	-15

Table 4. Crop yields, N concentration, and N uptake at Lamberton in 1993.

Cropping System	Yield	N Concentration	N Uptake
		%	lb/A
Cont. Corn			
Grain (bu/A)	97.6	1.22	66.7
Stover (lb DM/A)	4708.	0.62	29.2
Total			95.9
Corn-Sb			
Grain (bu/A)	105.3	1.08	63.7
Stover (lb DM/A)	5020.	0.62	31.1
Total			94.8
Soybean-C			
Seed (bu/A)	34.0	5.89	120.2
Stover (lb DM/A)	5021.	0.93	46.7
Total			166.9
Alfalfa			
1st Cut Forage (lb DM/A)	5000	2.60*	130.0
2nd Cut Forage (lb DM/A)	1520	2.71	41.2
3rd Cut Forage (lb DM/A)	2640	2.71	71.5
Total	4.58 T/A		242.7
CRP			
Grass (lb DM/A)	4570	0.71	32.4

* Approximation

Table 5. Soil profile NO_3-N concentrations and amounts in October, 1993 as influenced by cropping system at Lamberton.

Depth	Cont. Corn Avg.	Cont. Corn SE	Cont. Corn Avg.	Corn-Sb Avg.	Corn-Sb SE	Corn-Sb Avg.
feet	ppm		lb/A	ppm		lb/A
0 - 1	6.1	3.42	24.3	3.7	0.38	14.9
1 - 2	0.6	0.20	2.5	1.0	0.22	3.9
2 - 3	1.2	0.32	4.9	0.9	0.23	3.6
3 - 4	2.9	0.37	11.5	2.1	0.26	8.3
4 - 5	4.7	1.47	18.8	3.1	0.37	12.3
5 - 6	4.7	0.81	18.8	2.9	0.35	11.6
6 - 7	4.1	0.78	16.3	3.0	0.47	12.1
7 - 8	4.3	1.47	17.3	2.5	0.32	10.0
8 - 9	4.8	1.70	19.2	2.3	0.26	9.3
9 - 10	4.1	1.07	16.3	2.0	0.20	8.0
Totals						
0 - 5			62.0			43.0
5 - 8			52.4			33.7
8 - 10			35.5			17.3
0 - 10			149.7			94.0

Depth	Soybean-C Avg.	Soybean-C SE	Soybean-C Avg.	Alfalfa Avg.	Alfalfa SE	Alfalfa Avg.
feet	ppm		lb/A	ppm		lb/A
0 - 1	5.0	0.67	19.9	2.9	0.47	11.5
1 - 2	2.0	0.54	7.9	1.2	0.30	4.9
2 - 3	2.2	0.47	8.8	0.9	0.35	3.6
3 - 4	2.1	0.22	8.3	0.6	0.00	2.4
4 - 5	2.1	0.09	8.5	0.7	0.07	2.7
5 - 6	2.4	0.26	9.7	1.3	0.58	5.3
6 - 7	2.9	0.18	11.5	0.4	0.12	1.6
7 - 8	3.3	0.35	13.2	0.7	0.24	2.7
8 - 9	3.1	0.23	12.5	1.2	0.09	4.7
9 - 10	4.6	0.64	18.5	1.6	0.03	6.5
Totals						
0 - 5			53.4			25.1
5 - 8			34.4			9.6
8 - 10			31.0			11.2
0 - 10			118.8			45.9

Depth	CRP Avg.	CRP SE	CRP Avg.
feet	ppm		lb/A
0 - 1	3.3	1.63	13.2
1 - 2	0.9	0.32	3.6
2 - 3	0.4	0.09	1.5
3 - 4	0.4	0.06	1.6
4 - 5	0.4	0.03	1.5
5 - 6	0.4	0.03	1.5
6 - 7	0.4	0.12	1.5
7 - 8	0.8	0.35	3.2
8 - 9	1.5	0.62	6.1
9 - 10	2.0	0.46	8.1
Totals			
0 - 5			21.4
5 - 8			6.2
8 - 10			14.2
0 - 10			41.8

Table 6. Gravimetric water content of the 0-10' profile and "available" water in the 0-5' profile in October, 1993 as influenced by cropping system

Profile depth	Cropping system				
	Cont. Corn	Corn-Sb	Soybean-C	Alfalfa	CRP
feet	Water Content (%)				
0 - 1	22.8	24.0	23.7	20.7	24.5
1 - 2	20.7	20.4	21.6	20.8	20.9
2 - 3	19.3	18.4	19.8	19.2	19.8
3 - 4	21.0	18.7	18.5	18.7	18.9
4 - 5	22.8	19.4	19.3	18.9	19.5
5 - 6	22.0	19.9	20.3	19.4	17.6
6 - 7	21.4	20.1	20.1	19.6	19.1
7 - 8	20.8	19.9	20.0	19.4	20.0
8 - 9	22.5	19.6	20.1	19.9	21.7
9 - 10	20.0	19.8	20.7	19.6	20.9
"Available" Water 0-5' (inches)	8.06	7.08	7.39	6.77	7.50

Table 7. Tile discharge, flow-weighted NO_3-N concentration, and NO_3-N loss via the tile lines as influenced by cropping system.

Month	Cont. Corn	Corn-Sb	Soybean-C	Alfalfa	CRP
	Tile Flow (acre-in)				
March	0.06	0.24	0.36	0.42	2.69
April	1.95	2.54	2.53	2.62	3.83
May	3.52	4.87	3.69	2.20	2.90
June	9.36	9.45	10.10	6.02	9.23
July	2.35	2.13	2.09	1.35	1.41
August	0.10	0.01	0.04	0.05	0.01
November	0.02	0.00	0.01	0.00	0.00
Total	17.36	19.24	18.82	12.66	20.07
	Flow-weighted NO_3-N Conc. (ppm)				
March	11.6	9.2	9.1	2.3	0.5
April	27.1	19.4	16.3	2.3	0.4
May	23.0	19.3	15.1	1.2	0.3
June	18.7	18.3	13.5	0.6	0.2
July	17.8	16.5	12.5	1.0	0.3
August	20.9	16.0	11.3	1.7	0.3
November	23.3	-	14.2	-	-
Season Avg.	20.3	14.1	13.1	1.3	0.3
	NO_3-N Loss (lb/A)				
March	0.2	0.3	0.6	0.18	0.35
April	12.0	10.0	9.3	1.26	0.31
May	18.4	21.5	12.6	0.61	0.17
June	40.0	38.5	30.8	0.77	0.52
July	9.6	8.0	5.9	0.32	0.10
August	0.5	0.0	0.1	0.01	0.00
November	0.1	0.0	0.0	0.00	0.00
Total	80.8	78.3	59.3	3.15	1.45

ORGANIC CROP ROTATION STUDY ON THE KOCH FARM AT THE SOUTHWEST EXPERIMENT STATION, LAMBERTON

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. This study, initiated in 1990, was designed to evaluate the effects of crop rotation and poultry manure on crop yields in organic systems. Crop rotation consistently increased corn yields but had little effect on soybean or oat yields. Corn yields were increased with manure applications each year. Oat and soybean yields were increased by manure applications in 1990 and 1993. 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/soybeans, corn/soybean/oats, 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 design is a randomized complete block, 60' x 155', replicated 4 times, with split plot restrictions. Main plots consist of crop rotation, with each crop represented in each year, and subplots 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.

Three different analyses of composted poultry manure have been used: N-P_2O_5-K_2O analyses of 4-6-4, 4-4-2, and 3-5-3. The form and rate were 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 underseeded with alfalfa, plots were harrowed and the oats underseeded with alfalfa were also packed. This was done to increase weed control and soil to seed contact. The corn and soybean plots were rotary-hoed 5 to 7 days after planting depending on weed stage and rotary-hoed again, if weather conditions and crop emergence permitted. Cultivation of corn and soybean was done as necessary to obtain maximum weed control. Tillage and cultivation in like crops in all rotations are treated the same. All treatments except oat underseeded with alfalfa were moldboard plowed in the fall.

Total weed counts were taken in all plots in 1992 and 1993. All weed species were identified and counted in each sample. In 1992, two random samples four feet long were taken in corn and soybeans for grassy weeds. In oats and alfalfa two 1 foot squares per plot were collected. The whole plot area was sampled for broadleaf weeds in oat and alfalfa plots and one row 155' long was counted in corn and soybean. In 1993, two rows 155' long were sampled for broadleaf weeds in corn and soybean and the whole plot was sampled in oat and alfalfa. Grassy weeds were counted using three samples, four feet long, in corn and soybean and five 1 foot squares in oat and alfalfa.

RESULTS

Manure applications significantly increased corn yields in every year of the study (Fig. 1). Oat and soybean yields were increased significantly by applied manure in 1990 and 1993 and alfalfa yields responded positively to manure in 1991 - 1993 (Fig. 4). Continuous corn rotation yields were reduced, with or without manure, compared to corn yields in the other rotations (Fig. 1). The four years of soybean yield data showed no significant crop rotation effect on yield. Oat yields were reduced by interseeded alfalfa. Broadleaf weed populations were less than grassy weed populations and more variable across all crop rotations (Fig. 5). In each year grassy weed counts were higher in treatments without manure as compared to treatments with manure. Increased crop competition in manured treatments could have decreased weed populations. Grassy weeds were suppressed in corn and soybean where rotary hoe and cultivation treatments were used. Weed numbers in oat plots could be greater due to the earlier planting dates, lack of post-plant cultural weed control measures, and an absence of competition after the crop was removed (Fig. 5).

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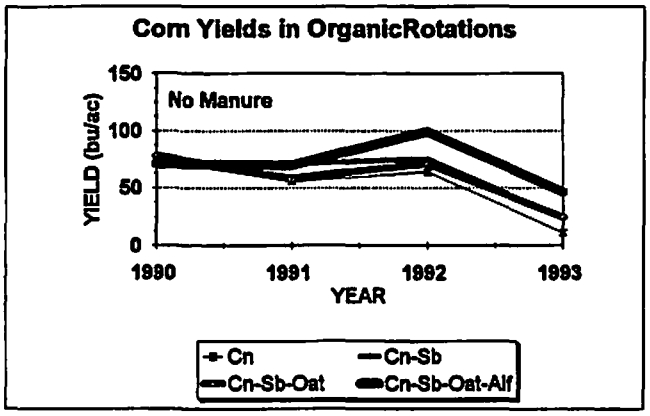
Fig. 1 Corn Yields by Rotation



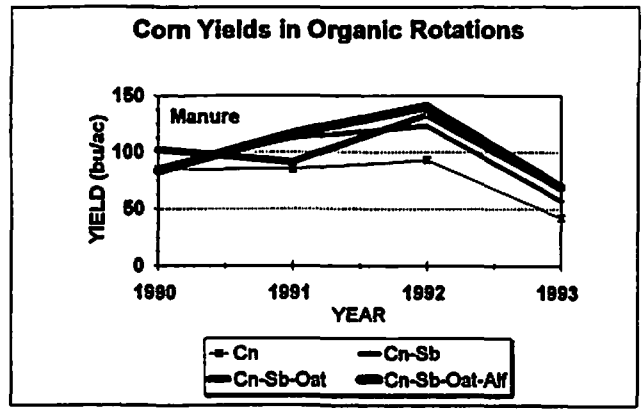
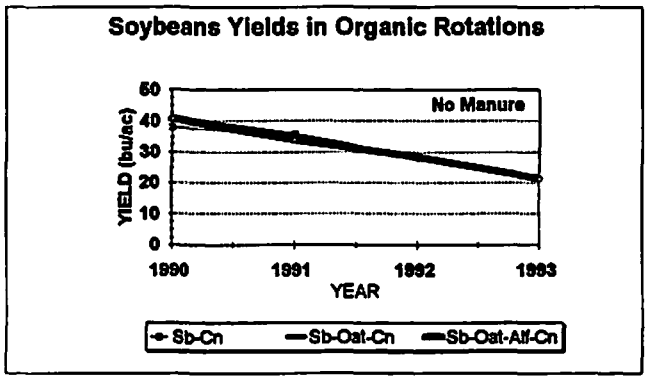


Fig. 2 Soybean Yields by Rotation



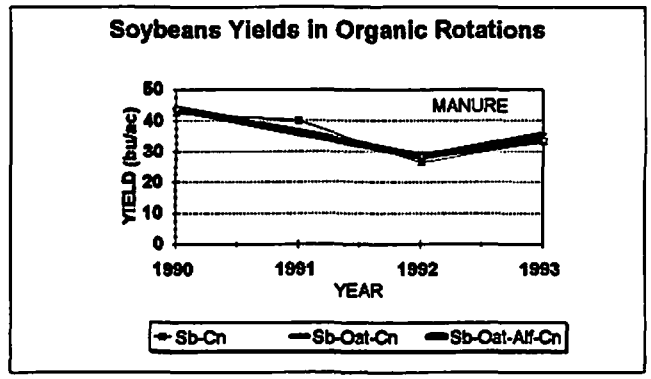


Fig. 3 Oat Yields by Rotation

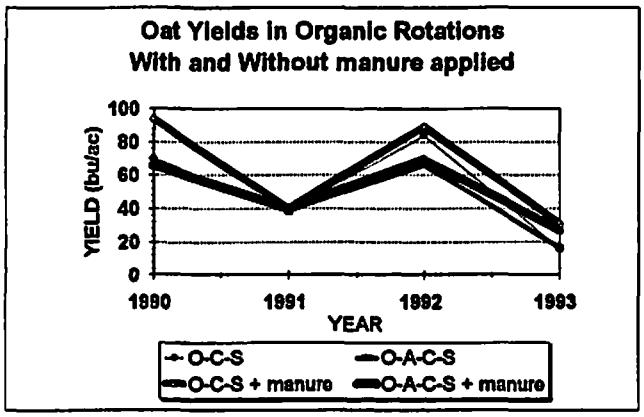


Fig. 4 Alfalfa Yields

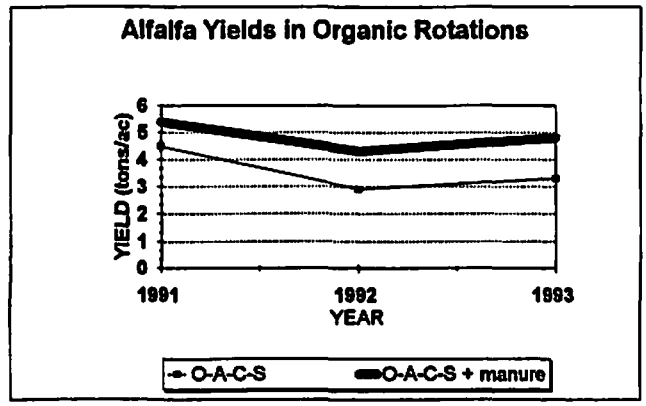
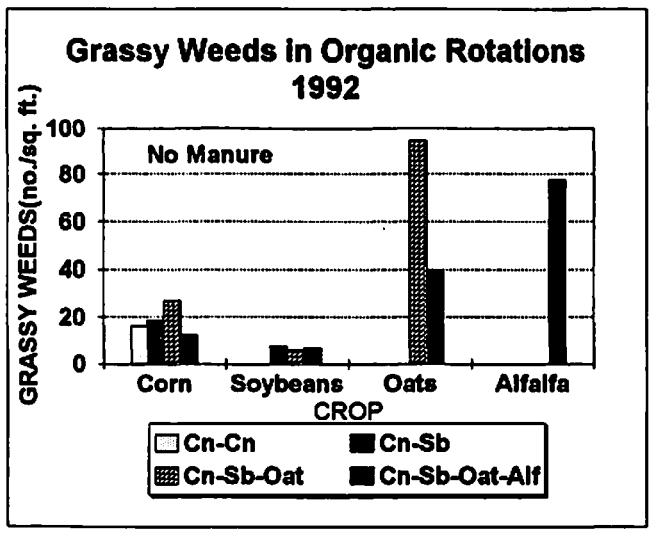
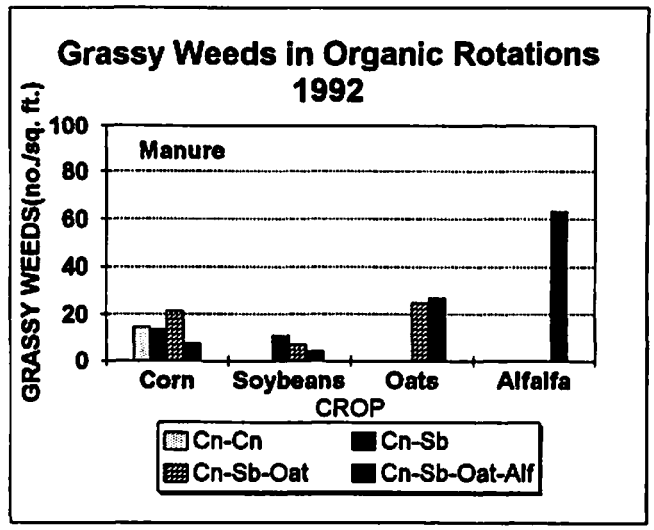
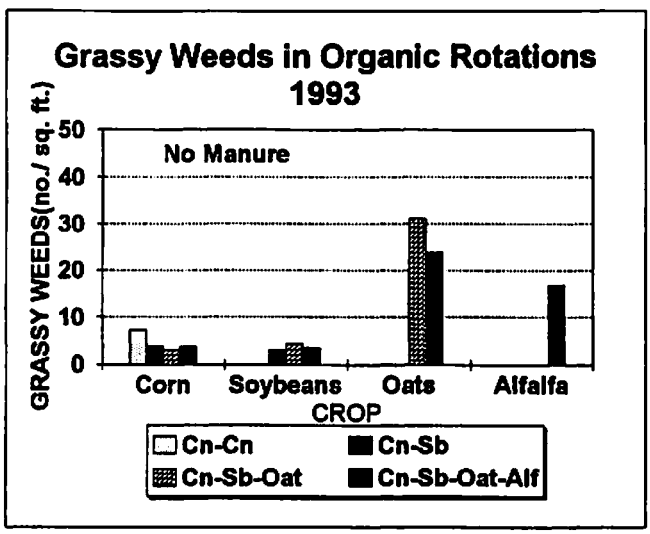
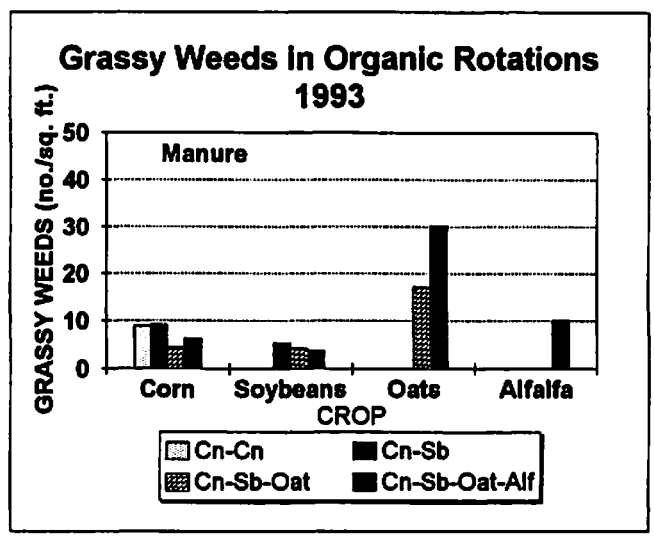


Fig. 5 Number of Grassy Weeds









VARIABLE INPUT CROP MANAGEMENT SYSTEMS: EVALUATION OF PRODUCTIVITY, PROFITABILITY AND ENERGY EFFICIENCY[1]

D.R. Huggins, D.J. Fuchs, J.H. Ford and K.D. Olson[2]

Abstract

Development of cropping systems that use purchased and on-farm inputs efficiently is an important goal of agricultural sustainability. Our objectives are to develop and evaluate cropping systems that minimize energy and chemical inputs while maintaining a profitable and environmentally safe agriculture. Cropping systems with low-purchased input, high purchased input, organic inputs and minimal input were established with two crop rotations (corn-soybean; corn-soybean-oat-alfalfa) and two prior levels of external (off-farm) input (low and high) in 1989. Corn yields were sensitive to external inputs of fertilizer and pesticides with high inputs consistently producing greater yields than low input systems. Crop rotation effects were strongly expressed with low input systems but were virtually eliminated as purchased inputs increased. Soybean yields were greatly affected by prior input level with organic treatments yielding greater than high input treatments where high inputs were previously applied. Economic analysis indicated that transition from a high to a low input system was not accompanied by a dramatic drop in income.

Introduction

In 1988, the University of Minnesota gained access to a unique and significant research site called the 'Koch Farm'. The Koch Farm and was a minimum input farm for at least 35 years prior to 1988. No insecticide had been used on this land, herbicide use was very minimal, and neither synthetic or natural fertilizer had been applied.

The overall objectives of the Variable Input Crop Management Study (VICMS) was to determine how to replace off-farm inputs and energy with on-farm resources, and includes the evaluation of cropping systems with variable off-farm inputs.

Materials and Methods

The study began in 1989 with treatments including 2 prior levels of external (off-farm) input: 1) **VICMS I** (Variable Input Crop Management System) located on the Koch farm with 30 years of minimal inputs. Soil test levels of P_2O_5 (Bray 1) were low (4 ppm), and weed pressure was high; and 2) **VICMS II** located on the Southwest Experiment Station with 30 years of high external inputs. Soil test levels of P_2O_5 (Bray 1) were high (30 ppm), and weed pressure low. Each study (VICMS I and VICMS II) has four different management systems (1) Minimum Input (MIN), (2) Organic (ORG), (3) Low Purchased Input (LPI), and (4) High Purchased Input (HPI) and two different rotations: (1) corn/soybean, and (2) corn/soybean/oat/alfalfa. For each rotation every crop is grown every year.

Minimum Input (MIN)

Tillage and Planting

Primary Tillage: Moldboard plow following corn and alfalfa. Chisel plow following soybean.
Secondary Tillage: As needed to control weeds before planting. Corn residue: disc then field cultivator; soybean residue: field cultivator.
Planting: Crops planted 1 to 2 weeks later than normal. Corn and soybean are planted on 30-inch rows. Oat is drilled and undersown with alfalfa.

Fertilizer

No fertilizer is applied.

Weed Control

Mechanical weed control only, included are rotary hoe (pre and post plant emergence in corn and soybean) and row cultivation (corn and soybean).

Organic (ORG)

Tillage and Planting

Primary Tillage: Moldboard plow following corn and alfalfa. Chisel plow following soybean.
Secondary Tillage: As needed to control weeds before planting. Corn residue: disc then field cultivator, soybean residue: field cultivator.

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[1] Support for this project was provided by a grant from the LCMR.

[2] D.R. Huggins, D.J. Fuchs and J. H. Ford are Assistant Professor, Scientist and Professor at the Southwest Experiment Station, Lamberton, MN 56152. K.D. Olson is Associate Professor at the Agricultural and Applied Economics Department at the University of Minnesota, St. Paul, MN 55108.

Planting: Crops planted 1 to 2 weeks later than normal. Corn and soybean are planted on 30-inch rows. Oat is drilled and undersown with alfalfa

Fertilizer
The 4-year rotation receives solid beef manure. The 2-year rotation receives liquid hog manure. Rates are based on soil tests and previous years' application manure analysis.

Weed Control
Mechanical weed control only, which includes the rotary hoe (pre- and post-plant emergence in corn and soybean) and row cultivation (corn and soybean).

Low Purchased Input (LPI)

Tillage and Planting
Primary Tillage: Chisel plow following corn, moldboard plow following alfalfa, no tillage following soybean (with secondary tillage before planting).
Secondary Tillage: one pass before planting (implement, disc or field cultivator, dependent on crop residue and soil conditions).
Planting: Crops planted as soon as practical in 30 inch rows for corn and soybean, and oat is drilled with alfalfa undersown.

Fertilizer
P & K fertilizers are applied in a 2 X 2 band for corn and soybean. Nitrogen is applied in 2 by 2 band in corn. Fertilizer is broadcast applied on the oat and alfalfa. Fertilizer rates are based on soil tests (NPK), previous crop and a realistic yield goal.

Weed Control
Mechanical weed control with rotary hoe and row cultivation. Herbicides are banded in corn and soybean, and broadcast in oat and alfalfa.

High Purchased Input (HPI)

Tillage and Planting
Primary Tillage: Moldboard plow following corn and alfalfa, chisel plow following soybean.
Secondary Tillage: One pass or two passes before planting (implement, disc or field cultivator, dependent on crop residue and soil conditions).
Planting: Crops planted as soon as practical in 30 inch rows for corn and soybean, and oat is drilled with alfalfa undersown.

Fertilizer
N, P, and K fertilizers are broadcast on all crops. Fertilizer rates are based on soil tests (NPK), previous crop, and an optimistic yield goal (10 percent above realistic yield goal).

Weed Control
Mechanical weed control with row cultivator (1 to 2 passes). Herbicides are broadcast applied for all crops.

Soil P_2O_5 and K_2O tests from the fall of 1992 for VICMS I and VICMS II are presented in Figure 1. Nutrients applied from 1989 to 1992 are presented in Figure 1. Grassy weed counts for 1992 are shown in Figure 2 for VICMS I and VICMS II. Yields for each crop from 1989 to 1993 are presented in Figure 3.

Enterprise budgets were developed annually on a per acre basis from inputs and results of the experiment (Figure 4, Table 1 and 2). Product prices were obtained from annual reports (1989-1992) of the Southwest Minnesota Farm Business Management Association and represent averages received by members. Economic cost estimates of farming operations included overhead costs, operating expenses, and labor costs (Fuller et al., 1992). Market prices were used for inputs except herbicides which were from Durgan et al. (1992).

Energy budgets were developed annually on a per acre basis and expressed as diesel gallons (1 gal. diesel = 34,849 kcal) (Figure 4, Table 1 and 2). Fuel requirements for machinery operation were from Fuller et al. (1992).

Energy for machinery manufacture and repair was assumed to be 1/2 that required for operating fuel (Griffith and Parsons, 1983). Energy inputs were included for the production, formulation, and transport of N, P, and K fertilizers (Lockeretz, 1980) and pesticides (Pimentel, 1980)(Figure 4, Table 1 and 2).. Energy returns were based on yields and calculated for corn (Pimentel and Burgess, 1980), soybean (Scott and Krummel, 1980), oat (Weaver, 1980), and alfalfa (Heichel and Martin, 1980).

Results

Productivity Evaluation

Soil test P_2O_5 levels for VICMS I were less than half of VICMS II for all management systems, even with large additions of P_2O_5 fertilizer in the HPI system (Figure 1). Soil test K_2O levels were similar for both VICMS I and VICMS II for all management systems.

Grassy weed pressure was generally higher on VICMS I than VICMS II and with MIN and ORG treatments as compared to LPI and HPI (Figure 2).

Corn yields were higher in LPI and HPI systems than ORG and MIN for both previous levels of external inputs (Figure 3). Rotation effects on corn yields were not apparent until 1992 and were more strongly expressed with the MIN and ORG systems.

Soybean yields were greater in ORG and MIN systems as compared to LPI and HPI during the first 3 years on VICMS II (Figure 3). Yield decline in 1992 and 1993 was associated with increased weed pressure. Yearly fluctuations in soybean yield were greater for MIN and ORG systems than LPI and HPI systems (VICMS I) and corresponded with yearly weed pressure dynamics (1992>1989>1991>1990).

Oat yields were least affected by previous levels of external input (Figure 3). Yields were influenced primarily by weather and associated disease problems (lodging and cereal rusts).

Alfalfa yields on VICMS II were similar for each management system from 1990-1993. Alfalfa yields on VICMS I were similar to VICMS II with the exception of MIN system where yields have declined since 1990.

Economic and Energy Evaluation

Variable levels of total listed costs and energy use were achieved by the systems (Figure 4). Fertilizer and pest control inputs provided the greatest differences. Input differences between VICMS I and II were due to greater initial fertility status and less weed pressure in VICMS II. The HPI system generally achieved the greatest gross income and energy yield, but at the greatest cost in terms of dollars and energy (Figure 4 and Tables 1 and 2). The HPI system appears to have reached a plateau where further expenditures in dollars or energy would not increase either gross income or energy yield. Systems with lower costs per unit can withstand poor prices better than systems with higher costs per unit. The costs per unit on VICMS II are consistently less than VICMS I and reflect the different history of inputs. The four year rotation on VICMS II has consistently lower costs per unit than the two year rotation. Preliminary economic conclusions indicate VICMS II returns were greater than those on VICMS I.

The systems are still evolving from a management standpoint as well as from an environmental interaction perspective. Even though the results are preliminary they do serve as a comparison among systems during the transition period. Higher productivity, profitability, and energy efficiency were obtained on VICMS II where weed control and fertility levels were initially high. Adopting ORG or LPI systems to fields with high weed pressure and low fertility levels will be difficult. Differences between the four and two year crop rotations were more noticeable for the MIN and ORG systems than the LPI and HPI systems. Weed and fertility management are areas that require improvement if the ORG and LPI systems are to become more viable. Differences between VICMS I and VICMS II for the various management systems appear to be diminishing with time. The LPI and ORG systems are the most difficult to manage and the most promising for reducing off-farm inputs. However, yields must be increased without significantly increasing cash and energy inputs if they are to become more viable.

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The authors recognize and thank R.K. Crookston, Head and Professor of Agronomy, Univ. of MN; W.W. Nelson, Emeritus Professor of Soil Science, Univ. of MN; members of the 'Koch Farm' Committee; and staff at the Southwest Experiment Station who played a large role in the design and implementation of this experiment

Figure 1. Soil tests and fertilizer additions.

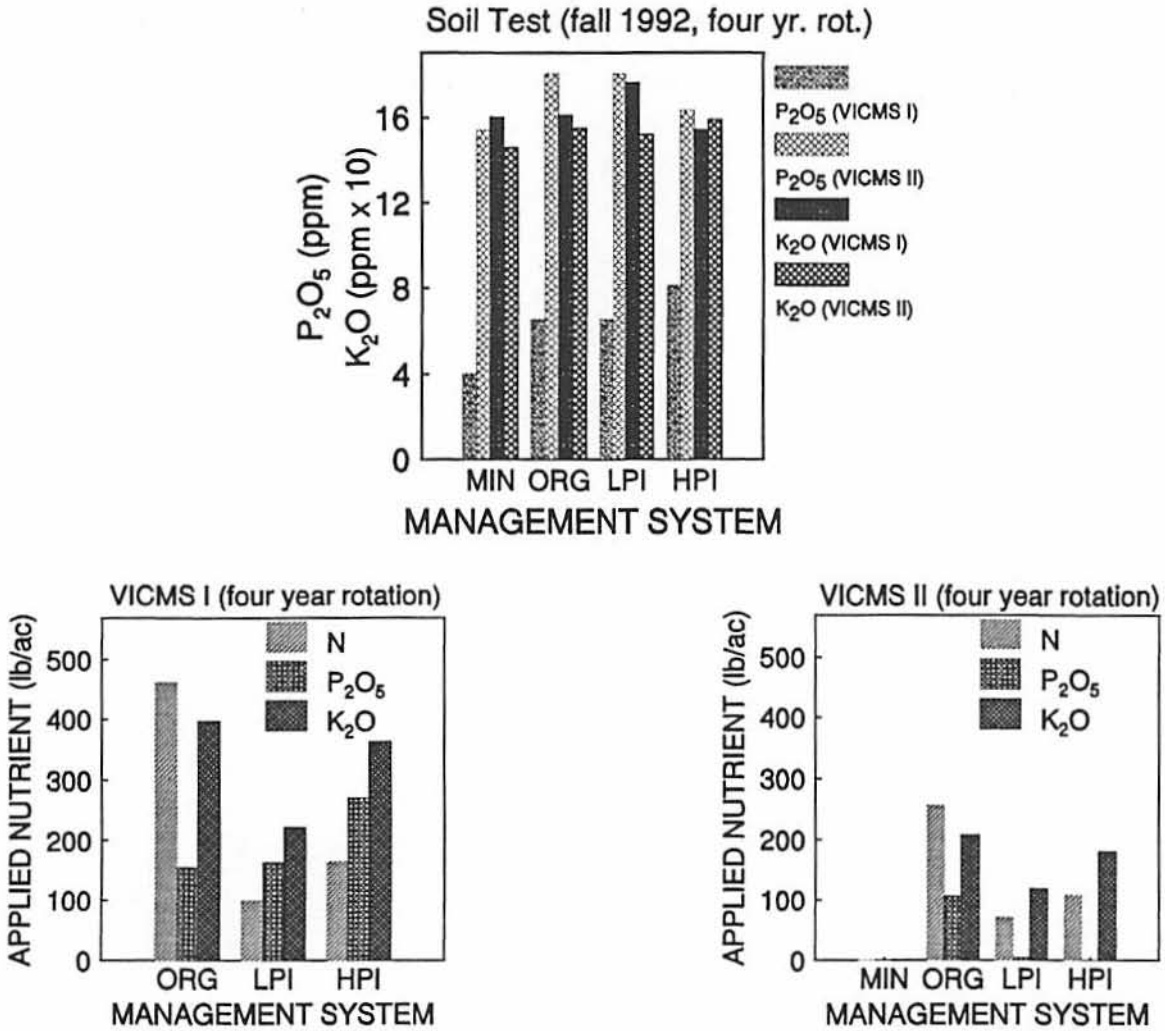


Figure 2. Grassy weed count in 1992.

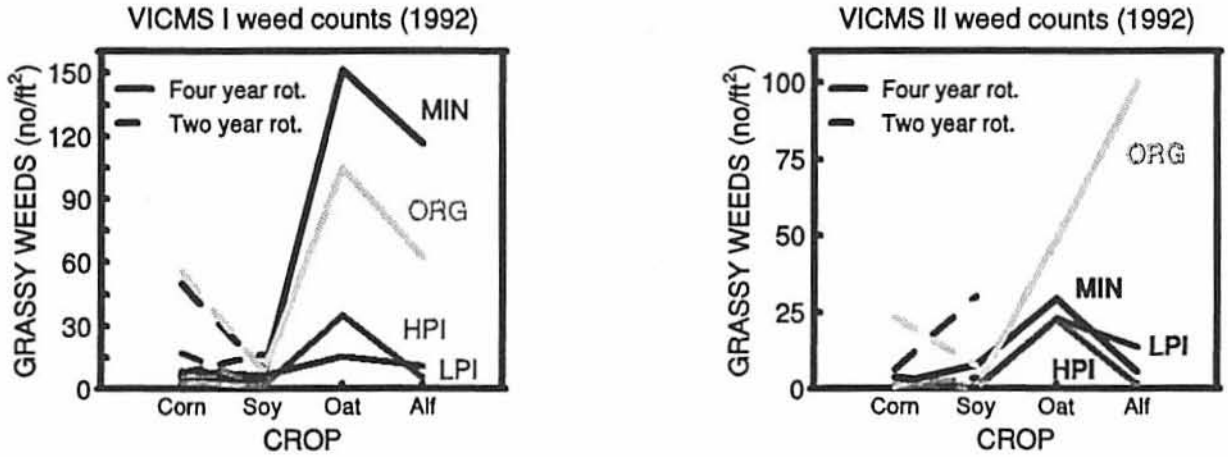


Figure 3. Crop yields.

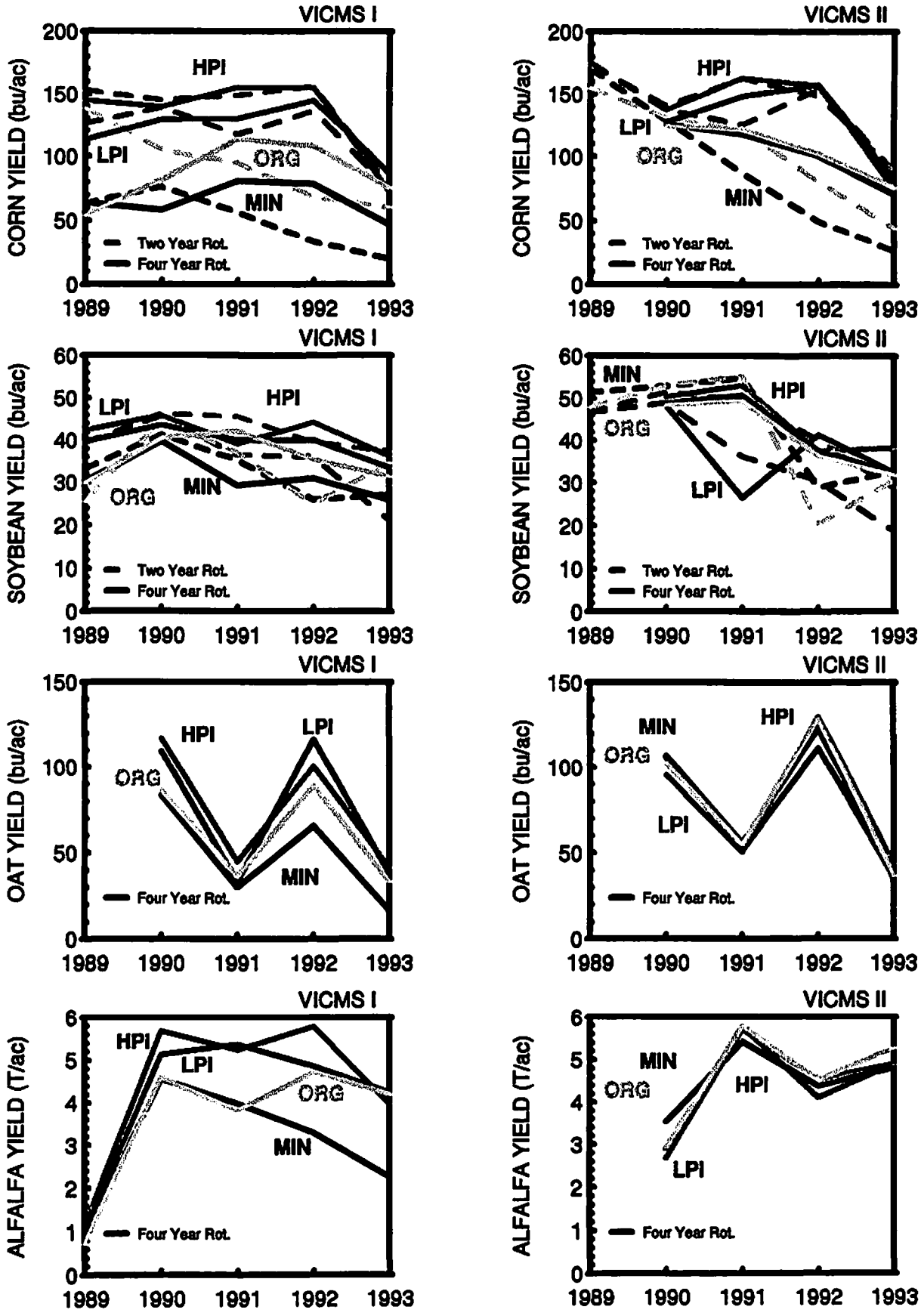


Figure 4. Economic and energy analysis 1989 - 1992.

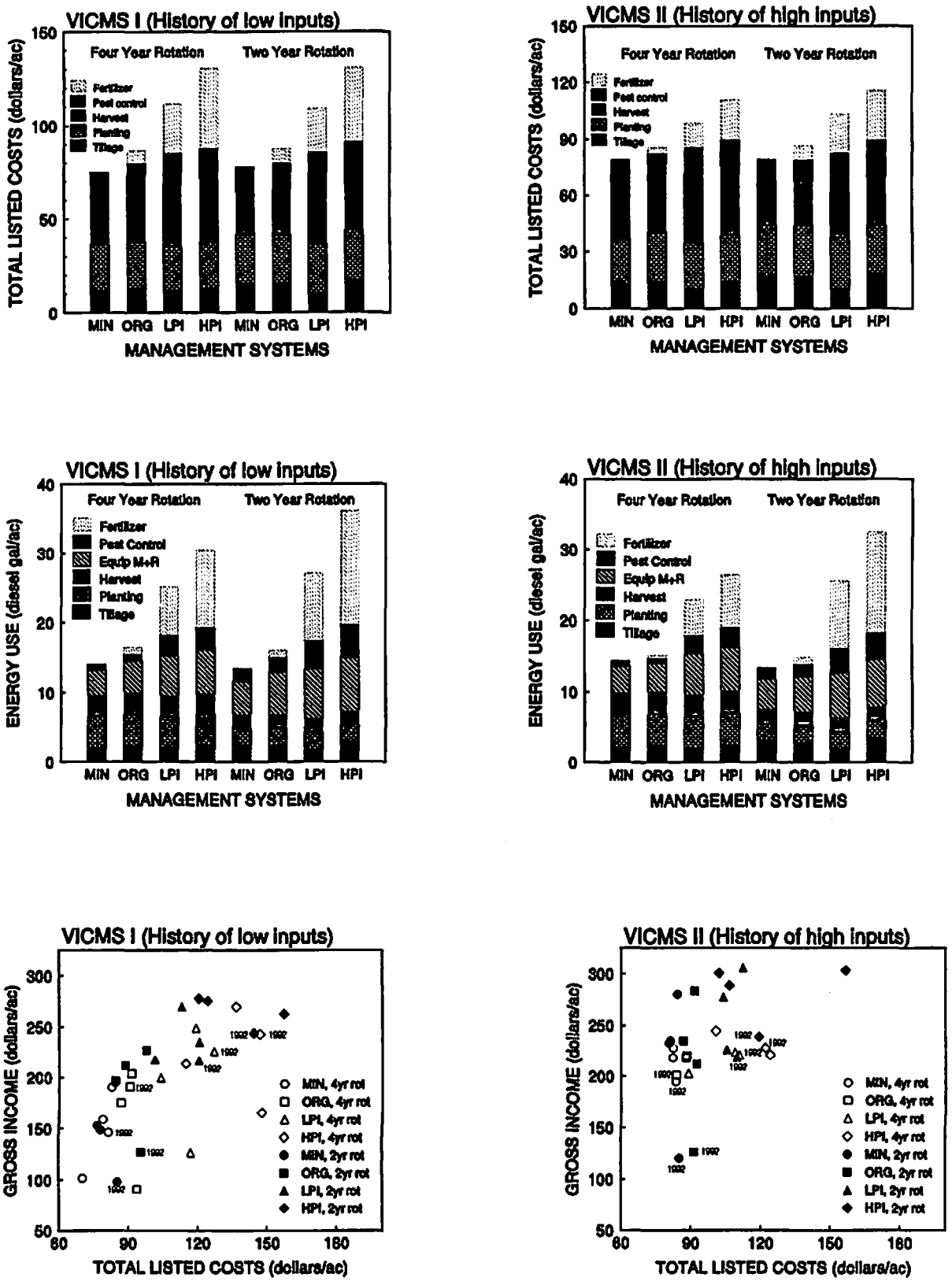
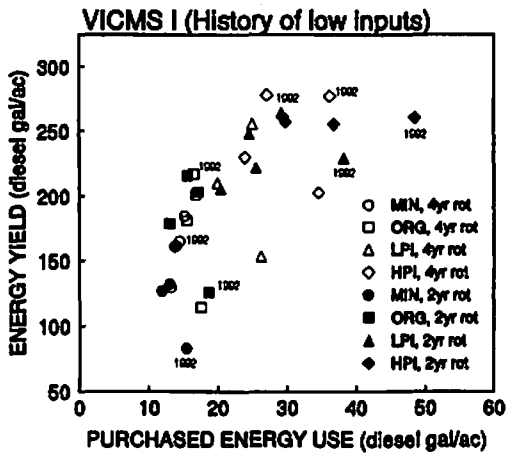


Figure 4 (cont.). Economic and energy analysis 1989 - 1992.



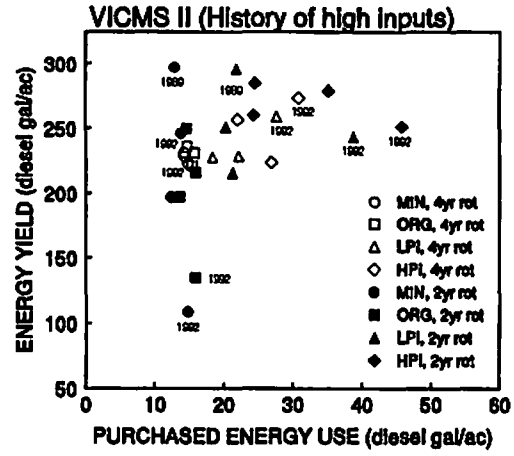


Table 1. VICMS I direct cash costs per unit (1989-1992).

	Four-Year Rotation			
Management	Corn	Soybean	Oat	Alfalfa
	($/bu)			($/ton)
MIN	1.38	2.05	0.90	43.50
ORG	1.25	2.24	0.75	52.64
LPI	1.02	2.56	1.18	56.12
HPI	1.14	2.40	1.18	57.43
	Two-Year Rotation			
MIN	1.77	2.14		
ORG	1.13	2.47		
LPI	1.03	2.42		
HPI	1.15	2.36		

Table 2. VICMS II direct cash costs per unit (1989-1992).

	Four-Year Rotation			
Management	Corn	Soybean	Oat	Alfalfa
	($/bu)			($/ton)
MIN	0.85	1.55	0.56	27.43
ORG	0.87	1.67	0.56	30.57
LPI	0.83	2.09	0.88	36.72
HPI	0.92	1.69	0.98	41.79
	Two-Year Rotation			
MIN	1.10	1.57		
ORG	1.04	2.31		
LPI	0.85	2.31		
HPI	1.00	1.83		

TILLAGE MANAGEMENT FOR INCREASING CROP YIELDS AND DECREASING SOIL EROSION AT THE SOUTHWEST EXPERIMENT STATION[1]

D.J. Fuchs, M. Lindstrom, and D.R. Huggins[2]

Field research is needed to evaluate soil movement under different crop production practices and its consequent effect on crop yield. This study was conducted to examine soil movement and crop yields on three different slope percentages (1%, 4%, and 8%), three tillages (ridge tillage, moldboard plow, and chisel), and tillage/planting directions (up and down the slope, or contour to the slope) in a corn - soybean rotation. In 1993, tillage treatments had a significant effect on soybean yield on all slope percentages. Yields with moldboard plow and chisel plow treatments were significantly greater than yields with ridge tillage in all cases. No other treatments significantly affected soybean yield.

MATERIALS AND METHODS

This study began in the spring of 1985 to examine the effect of slope percentage (1%, 4%, and 8%), tillage (ridge tillage, moldboard plow, and chisel), tillage/planting direction (up and down the slope, or contour to the slope), and slope position (top, middle, and bottom) on soil movement and yield in a corn and soybean rotation. The field experiments are located at three different sites with one site for each slope percentage. Treatments at the site with 8 percent slope are tillage, plant row direction, and position on the slope (top, middle, or bottom). Treatments at the site with 4 percent slope are tillage, and plant row direction while the site with 1 percent slope has only tillage treatment. Yields are measured every year. Base line data on soil movement was collected at the start of the experiment. The experiment was concluded in 1993, and soil movement was assessed by grass catch strips and infrared transit survey. Additional management information is provided in Table 1. Analysis of variance was performed for each slope percentage. If treatments were significantly different (0.05 level), means were separated using Fisher's $LSD_{0.05}$., and are included with the appropriate tables.

RESULTS

In 1993, soybean yields for the various tillage treatments were significantly different for each slope percentage. The moldboard plow and chisel plow yielded more than the ridge tillage treatments in all cases (Table 2-5). Yields with moldboard plowing were 5 percent greater than with chisel plowing and 22 percent greater than yields with ridge tillage on the 8 percent slope (Table 2 and 3). No significant yield difference occurred on the 8 percent slope due to row direction or position (Table 3).

On the 4 percent slope, soybean with moldboard plow yielded 20 percent and chisel plow 18 percent more than the ridge tillage treatment (Table 4). There was no significant effect of row direction on corn yield on the site with 4 percent slope. On the 1 percent slope, soybean with moldboard plow yielded 19 percent and chisel plow 18 percent more than the ridge tillage treatment (Table 5).

Table 1. Management Information for 1993.

Item	Type	Rate	Date
Primary Tillage[1]	CP and MP	Once	Fall 1992
Secondary Tillage	Disc	1 pass	5/21,5/25
Seed	Hardin	150,000 seeds/ac	5/26
Herbicides	Lasso and Sencor	3.0 lbs/ac (ai) 1.5 lbs/ac (ai)	5/26
Row Cultivation		Once	7/15
Ridging			7/27

[1] No primary or secondary tillage on ridge tillage plots.

[1] Funding provided by the USDA - CSRS and the Agricultural Experiment Station.

[2] Scientist - U of MN, Southwest Experiment Station; Soil Scientist - USDA-ARS, Morris, MN 56267; Assistant Professor - U of MN, Southwest Experiment Station, respectively.

Table 2. Soybean Yields on the 8 Percent Slope by Tillage.

Tillage[1]	Average yield	Standard deviation
	bu/ac	
Moldboard Plow	39.2	4.1
Chisel	37.4	3.6
Ridge Tillage	30.7	4.2

[1] $LSD_{(0.05)}$ = 2.2 bu/ac

Table 3. Soybean Yields on the 8 Percent Slope by Tillage-Row Direction-Slope Position.

Row direction	Tillage	Slope Position	Average yield	Standard deviation
			bu/ac	
Up & Down	Moldboard Plow	Top	39.1	3.2
		Middle	39.5	3.3
		Bottom	37.5	7.1
	Chisel Plow	Top	36.6	3.3
		Middle	37.3	1.7
		Bottom	37.6	1.9
	Ridge Tillage	Top	28.7	4.0
		Middle	27.1	4.9
		Bottom	31.3	4.3
Contour	Moldboard Plow	Top	37.7	4.1
		Middle	40.5	1.9
		Bottom	40.7	4.2
	Chisel Plow	Top	35.6	5.9
		Middle	36.8	3.0
		Bottom	40.2	3.7
	Ridge Tillage	Top	31.6	4.3
		Middle	33.7	1.8
		Bottom	32.0	2.9

Table 4. Soybean Yields on the 4 Percent Slope by Tillage-Row Direction Interaction.

Tillage	Avg. Yield[1]	Row Direction	Average yield	Standard deviation
	bu/ac		bu/ac	
Moldboard Plow	40.9	Up & Down	40.8	1.0
		Contour	40.9	2.5
Chisel Plow	36.7	Up & Down	37.4	2.6
		Contour	35.9	5.4
Ridge Tillage	32.7	Up & Down	29.2	2.4
		Contour	36.1	5.9

[1] $LSD_{(0.05)}$ = 4.0 bu/ac

Table 5. Soybean Yields on the 1 Percent Slope by Tillage.

Tillage	Average yield[1]	Standard deviation
	bu/ac	
Moldboard Plow	38.8	4.8
Chisel Plow	38.2	2.8
Ridge Tillage	31.4	3.1

[1] $LSD_{(0.05)}$ = 4.3 bu/ac

THE EFFECT OF TILLAGE SYSTEMS ON SOIL BULK DENSITY AND LONG-TERM CROP YIELDS AT THE SOUTHWEST EXPERIMENT STATION[1]

D.J. Fuchs, J.F. Moncrief, and D.R. Huggins[2]

ABSTRACT

The wet soil conditions for the past year and latter part of 1992 have increased the potential of soil compaction. This study was conducted in the fall of 1993 (10/18/93) to evaluate bulk density differences in a corn -soybean rotation, with each crop grown every year, with four tillage systems: 1) no-tillage, 2) ridge tillage, 3) Reduced tillage and 4) Conventional tillage. Within each tillage system, wheel traffic and no wheel traffic areas were sampled at the 0 to 6 inch and 6 to 12 inch depth increments. Results show relatively high bulk densities across all treatments, averaging 1.56 (g/cm^3). There was no significant difference in bulk densities between tillage systems. There were significantly greater bulk densities in wheel traffic areas, and at the 6 to 12 inch depth increment.

MATERIALS AND METHODS

The wet conditions that have occurred since the fall of 1992 may have predisposed the soils to increased compaction from harvest and planting equipment. This study was conducted in the fall of 1993 (10/18/93) to evaluate bulk density differences in a corn -soybean rotation, with each crop grown every year, with four tillage systems: 1) no-tillage, 2) ridge tillage, 3) Reduced tillage and 4) Conventional tillage. Three of the four tillage replications were sampled in the corn portion of the rotation. The no-tillage system has no primary tillage, secondary tillage or row cultivation. The ridge tillage system has no primary or secondary tillage, row cultivating and ridging were timed for optimum weed control and minimal crop damage. The reduced tillage system has chisel plowing after corn harvest and no-tillage after soybean harvest. Both crops receive secondary tillage in the spring before planting and row cultivation for weed control. The conventional tillage system has moldboard plowing after corn harvest and chisel plowing after soybean harvest. Both crops receive secondary tillage in the spring before planting and row cultivation for weed control. Within each tillage system, areas with and without wheel traffic were sampled at the 0 to 6 inch and 6 to 12 inch depth increments. Five soil cores (1.8-cm diam.) were taken for each treatment replication and composited. Soil samples were dried at 105 degrees C for 24 hours and then weighed to determine bulk densities and gravimetric water contents.

A preliminary soil bulk density sampling was conducted earlier (9/8/93) on three of the four tillage systems mentioned above. The tillage systems evaluated included: 1) no-tillage, 2) conventional tillage, and 3) reduced tillage. Also, within each tillage system, wheel traffic and no wheel traffic areas were sampled at the 0 to 6 inch and 6 to 12 inch depth increments. One replication of the both the corn and soybean crops were sampled. Bulk density and gravimetric water contents from the preliminary sampling and the October 18 sampling are presented in Tables 1 and 2. Corn and soybean yields from 1986 to 1993 are presented in Table 3 and 4.

RESULTS AND DISCUSSION

The preliminary sampling on 9/8/93 indicated high bulk density measurements for all treatments. Bulk densities were greater in wheel traffic areas and at the 6 to 12 inch depth (Table 1). The sampling on 10/18/93 verified the preliminary sampling with significant differences in bulk densities and gravimetric water contents between areas with and without wheel traffic, and between depth increments. Average wheel traffic areas had bulk densities 9.8 percent and water contents 6.8 percent greater than in non-wheel traffic areas. The 6 to 12 inch depth increment had bulk densities 4.2 percent greater than the 0 to 6 inch depth increment. The water content was 4.3 percent greater in the 0 to 6 inch depth increment than in the 6 to 12 inch depth increment (Table 2). There was a significant interaction between wheel traffic and depth increment. The 6 to 12 inch depth was less effected by wheel traffic than the 0 to 6 inch depth (Figure 1). Tillage had no significant effect on measured soil bulk density or water content.

Long-term yields indicate that conventional tillage has resulted in the greatest corn and soybean yields (Table 3 and 4). Past research has shown that the moldboard plow decreases soil bulk density in the soil surface more than chisel plowing or no-tilling. This may be one factor that contributes to yields being greater in conventional tillage, even though there was no significant difference in bulk densities between tillages in the fall of 1993.

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1 Funding provided by the Agricultural Experiment Station.

2 Scientist - U of MN, Southwest Experiment Station; Associate Professor - U of MN, St Paul, MN 55108; Assistant Professor - U of MN, Southwest Experiment Station, respectively.

Table 1. Preliminary bulk density and gravimetric water content measurements.

Tillage	Wheel Traffic	Depth	Bulk Density	Gravimetric Water
	(yes/no)	(in.)	(g/cm^3)	(g/g)
No-tillage	no	0-6	1.46	21.99
	no	6-12	1.59	24.20
	yes	0-6	1.57	21.99
	yes	6-12	1.66	23.78
Reduced	no	0-6	1.54	21.87
	no	6-12	1.66	21.86
	yes	0-6	1.65	20.97
	yes	6-12	1.69	21.66
Conventional	no	0-6	1.34	23.10
	no	6-12	1.55	22.42
	yes	0-6	1.58	22.48
	yes	6-12	1.67	22.69

Table 2. Bulk density and gravimetric water content measurements.

Tillage	Wheel Traffic[1]	Depth[2]	Bulk Density	Std. Dev.	Gravimetric Water	Std. Dev.
	(yes/no)	(in.)	(g/cm^3)		(g/g)	
No-tillage	no	0-6	1.44	0.03	26.82	0.45
	no	6-12	1.52	0.06	25.21	0.82
	yes	0-6	1.63	0.04	24.05	0.19
	yes	6-12	1.62	0.06	24.66	0.94
Ridge Tillage	no	0-6	1.38	0.05	26.83	1.00
	no	6-12	1.54	0.05	25.75	1.01
	yes	0-6	1.64	0.06	24.98	1.51
	yes	6-12	1.64	0.07	25.04	1.44
Reduced	no	0-6	1.47	0.07	27.45	1.18
	no	6-12	1.58	0.08	25.76	0.68
	yes	0-6	1.62	0.07	25.41	0.85
	yes	6-12	1.66	0.06	24.36	0.55
Conventional	no	0-6	1.43	0.01	27.96	1.48
	no	6-12	1.55	0.03	25.28	0.56
	yes	0-6	1.61	0.03	25.18	2.11
	yes	6-12	1.63	0.06	23.94	2.16

1 $LSD_{(0.05)}$ = 0.02 (g/cm^3) and 0.61 (g/g) in comparison between wheel traffic and no wheel traffic for bulk density and gravimetric water content measurements, respectively.

2 $LSD_{(0.05)}$ = 0.03 (g/cm^3) and 0.61 (g/g) in comparison between 0 to 6 in. depth and 6 to 12 in. depth increments for bulk density and gravimetric water content measurements, respectively.

Figure 1. Bulk densities measurements with and without wheel traffic by depth.

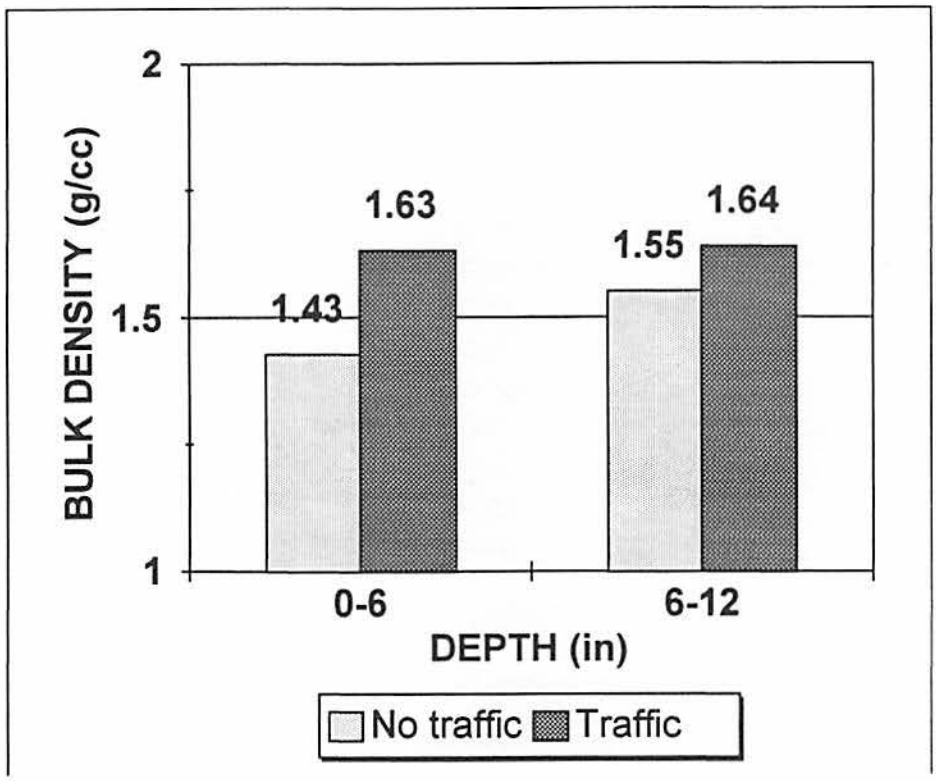

Table 3. Soybean yields 1986 - 1993.

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	Average
	(bu/ac)								
Notill	47.4	39.3	26.9	40.9	44.7	40.3	35.9	19.8	37.8
Ridge Tillage	47.2	38.7	26.7	49.2	48.7	41.3	35.3	31.5	38.5
Conv.	47.9	38.8	32.7	48.8	51.8	48.0	37.3	38.9	40.8
Reduced	46.7	39.5	26.3	45.8	51.6	46.2	37.7	34.5	38.5
Spr. till	48.9	37.0	26.2	47.1	45.4	44.4	36.5	33.1	38.2
$LSD_{0.05}$	1.5	1.4	1.5	2.6	2.6	3.5	2.0	2.9	1.4

Table 4. Corn yields 1986 - 1993.

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	Average
	(bu/ac)								
Notill	142.0	132.4	73.7	122.2	114.5	133.4	134.2	71.9	116.1
Ridge Tillage	145.4	125.4	82.2	132.6	118.4	128.9	145.3	72.0	119.6
Conv.	141.5	136.4	76.7	139.0	137.2	132.2	153.6	76.6	125.2
Reduced	139.8	124.8	70.1	128.1	120.5	133.6	130.7	75.1	115.9
Spr. till	132.4	119.8	65.4	131.8	122.8	132.6	136.6	73.4	114.1
$LSD_{0.05}$	11.7	6.7	6.7	6.9	6.0	6.2	10.2	4.3	5.4

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1993

Month/ Period	Dates/ Period	Precipitation 1993	Precipitation 100-yr. average	Precipitation Dev. from av.	Air Temperature 1993	Air Temperature 100-yr. average	Air Temperature Dev. from av.	Soil Temperature (10 cm depth) 1993	Soil Temperature (10 cm depth) 10-yr. average
January	1-31	0.89	0.68	+0.21	7.4	8.0	- 0.6	27.2	20.7
February	1-28	0.36	0.67	- 0.31	10.7	12.8	- 2.1	29.5	23.9
March	1-31	1.68	1.13	+0.55	23.9	26.7	- 2.8	31.2	29.2
April	1-10	0.41	0.57	- 0.16	38.0	38.0	0	38.9	
	11-20	0.98	0.64	+0.34	43.4	44.4	- 1.0	41.9	
	21-30	0.46	1.05	- 0.59	42.4	48.3	- 5.9	47.6	
Total/ av.		1.85	2.26	- 0.41	43.0	43.6	- 0.6	42.8	41.4
May	1-10	2.60	0.77	+1.83	57.6	52.0	+ 5.6	55.8	
	11-20	0.12	0.95	- 0.83	56.2	55.8	+ 0.4	61.2	
	21-31	3.46	1.25	+2.21	55.6	60.0	- 4.4	58.2	
Total/av.		6.18	2.97	+3.21	56.4	56.1	+ 0.3	58.4	57.1
June	1-10	0.33	1.29	- 0.96	58.3	63.0	- 4.7	61.7	
	11-20	3.06	1.30	+1.76	64.8	66.3	- 1.8	66.8	
	21-30	2.08	1.37	+0.71	64.8	68.1	- 3.3	69.6	
Total/av.		5.47	3.96	+1.51	62.6	65.8	- 3.2	66.0	69.3
July	1-10	5.13	1.44	+3.69	66.4	70.1	- 3.7	67.7	
	11-20	1.10	1.06	+0.04	67.2	71.4	- 4.2	70.7	
	21-31	1.68	1.01	+0.67	70.4	71.4	- 1.0	73.5	
Total/av.		7.91	3.51	+4.40	68.1	70.9	- 2.8	71.0	76.7
August	1-10	0.23	1.04	- 0.81	65.8	70.4	- 4.6	74.8	
	11-20	2.08	0.93	+1.15	71.0	69.0	+ 2.0	76.2	
	21-31	0.53	1.04	- 0.51	68.3	66.9	- 1.4	73.9	
Total/av.		2.84	3.01	- 0.17	68.4	68.7	- 0.3	74.9	73.9
September	1-30	2.14	2.20	- 0.06	53.2	59.0	- 5.8	60.6	61.5
October	1-31	1.06	1.74	- 0.68	43.9	47.2	- 3.3	48.9	47.8
November	1-30	1.66	0.97	+0.69	26.3	29.7	- 3.4	35.1	33.6
December	1-31	0.77	0.68	+0.09	14.8	15.2	- 0.4	34.6	23.4
Growing Season	4/1-8/31	24.25	15.71	+8.54	59.8	61.0	- 1.2	62.7	63.8
Annual	1/1-12/31	32.81	23.78	+9.03	40.0	42.0	- 2.0	48.5	46.7

LONG-TERM CORN-SOYBEAN TILLAGE[1]

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

Abstract

This study covers the results of the eleventh year of a continuous tillage study at Morris, MN to evaluate the interaction of tillage with various other factors in a corn-soybean rotation. In 1993 the study was seeded to soybean following various K placement and hybrid treatments in 1992. There were no significant effects of K placement or hybrid from the previous year's treatment, but soybean yields were significantly lower with ridge till and no till than with moldboard plow and chisel plow. Yields on chisel plow were significantly higher than on moldboard plow.

Materials and Methods

This is eleventh year of a continuous tillage experiment carried out on a Tara silt loam (Pachic Udic Haploborall, fine-silty, mixed) 2 miles east of Morris, MN. A randomized, split-block design with four replicates was established in the fall of 1983. At initiation, blocks were randomly subdivided between four tillage treatments; no-till (NT), fall chisel plowing (CP), fall moldboard plowing (MP), and ridge tillage (RT). For RT, the ridging operation was performed each year in mid- to late-June except when the plots were in soybeans when ridging was performed in July. A Hiniker Econ-0-Till cultivator was used to move the soil to the inter-row area to effect a height difference of about 6 to 9 in. After tillage initiation, each plot continued to receive the same tillage treatment. Tillage blocks measured 110 ft by 40 ft. Tillage blocks were randomly divided into five sub-blocks. Because of record rainfall in 1984 and 1992, the usual fall moldboard and fall chisel operations were carried out the following spring prior to planting.

From 1983-1989 the plots were in continuous corn with sub-blocks in N fertilizer x hybrid combinations. In 1990 the study was in a soybean inoculation study. In 1991 and 1992 the study was again in corn with sub-blocks in K placement x hybrid combinations. The treatments in 1991 and 1992 were as follows:

Treatment	Description
1	Control (no K_2O) + 124 lb/ac 10-34-0 starter
2	200 lb/ac 7-21-7 starter
3	40 lb/ac K_2O in row-band (fall) + 124 lb/ac 10-34-0 starter
4	80 lb/ac K_2O broadcast (fall) + 124 lb/ac 10-34-0 starter
5	40 lb/ac K_2O in row-band (fall) + 200 lb/ac 7-21-7 starter

Each fertilizer sub-block was further subdivided into two hybrid plots; Pioneer 3732 and Pioneer 3737. In 1993 the study was seeded to soybeans with no further treatment to the sub-blocks. In 1993 corn stalks were chopped on May 4. The MP and CP treatments were applied on May 19. These two treatments were field cultivated twice in preparation for seeding. All tillage treatments were seeded with a Hiniker planter on May 20 to Evans soybeans at 15-20 seeds/foot in 30-inch rows. The planter was set for ridge till planting for all plots to eliminate turning for each plot (enabled us to straighten rows between tillage blocks). The study was sprayed with Lasso at 3 lb/ac a.i. preemerge on May 20. Poast at 0.42 lb/ac a.i.+ COC at 1 qt/ac were applied postemergence on June 12. The MP and ACP plots were cultivated on July 20 and July 29. The RT plots were cultivated on July 20 and ridged on July 30. The first killing frost was on September 15. All plots were harvested on October 6 with a plot combine. Plot yields and seed moisture were recorded.

Results and Discussion

There were no significant effects of the previous K placement or hybrid treatments. There were significant effects of tillage (Table 1). RT and NT were significantly lower yielding than MP and CP, and CP was significantly higher yielding than MP.

Table 1. Effect of tillage treatments on soybean yield in 1993.

Tillage	Grain Yield
	- - bu/ac - -
Chisel plow	35.3 a
Moldboard plow	32.8 b
Ridge till	26.7 c
No till	26.0 c
C.V. (%)	13.6
Pr>F	0.001

[1] Support for this project provided by the West Cent. Exp. Sta., Univ. of Minnesota.

[2] Professor and Asst. Scientist, West Cent. Exp. Sta., Univ. of Minnesota.

MATCHING PRECISION PLACEMENT OF POTASH FERTILIZER TO ROOT GROWTH IN A RIDGE-TILL PLANTING SYSTEM

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ABSTRACT: Early growth, K concentration and uptake, and grain moisture and yield were compared for two tillage systems (fall chisel, ridge-till), two hybrids (Pioneer 3732, Pioneer 3737), and three potash fertilizer treatments (control, 40 lb. K_2O per acre banded, 40 lb. K_2O per acre broadcast). Early growth, K uptake, and total dry matter yields were greater in the fall chisel system and for the Pioneer 3737 hybrid. Banded application of K_2O also improved early growth and dry matter yield especially in the ridge-till planting system. Potassium uptake was always highest from the banded K_2O application, with little difference between the broadcast and control treatments. The Pioneer 3737 hybrid has higher root activity and root density in the surface, especially at interrow positions more than 3 inches from the row. The Pioneer 3732 hybrid had a higher root activity and root density was deeper in the profile early in the growing season.

Introduction:

Potassium (K) deficiency is a common problem and/or concern for corn planted in either ridge-till or no-till planting systems in Minnesota, Iowa, and South Dakota, and can cause substantial reductions in corn yields. This deficiency occurs even though soils may have a high or very high level of soil test K. The severity of the deficiency also varies with hybrid. Past research has shown that an annual banded application of 40-50 lb. K_2O per acre per year will correct the problem. This early research was summarized in the Proceedings of the 1992 North Central Extension-Industry Soil Fertility Conference.

The findings summarized in that report were the catalyst for the present research. Since response to potash varied with hybrid, it seemed that the explanation for the need for potash fertilization in these conservation tillage systems was related to differences in root growth and development as affected by tillage. The purpose of the research summarized in this report was to identify the physiological basis for early season K deficiency in ridge-till planting systems by comparing the development and morphology for a sensitive and a tolerant hybrid in ridge-till and fall chisel planting systems.

Objectives:

The research described in the study that is summarized in this report is designed to:

1. Determine more precisely the effect of potash placement on root growth and subsequent corn yield in a ridge-till planting system as contrasted to a fall chisel planting system.

2. To quantify root growth in both ridge-till and fall chisel planting systems as affected by corn hybrid.

Materials and Methods: This study is being conducted at the West-Central Experiment Station of the University of Minnesota at Morris. Three factors (tillage system, hybrid, K_2O treatment) are combined in a randomized complete block design with four replications. A split-plot arrangement is used. Tillage systems (fall chisel, ridge-till) are used as the main plots. The sub-plots are hybrids (Pioneer 3732, Pioneer 3737) and potash fertilizer treatment. The three potash fertilizer treatments are: 1) control, 2) 40 lb. K_2O per acre in a fall applied band, and 3) 40 lb. K_2O per acre broadcast in the fall.

When applied in a band, the K_2O supplied as 0-0-60 was placed at a depth of 3-4 inches below the soil surface directly below the existing row. The banded and broadcast applications were made before the fall chisel operation. All treatments received 10-34-0 as a starter at planting and ample N as anhydrous ammonia in the fall. A recommended herbicide program was used for weed control after planting.

One major objective of this study is to quantify root activity. To do this, strontium (Sr), rubidium (Rb), and lithium (Li), all non-essential cations, are injected by hand to various depths at a distance of 4 inches perpendicular to the row. These tracers are injected shortly after corn emergence. Plant and soil samples are collected at approximately 30 (V4), 40 (V6-V8), and 60 (tasseling) days after planting. The plant samples are dried, weighed, ground, and analyzed for K, Sr, Rb, and Li. Total uptake of the tracers is computed on a per plant basis and is used as an estimate of root activity. Amounts of these non-essential cations taken up by plants in a non-treated area are subtracted from uptake of plants in the treated area to determine the net uptake of the tracer. The uptake of Sr, Rb, and Li by corn differs because of differences in the chemistry of the ions and the physiology of each ion in the plant. Therefore, uptake of the tracer cations is converted to a common measure (net Rb uptake per plant). To do this, plots are established in a border area where the same amounts of Sr, Rb, and Li are injected at the same depth to determine ratios of uptake of Rb/Sr, and Rb/Li.

Soil samples are collected at 0 and 2 inches from the row at 30 and 45 days after emergence. Soil is separated into 0-3 and 3-6 inch depths. Roots are separated from the soil by washing and root length is then calculated. Root density is calculated from the root length and soil volume measurements. Soil samples for measurement of root length are also taken from the control treatments.

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Root Density As Measured By The Root Core Technique:

In addition to the use of the tracer injection technique to measure root activity, root density was measured from soil cores taken at the V4 and V8 growth stages. The results of the sampling at the V4 stage are summarized in Table 3. Results from the sampling at the V8 growth stage are provided in Figures 1 and 2.

Table 3. Root length density at V4 as measured by the root core technique, 1993.

		Tillage System and Distance From Row			
		Ridge-Till		Fall Chisel	
		Distance from Row		Distance from Row	
Hybrid	Depth	0 in.	2 in.	0 in.	2 in.
		cm/cm³			
3732	0 - 3	0.07	0.08	0.37	0.30
	3 - 6	0.04	0.05	0.08	0.05
3737	0 - 3	0.27	0.24	0.31	0.29
	3 - 6	0.04	0.04	0.08	0.07

In 1993, there were dramatic differences in root density between the two hybrids planted in the ridge-till system. Pioneer 3737 had three to four times greater root density in the 0-3 inch increment. There was little or no difference between hybrids for the 3-6 inch depth increment. In evaluating this data, it is important to remember that the excessively cool and wet weather conditions probably inhibited a substantial amount of root growth below three inches in the early part of the growing season.

For the second sampling, cores were taken in the row and at positions 3, 6, and 12 inches from the row. Although samples were collected to a depth of 24 inches, the results from the 0-6 and 6-12 inch depths are shown because they show the largest differences.

In 1993, there were much larger differences between tillage systems and between hybrids than measured in 1992. The roots in the fall chisel system were twice as dense as in the ridge-till planting system (maximum root density = .59 cm/cm³ and .30 cm/cm³ in fall chisel and ridge-till planting systems). Pioneer 3737 had a higher root density than Pioneer 3732. In the ridge-till planting system, there was little difference in root density between hybrids at the in row and 3 inches from the row positions. But, the root system of Pioneer 3737 was much more dense at 6 and 12 inches from the row in the ridge-till planting system (Figure 2). In the fall chisel system, Pioneer 3737 had a root system that was twice as dense as the root system from Pioneer 3732 at the 0-6 inch depth (Figure 2).

Potash Effects on Root Distribution:

The effect of potash fertilization on root activity is summarized in Table 4. The data show that there was increased root activity at the 6 and 12-inch depths from banded application.

Table 4. Effect of placement of potash fertilizer on root activity at three depths as estimated by net rubidium uptake.

	Time of Sampling and Depth								
K_2O	3 inches			6 inches			12 inches		
Treatment	30	40	60	30	40	60	30	40	60
	mg net Rb uptake/plant								
control	0.26	2.47	7.70	0.11	0.83	4.29	0.001	0.02	0.70
40 lb. K_2O/acre (band)	0.36	2.48	4.72	0.07	1.17	3.90	0.002	0.02	0.89
40 lb. K_2O/acre (bdcst)	0.16	2.42	4.85	0.05	0.58	4.58	0.002	0.01	0.68

Summary of Root Data: Both types of root measurements indicate that Pioneer 3737 has higher root activity and higher root density in the surface, especially at interrow positions more than 3 inches from the row. Pioneer 3732 had a higher root activity and root density was deeper in the soil profile early in the growing season. By tasseling, the root development of Pioneer 3737 catches up. In the ridge-till planting system, Pioneer 3737 extends more roots laterally and fewer vertically in the early growth stages. By contrast, Pioneer 3732 develops most of the root system near the row and then extends vertically. Since potassium accumulation occurs very near the soil surface in the ridge-till planting system, the root morphology of Pioneer 3737 should stimulate the uptake of potassium at the early growth stages of corn.

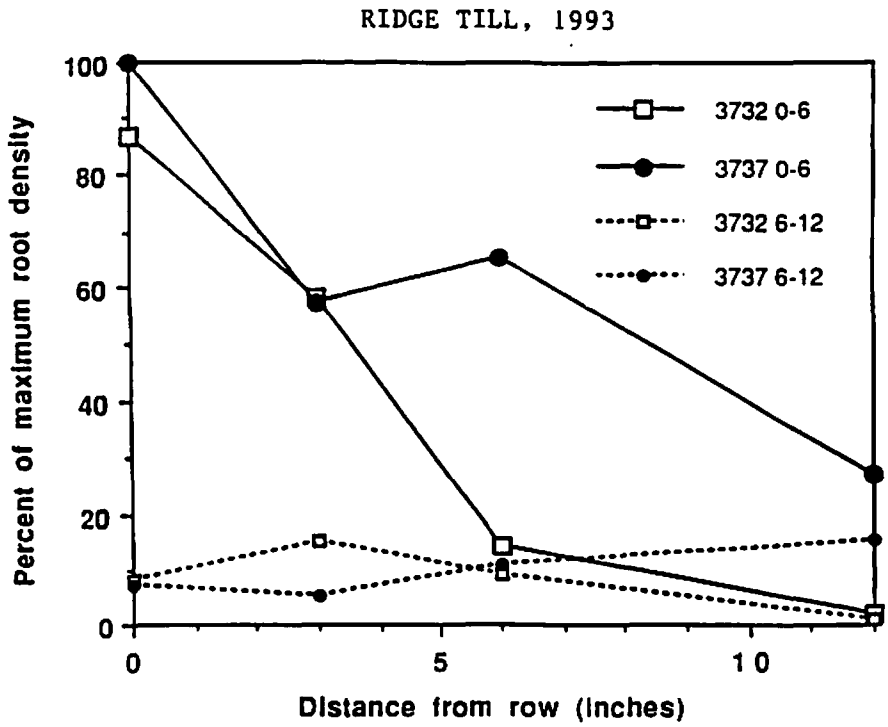

Fig. 1. Percent of maximum root density (0.30 cm/cm^3) at V8 as measured by the root core technique.

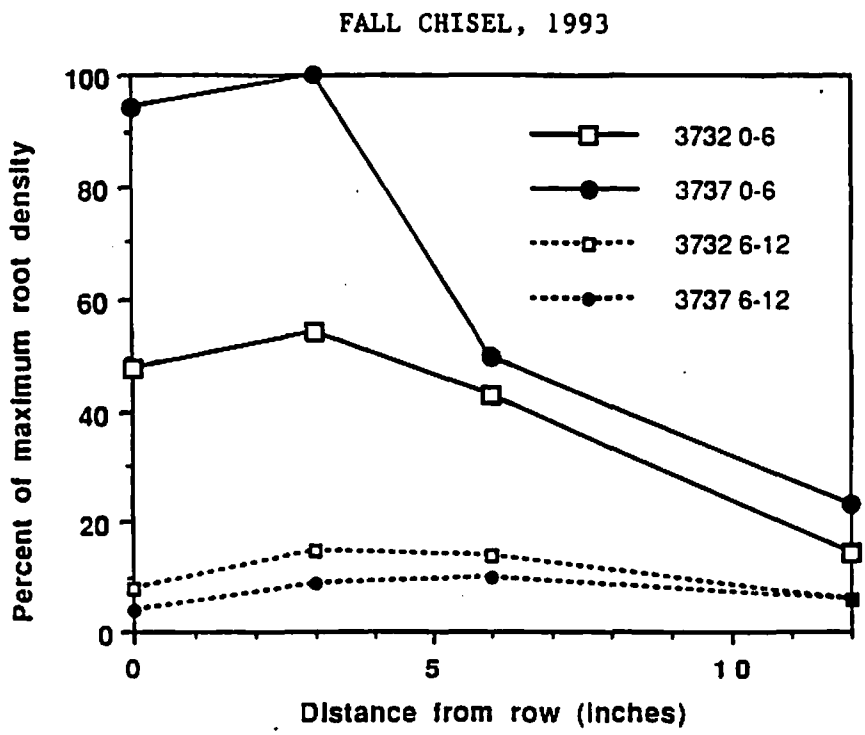

Fig. 2. Percent of maximum root density (0.59 cm/cm^3) at V8 as measured by the root core technique.

Total dry matter production was measured at physiological maturity in 1993. There were no grain yields because of the excessively cool and wet growing season.

Results and Discussion:

The excessively cool and wet growing conditions limited corn growth and caused substantial delays in maturity in 1993. Consequently, there was no harvest for grain. Instead, total dry matter yields were measured. These yields are reported in Table 1. Dry matter production was significantly affected by tillage system, hybrid, and management of the potash fertilizer. When averaged over other factors, yields were higher with the fall chisel planting system. The yield from Pioneer 3737 was higher than the yield from Pioneer 3732. There was a highly significant response to potash with the banded application being superior to the broadcast application. The largest response to potash use was measured when Pioneer 3732 was planted in the ridge-till planting system. The effect of the three factors on total dry matter yield in 1993 parallels the effects on grain yields measured in 1992.

Table 1. The effect of tillage system, hybrid, and management of potash fertilizer on dry matter yield of corn. 1993.

Tillage System	K_2O Management	Corn Hybrid 3732	Corn Hybrid 3737
		- lb. dry matter per acre -	
fall chisel	none	7213	8055
	40 lb. K_2O (band)	8675	9546
	40 lb. K_2O (broadcast)	7944	8293
ridge-till	none	5665	7343
	40 lb. K_2O (band)	8860	7484
	40 lb. K_2O (broadcast)	7151	8274

soil test K = 161 ppm

The measure of the uptake of the non-essential cations (Sr, Rb, Li) injected at depths of 3, 6, and 12 inches was used as an evaluation of root activity. Root activity data for 1993 are summarized in Table 2. The uptake of Sr and Li was normalized to Rb uptake and all uptake data are reported as mg net Rb uptake per plant.

Table 2. Root activity at three depths as estimated by net rubidium uptake during the 1993 growing season

	Time of Sampling and Depth								
	3 inches			6 inches			12 inches		
Treatment	30	40	60	30	40	60	30	40	60
	mg net Rb uptake/plant								
Tillage Main Effects:									
Fall Chisel	0.32	2.91	5.83	0.10	1.13	4.66	0.001	0.02	0.65
Ridge-Till	0.23	1.99	5.68	0.05	0.58	3.85	0.002	0.02	0.87
Hybrid Main Effects:									
3732	0.21	2.28	4.97	0.09	0.97	4.35	0.001	0.02	0.65
3737	0.34	2.63	6.55	0.06	0.74	4.16	0.002	0.01	0.85
Tillage X Hybrid Interaction:									
Chisel Plow:									
3732	0.19	2.97	5.37	0.13	1.22	4.70	0.001	0.017	0.61
3737	0.46	2.86	6.29	0.08	1.05	4.62	0.001	0.015	0.69
Ridge-Till:									
3732	0.23	1.58	4.57	0.06	0.71	4.00	0.001	0.024	0.73
3737	0.22	2.41	6.80	0.04	0.44	3.70	0.003	0.013	1.00

In 1993, root activity was greater at all sampling times when the fall chisel planting system was used. This activity was approximately 40% higher at the 3-inch depth and 100% higher at the 6-inch depth. When averaged over tillage treatments, Pioneer 3737 had higher root activity than Pioneer 3732 at the 3-inch depth. The reverse was true at the 6-inch depth. In general, effects of tillage system and hybrid on root activity were consistent for both 1992 and 1993.

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

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Abstract

The effects of application of liquid swine and liquid dairy manure applications on soil NO_3-N content and various crop parameters were evaluated for one season following fall injection. All manure treatments increased soil NO_3-N at corn emergence and at stage V5. Chlorophyll meter readings at stage V5 varied only slightly from the inorganic check, but just prior to tasseling the differences were much greater. Corn silage yield, grain yield, grain moisture, and grain N content were significantly affected by both urea and manure applications. There was a positive relationship between soil NO_3-N to a 2-ft depth at corn stage V5 and corn grain yield.

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.

Materials and Methods

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 and the other to commence with manure and fertilizer applications in the fall of 1993.

Treatment areas were staked out in the first site on October 5, 1992. The design was a randomized, compete 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). On October 6 the site was grid sampled on the corners of every second plot to determine depth of topsoil, soil drainage characteristics, soil pH, soil organic matter content, and depth to carbonates. Samples were air dried and saved for analysis. Each replication was sampled for N content on October 6 by compositing 10 random probes to a depth of 5 feet in 1-ft increments. The samples for N analysis were air dried. The initial NO_3-N values averaged over replicates were as follows: 0-1 ft = 4.0 ppm, 1-2 ft = 2.0 ppm, 2-3 ft = 6.7 ppm, 3-4 ft = 8.6 ppm, and 4-5 = 13.1 ppm. Fertilizer was applied broadcast to the entire study on October 13 to provide 75 lb/ac P_2O_5 and 75 lb/ac K_2O. The entire study was chisel plowed on October 14. The study was field cultivated on October 15 to level the soil to insure uniform manure application.

Manure rates were based on estimates of N content of the manures from previous samplings (Table 1). On October 19 the first 3 swine manure treatments were applied to provide 80, 160, and 240 lb/ac N and on October 20 the highest swine manure treatment was applied to provide 320 lb/ac N. All dairy manure treatments were applied on October 20 to provide 80, 160, 240, and 320 lb/ac N. 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 taken at this time 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 very accurate, uniform application. The applicator was outfitted with 4 18-inch sweeps, 24 inches on center, for a total applicator width of 7.5 ft. Two passes were required for each plot. Application of all manure rates, except for the 320-lb dairy rate, were at a 4-5-inch depth with a single pass. For the 320-lb dairy rate one -half the manure was

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applied at a 5-6 inch depth on an initial pass and the other half at a 3-4-inch depth with a second pass. Inorganic fertilizer as urea was applied to provide 40, 80, 120, and 160 lb/ac N. The entire study was field cultivated on October 22 to incorporate the inorganic fertilizer and remove wheel tracks from the manure applicator.

In the spring of 1993 the study was field cultivated (April 28) parallel to the manure applicator bands and future row direction. The study was planted on April 28 to Ciba-Geigy 4172 at 30,100 seeds/ac. Counter 15G was applied at 8.7 lb/ac at seeding with the planter. Lasso (3 lb/ac a.i.) + Bladex (2.2 lb/ac a.i.) was broadcast preemergence on April 29.

All plots were soil sampled in 0-1 and 1-2 ft increments on May 17 at the emergence stage of corn for soil N content. 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). The study was sprayed with a postemergence application of Atrazine (2 lb/ac a.i.) + 1 qt/ac COC on June 18 for additional grass control. At the V5 stage of corn growth all plots were soil sampled using the same procedures as at the emergence stage. Reps 1 and 3 were sampled on June 22, and reps 2 and 4 were sampled on June 28. The delay in sampling was due to a 0.34-inch rainfall on the afternoon of June 22. Total rainfall between ceasing sampling on June 22 and beginning on June 28 was 2.29 inches. All soil samples at emergence and V5 were dried at 100°F.

Chlorophyll meter readings were taken at V5 stage on June 25 and again on July 26, just prior to tasseling. Meter readings were taken halfway between the midrib and the leaf edge, halfway between the stalk and the end of the leaf, on the most recently fully extended leaf. The study was cultivated on June 28 with a 6-row cultivator.

Silage yields were taken from 45 ft of row on September 16. Ears and stover were weighed separately and 5 stalks and the center 3/4 inch of 10 ears was saved for moisture and N analysis. Basal stalk samples from 10 plants (an 8-inch section from 6 to 14 inches from the soil surface) were collected on October 1 and saved for NO_3-N analysis. Grain yields were taken from 45 ft of two center rows on October 11 with a plot combine and a grain sample was saved for test weight and N analysis.

Post harvest soil samples were taken to a depth of 5 ft in 1-ft increments. Reps 1 and 2 and plots 302-305 (rep 3) were sampled on October 14, plots 301, 306-313, and 401-404 were sampled on October 15, and plots 405-413 were sampled on October 18. The plots were sampled using the same procedures as at the emergence stage. These samples were dried at 100°F. Urea was applied on October 18 to the same plots and rates as in the fall of 1992. The study was chisel plowed on October 18.

Results and Discussion

Manure Application

The target N rates were not achieved because of differences in manure N content measured at application (Table 2). Swine manure N rates were about 58% of the target and dairy manure N rates were about 115% of the target values.

Soil N Content

There were significant effects of treatment on soil NO_3-N content at all sample dates and depth combinations shown (Table 3). The NO_3-N values with both manures in the 0-1 and 0-2 ft depths at emergence were very similar to that with urea, except for D4 where the values were about 90% above those of F4.

At corn stage V5 the NO_3-N values were much lower than at emergence (Table 3), but there were still significant treatment effects. Precipitation at the site between the May 17 sampling date and June 22 was 7.78 in (long-term average = 4.35 in). The total precipitation between May 17 and the completion of V5 sampling on June 28 was 10.07 in (long-term average = 5.06 in). The amounts of NO_3-N in the second foot were about the same as that in the first foot indicated by the similarity between the 0-1 and 0-2 ft values. In general, the NO_3-N values increased as applied N increased.

In October after harvest the NO_3-N values of the 0-1 and 0-2 ft zones were much lower than at the earlier two sampling dates. There were significant treatment effects of all depth increments (Table 3). There was considerable NO_3-N below the 0-1 ft zone as indicated by the higher values in the 0-5 ft profile averages.

There were no significant effects of treatment on soil NH_4-N values at emergence, V5, and post harvest.

Plant Measurements

Relative chlorophyll meter readings were significantly affected by treatment on both measuring dates (Table 4), even though the range was very small on June 25. The F4 treatment was used as the corn with adequate N, but ratios at high manure rates were slightly higher than those on F4. The relative chlorophyll readings of S1 through S4 and D1 through D4 were similar to F1 through F4, respectively.

Silage dry matter yield increased with the first two increments of all N sources (Table 4). There were very small if any increases with the third and fourth increments of all N sources.

The maximum grain yield was 106.4 bu/ac with D4. Both grain and silage yields were limited by the excessive rainfall, cool temperatures, and low solar radiation during the 1993 growing season. Grain yield, grain moisture, bushel weight, and grain N were all significantly affected by treatment (Table 4). Grain yields appeared to respond to the actual N applied and the resulting soil NO_3-N levels. It appeared that 160 lb/ac N as urea was not sufficient for maximum yields in 1993 due to losses by leaching and denitrification. With the manure sources, N release during the growing season continued to supply the plant with N, resulting in higher yields with S4 and D4. However, the differences were not significant due to the high coefficient of variation. Grain moisture appeared to decline slightly as N rates increased. Grain test weight was lower than normal, but there were no apparent trends due to treatment. Grain N content increased with applied N. Significant differences were observed in the comparison of CK, F1, S1, and D1 with F3, S4, D3, and D4.

The relationship between grain yield and soil NO_3-N values (0-2 ft) at corn stage V5 is shown in Fig. 1. The best relationship (r^2 = 0.81) was with inorganic N sources. With the organic sources the r^2 = 0.49. The plot of all the data (the top graph in Fig. 1) indicates that yield reached a plateau at about 15 ppm NO_3-N in the 0-2 ft zone at corn stage V5.

Table 1. Nitrogen content of manure used.

Manure Source	Time of Sample	Total N	Organic N	NH_4-N	Available N†
		lb/1000 gal			
Swine	Pre-application‡	44.6	22.7	21.9	28.7
Swine	During application§	31.5	18.2	13.4	18.9
Dairy	Pre-application‡	28.0	14.0	14.0	18.2
Dairy	During application§	35.6	17.4	18.3	23.5

† Available N = NH_4-N + 30% of organic N
‡ Values from previous manure analyses from these manure sources
§ Sampled from the manure applicator in the field during application

Table 2. Treatments, target N rates, manure applied, and actual N applied at Morris, MN in October, 1992.

Treatment	N Source	Target N Rates	Manure Applied	Applied N Rates†
		- lb/ac -	- gal/ac -	- lb/ac -
CK	- - - -	0	0	0
F1	Urea	40	0	40
F2	Urea	80	0	80
F3	Urea	120	0	120
F4	Urea	160	0	160
S1	Swine manure	80	2440	46
S2	Swine manure	160	4880	92
S3	Swine manure	240	7180	136
S4	Swine manure	320	9740	184
D1	Dairy manure	80	3880	91
D2	Dairy manure	160	7860	185
D3	Dairy manure	240	11320	266
D4	Dairy manure	320	15730	370

† Based on actual weight of manure applied and available N values during application from Table 1.

Table 3. Effect of N source and rate on nitrate-N in the soil profile at emergence, V5, and post harvest stages of corn growth.

Treatment	N Rate	Emergence NO_3-N		V5 NO_3-N		Post Fall Harvest NO_3-N		
		0-1 ft	0-2 ft	0-1 ft	0-2 ft	0-1 ft	0-2 ft	0-5 ft
	lb/ac	--------	--------	--------	--ppm--	--------	--------	--------
CK	0	6.5	5.4	4.8	4.9	3.4	2.2	2.4
F1	40	9.3	9.0	5.5	5.8	3.5	2.3	3.4
F2	80	15.8	12.7	7.4	8.3	4.5	3.2	5.6
F3	120	19.8	16.0	10.5	11.2	4.6	2.9	5.1
F4	160	22.1	15.7	11.7	11.0	4.4	3.3	7.9
S1	46	6.9	7.4	4.6	5.2	3.5	3.6	6.5
S2	92	16.6	16.6	8.2	9.7	3.4	2.7	7.6
S3	136	24.2	23.3	15.3	16.1	6.9	5.4	9.5
S4	184	22.3	25.1	11.9	15.2	7.8	7.4	10.4
D1	91	7.7	6.2	9.1	7.3	3.8	2.4	4.3
D2	185	15.7	15.6	11.0	12.2	6.6	4.2	5.6
D3	266	17.5	16.0	11.0	10.9	6.9	4.9	6.9
D4	370	41.2	29.8	18.9	21.2	8.1	10.6	11.5
Pr > F		.0001	.0001	.0385	.0006	.0140	.0067	.0078
BLSD(.05)		9.2	5.4	9.7	6.6	3.6	4.4	5.0
C.V. (%)		32.7	22.6	46.9	35.6	35.3	55.1	39.2

Table 4. Influence of nitrogen source and rate on plant measurements: chlorophyll meter readings, grain yield, grain moisture, grain bushel weight, grainl N, and silage yield.

Treatment	N Rate	Chlorophyll†		Grain Yield	Grain Moisture	Grain test wt	Grain Tot. N	Silage DM Yield
		June 25	July 26	-bu/ac-	--%--	-lbs/bu-	--%--	-lbs/ac-
CK	0	0.98	0.72	51.7	25.7	50.7	1.17	8142
F1	40	0.97	0.81	66.0	24.3	51.1	1.19	9165
F2	80	0.99	0.89	71.8	24.4	49.3	1.26	10688
F3	120	1.04	0.93	94.7	21.0	51.8	1.38	10994
F4	160	1.00	1.00	91.5	21.1	52.0	1.32	11829
S1	46	0.97	0.83	59.1	25.6	49.7	1.22	9651
S2	92	0.99	0.89	74.0	23.2	50.5	1.31	11917
S3	136	1.00	1.01	99.3	21.2	52.2	1.33	13087
S4	184	1.03	1.02	102.8	21.5	51.2	1.48	13690
D1	91	0.95	0.79	63.8	25.7	49.5	1.19	9637
D2	185	0.97	0.97	97.6	23.5	50.8	1.39	12919
D3	266	1.00	0.97	95.9	22.6	52.2	1.46	12630
D4	370	1.03	1.01	106.4	21.3	51.3	1.43	12653
Pr > F		.0354	.0044	.0001	.0002	.0570	.0062	.0001
BLSD(.05)		0.06	0.17	22.2	2.4	2.5	0.19	1896
C.V. (%)		2.9	10.3	16.0	6.0	2.3	7.7	10.2

† Actual chlorophyll meter readings for each replicate were divided by the reading on treatment F4 for that replicate.

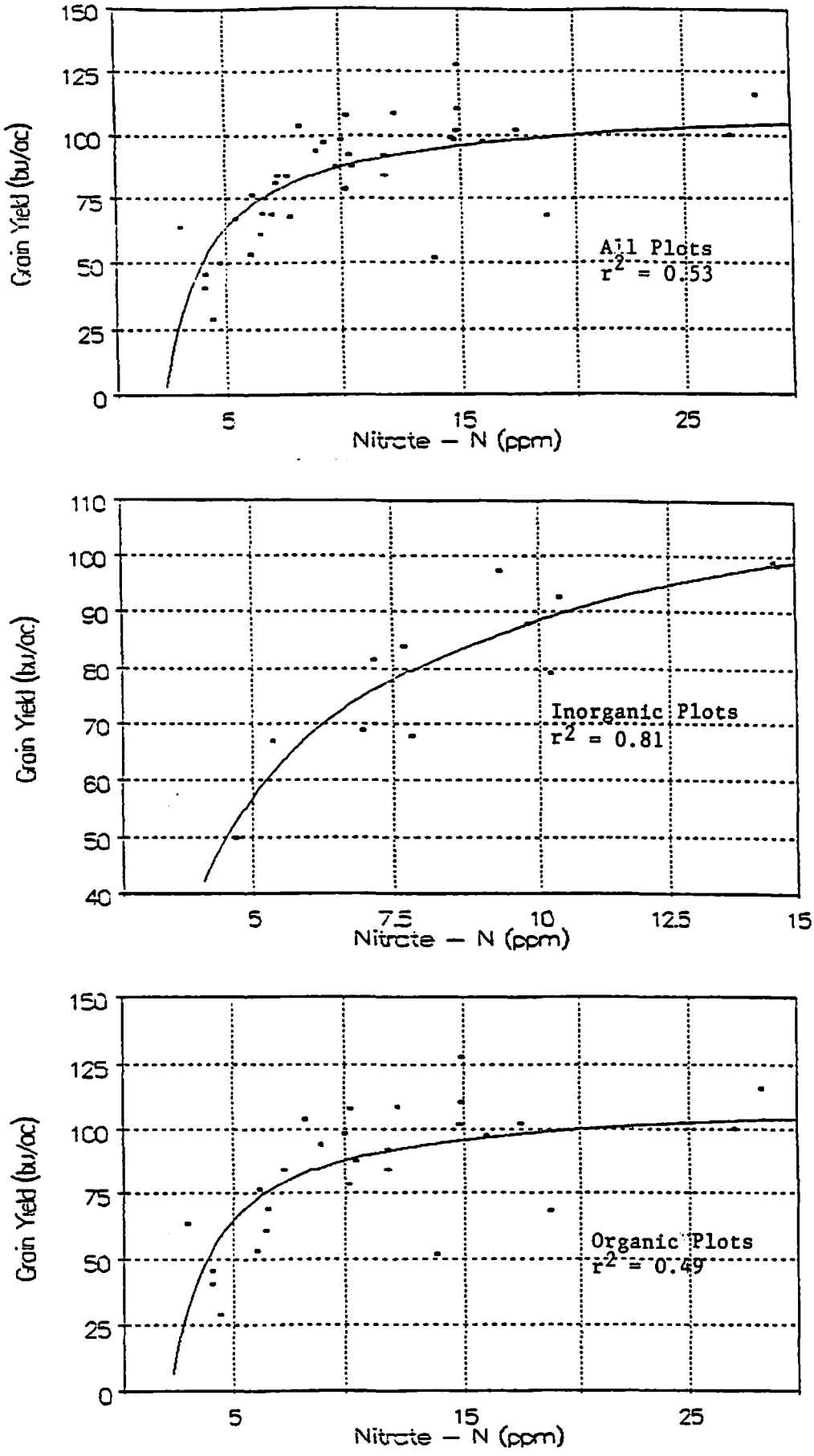

Fig. 1. Relationship between soil nitrate-N (0-2 ft. at corn stage V-5) and grain yield.

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

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

Abstract

Due to low surface depressional storage, ridge till resulted in greater runoff from snow melt. During the growing season, residue between plant rows greatly reduced runoff and sediment load with the ridge tillage system. With high rainfall, ridge till system resulted in 7 and 300 times less runoff and sediment respectively compared to moldboard plowing system. The ridge till system resulted in greater runoff, higher concentration of total-P and bioavailable-P in snow melt. Application of manure improves soil properties that results in less runoff, sediment and total-P loss.

Grain yield with the moldboard system was 1.2 Mg/ha higher compared to ridge tillage system. The grain yield difference was associated with greater number of ears with the moldboard systems. Difference in tillage systems did not result in different plant stands, broken plants due to corn borer and stover yield. The absence of interaction and similar results of with and without manure application in grain yield indicates that there is not any significant residual effect of beef manure applied in May 1992.

The incubation study indicated that Olson-P decreased exponentially both in the control and the manured soil. The greater the manure rate, the greater the decrease of Olson-P with time. This suggests that the calcareous soil is a sink for mineralized phosphorus from manure through precipitation of phosphate and calcium. The mineralization of manure-P in soil with time after application needs to be considered in estimating runoff since the amount of phosphorus in runoff is dependent on the extractable initial-P in the manured soil.

Introduction

There is considerable concern regarding the contamination of surface and ground waters from land applied agricultural chemicals. Among the contaminants are nutrients (nitrate, phosphorus), herbicides and suspended sediments. Sediment is the most visible of agriculturally derived pollutants. Sediments not only contribute to costly dredging requirements of lakes, ports, and marinas but also carry sediment-bound pollutants, such as particulate P, to surface waters such as lakes. Research indicates that for water quality management, adoption of conservation tillage reduces sediment and P loading to surface water.

The concern over phosphorus with respect to water quality is focused with stimulation of algae and other aquatic plant growth. For most water bodies, phosphorus is the key limiting nutrient for aquatic plant growth. However, 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 show that reducing sediments will not necessarily lead to a reduction in eutrophication. The importance of agriculture as a non-point source of pollutants lies in the significant association between total phosphorus increases in natural water bodies and various measures of agricultural land use, including fertilized acreage and cattle population density.

In Minnesota while pollution from point sources is decreasing, storm water from non-point sources continues to be an important pollution source of sediment, fertilizers, pesticides and other wastes. Confounding the problem of non-point source pollution in the Minnesota River Basin is 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: what degree of soil cultivation is necessary to incorporate manure while maintaining enough residue to prevent excessive erosive losses of sediment and phosphorus. The focus of this study will be to quantify and model the effect of tillage and manure interaction on phosphorus loading in surface runoff in soils of West Central Minnesota.

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[1]Support for this project was provided by the Legislature Commission on Minnesota Resources.

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Objectives

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.

3. To characterize the mineralization of manure-P mixed with calcareous Udic Haploborolls.

Materials and Methods

Objective 1

Tillage and manure interactions on sediment and phosphorus transport in surface runoff are being evaluated in the field at Morris, MN. The soil at the experimental site is a Barnes loam (fine-loamy mixed Udic Haploborolls, 12 % slope with south-eastern aspect). The soil surface layer is a black loam about 20-cm thick. The initial soil test in 1992 for pH (in water), Olson-P, Bray-P and ammonium acetate extractable K were 8, 17 ppm, 23 ppm and 155 ppm respectively.

The experimental design is a randomized complete block with split plots and three replications (tillage main plots and manure subplots). Twelve erosion plots, 22 m by 10 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 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. The plot layout is presented in Fig 1.

Tillage treatments include ridge tillage and moldboard plowing systems. Moldboard plowing allows complete soil incorporation of manure. In the moldboard system, primary tillage in fall was achieved with moldboard plowing and followed in the spring by a field cultivation prior to planting. Ridge tillage represents an intermediate level of soil incorporation. Plant residue was concentrated between plant rows during winter and spring. Ridging was done in early July. The time line of cultural practices for 1992 and 1993 is shown Fig. 2. Detailed cultural practices are presented in Table 1.

Manure treatments are with and without. Solid beef manure was applied at the rate of 56 Mg/ha. The manure contained approximately 161 kg total-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 (total-P, bioavailable-P) 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.

Bioavailable phosphorus was measured using extraction of the 20 mL of suspension with 180 mL of NaOH to make a final concentration of 0.1 N NaOH. This procedure has been correlated with algal available-P using an algal assay. Extraction with NaOH was done by shaking for 18 hours on a reciprocating shaker. The bioavailable-P was measured after filtration of suspension through 0.45 µm membrane filter, preceded by centrifugation. The phosphorus was then determined by measuring the intensity of blue molybdate as a coloring agent at wave length of 882 nm.

Objective 2

Corn was planted on the twelve erosion plots (objective 1) at the seeding rate of 79,319 seeds/ha. Seeding

was done up and down the slope. 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 stand at harvest were estimated from rows of 60 feet long. Stover yield was estimated by harvesting randomly 10 corn plants. The plants were chopped above the ground, shredded and sample was taken for moisture determination.

Objective 3

Decomposing organic material such as manure and crop residues will release phosphorus and increase soil-P. Evaluations on the release of P from plant material in an incubation study has been reported. However incubation studies on solely plant material will not explain how phosphorus is released to runoff from cultivated soils since the P released will interact with soil. There is also a lack of data on the release of P from manure and its subsequent fate in a calcareous soil. Therefore an incubation study was undertaken to evaluate the change over time of the released inorganic-P in manured-soil. This study basically characterized the mineralization of P from manure mixed with soil.

The procedure for the incubation study involved air drying of soils and oven drying of manure at 60 °C. The dried soil and manure were ground to pass a 2-mm diameter sieve. Soil was taken from 0-15 cm from the experimental field mentioned in objective 1. Fresh beef manure was taken from the Morris Experimental Station. Moisture contents of air-dried soil and oven-dried manure were determined by oven drying the samples at 105 °C. Manure and soil were then mixed at the rate of 0 g of manure/kg soil (control), 8.7 g of manure/kg soil (equivalent to the manure-soil mixing ratio of moldboard plow treatment) and 26.1 g of manure/kg soil (equivalent to manure-soil mixing ratio of the ridge till treatment). This equivalence of soil and manure was based on assumption that manure will be mixed to 15 cm depth in moldboard system and 5 cm depth with ridge till system. Soil-manure mixing was done using a rolling drum mixer.

Incubation was done in polypropylene bottles. The procedure involved weighing a 5.1 g of soil-manure mixture in each 250 mL polypropylene bottle, adding 1.34 g of water with a syringe and incubating the mixture for 0, 1, 3, 5, 10, 30 days. The amount of water corresponded to the water content at -33 kPa matric potential (field capacity). Incubation was done at a field capacity water content and temperature of 30 °C. The experiment was arranged in a completely randomized design with three replications.

At the end of each incubation time, dissolved inorganic-P was extracted with sodium bicarbonate as Olson-P. Spectroscopy determination of P was done by measuring the intensity of blue molybdate as a coloring agent at wave length of 882 nm.

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

Tillage		**Cropping History**
1992	No-till	
	Ridge till (July 21, 1992)	1991-Alfalfa
	Spring moldboard (May 6, 1992)	1992-Corn Pioneer-3751
1993	Fall Moldboard (Oct 27, 1992)	-Corn Pioneer-3617
	Spring Moldboard(Apr. 28, 1993)	-Corn Pioneer-3921
	Ridge till (July 6, 1993)	1993-Corn Pioneer-3751

Planting and Harvest Dates

Corn - was planted with a Hiniker 4 row planter with 76 cm row spacing.
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.

Table 1. Continued

1992 Applied-Manure Analysis

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

Rate of applied and available N, P_2O_5 and K_2O

Manure source	Rate	Date Applied	NH4	NO3	Mineral	Organic	available N	Total N	P2O5	K2O
			kg/ha							
Beef Manure	56 Mg/ha	May 6/92	120.4	2.8	123.2	358.4	212.8	481.6	370.7	374.1

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 to all plots.
Non-manure plots received a topdress application of 50.4 kg/ha (NH_4NO_3) in 7/6/93.

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.

Weed 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)

Results and Discussion

Objective 1.

Ridge Till vs. Moldboard Plow

At spring thaw, due to lack of depressional storage, ridge till resulted in higher runoff compared to moldboard plow. However, after secondary tillage, moldboard plowed soil resulted in rapid increase of cumulative runoff due to the lack of residue cover. The lack of residue and susceptibility to crust formation in the moldboard plow system resulted in excessive runoff from a heavy rain in early July (Fig. 3).

At spring thaw, runoff contained a trace amount of sediment in both moldboard and ridge tilled plot. During the growing season, after secondary tillage, sediment loads from the moldboard plowing system

increased rapidly. Initially due to higher runoff and total-P concentration in the snow melt, the ridge till system resulted in greater cumulative total-P losses (Fig. 3).

Due to a heavy rain in early July the moldboard plowing system had greater runoff and sediment load resulting in greater seasonal total-P loss. Similar to total-P, bioavailable-P under the ridge till system was initially higher. This was due to higher runoff and higher bioavailable-P in the snow melt (Fig.3).

The comparison between ridge till and moldboard plowing system on the cumulative loss of measured variables at the end of the season is presented (Table 2). Moldboard plowing resulted in higher cumulative runoff, sediment, total-P and bioavailable-P. Higher total-P and bioavailable-P were solely due to a heavy rainfall at the end of measurement.

Table 2. The effects of tillage and manure application on the cumulative losses, 3/29/93 (spring thaw) to 7/4/93.

	RIDGE TILL			MOLDBOARD		
	No Man	Man	Avg	No Man	Man	Avg
Runoff (cm)	3.0	1.5	2.3	5.6	4.6	5.1
Sediment (Mg/ha)	0.7	0.4	0.6	22.4	14.3	14.4
Total-P (kg/ha)	2.4	0.7	1.6	7.5	2.4	5.0
Algal-P (kg/ha)	0.2	0.3	0.3	0.7	0.4	0.6

MANURE VS. NO MANURE.

Manure application reduced runoff during winter and the growing season. This was likely due to improvement of soil structure. Manure application also reduced sediment load in runoff water (Fig. 4).

The snow melt caused greater cumulative total-P in the non-manured plots initially. Greater total-P in the snow melt was simply due to more runoff from non-manured plots; both manure and non-manured plots had similar total-P concentration. Under non-manure system, a heavy rainfall at early July which caused greater runoff and sediment load resulted in a very significant load of total-P (Fig.4).
On the contrary to total-P, despite of less runoff, bioavailable-p from the manured plots is greater initially. This was mainly due to higher concentration of bioavailable P in the snow melt from manured plots.

A heavy rainfall which resulted in an excessive runoff and sediment load in early July eliminated the difference in bioavailable-P between manured and non-manured plots (Fig. 4).

The comparison between the manure and non-manure system on the cumulative loss of measured variable at the end of measurement is presented. The non-manured system resulted in higher cumulative runoff, sediment and total-P. Bioavailable-P was similar which was due to rainfall at the end of the measurement period (Fig. 4).

Objective 2.

Grain yield differs significantly with tillage system. Average yield with the moldboard system resulted in 1.2 Mg/ha higher compared to the ridge tillage system. This significantly higher yield is partly associated with significantly greater number of corn ears with moldboard systems compared to ridge tillage systems. Differences in tillage systems did not result in different plant stands, broken plants due to corn borer or stover yield.

With and without manure application resulted in similar grain yield, numbers of corn ears, number of plants, number of corn borer damage, and stover yield. There is no significant interaction between tillage systems and manure application in any variables measured (Table 3). This indicated that there is not any significant residual effect of beef manure applied in July 1992.

Table 3. The effects of tillage and manure application on the grain yield, number of corn ears, number of plants and broken plants, and stover yield, at West central Experimental Station, Morris, MN, 1993.

	RIDGE TILL			MOLDBOARD		
	No Man	Man	Avg	No Man	Man	Avg
Grain (Mg/ha)	6.1(.4)	6.3(0.3)	6.2(0.3)	7.1(0.6)b	7.7(0.7)	7.4(0.7)a†
Ears (1000/ha)	70.1(5.5)	63.9(5.0)	67.0(5.8)b	73.7(2.2)	72.7(4.0)	73.2(2.9)a
Plants (1000/ha)	74.9(6.7)	63.1(6.5)	69.0(8.7)a	73.9(1.2)	75.3(6.4)	74.6(4.1)a
Broken Plants (1000/ha)	21.0(6.3)	13.4(2.3)	17.2(6.0)a	31.8(18.2)	27.3(9.7)	29.5(13.3)a
Stover (Mg/ha)	4.9(1.0)	5.1(0.4)	5.0(0.7)a	5.4(0.1)	5.6(0.6)	5.5(0.4)a

† different letters following the average value in the same line indicates significant difference by tillage at significant level of 0.1.

The main effects of the manure and without manure application do not differ significantly in any variables measured. Also, there is no significant interaction between tillage and manure in any variables measured (Table 4).

Table 4. Probability (P > F) value of main and interaction effects of tillage and manure on the grain yield, number of corn ears, number of plants and broken plants, and stover yield, at West central Experimental Station, Morris, MN, 1993.

	Grain yield	Number of ears	Plants	Broken Plant	Stover
Tillage	0.060	0.096	0.162	0.245	0.237
Manure	0.277	0.281	0.269	0.352	0.655
Tillage*Manure	0.496	0.413	0.177	0.802	0.959

Objective 3

INCUBATION STUDY

Olson-P decreased exponentially both in the control and the manured soil. The greater the manure rate, the greater the decrease of the slope of the regression line. The regression lines from manured treated soil converge after incubation of 30 days (Fig. 5). This suggests that the calcareous soil is a sink for mineralized phosphorus from manure.

Since desorption of P to runoff depends on the initial soil-P level, the mineralization of manure-P in the with time after application needs to be considered.

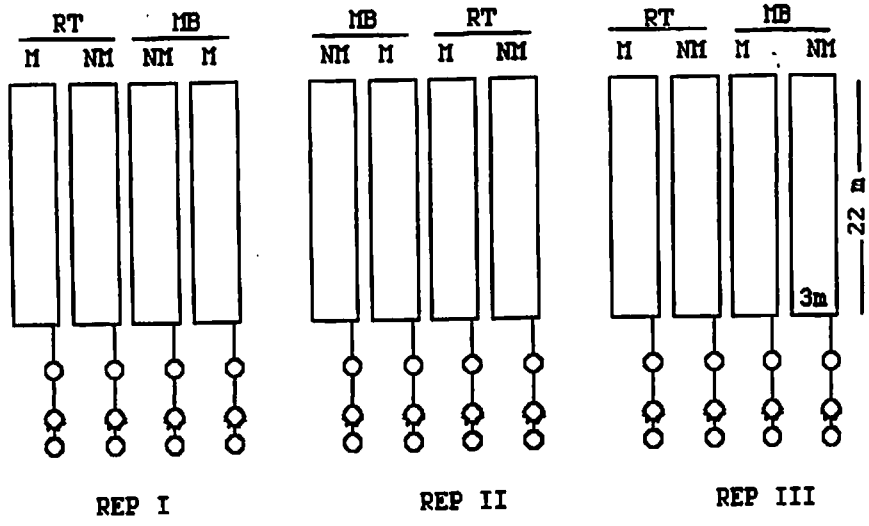


Fig. 1. Plot diagramm of erosion study at West Central Experiment Station, Morris, MN.

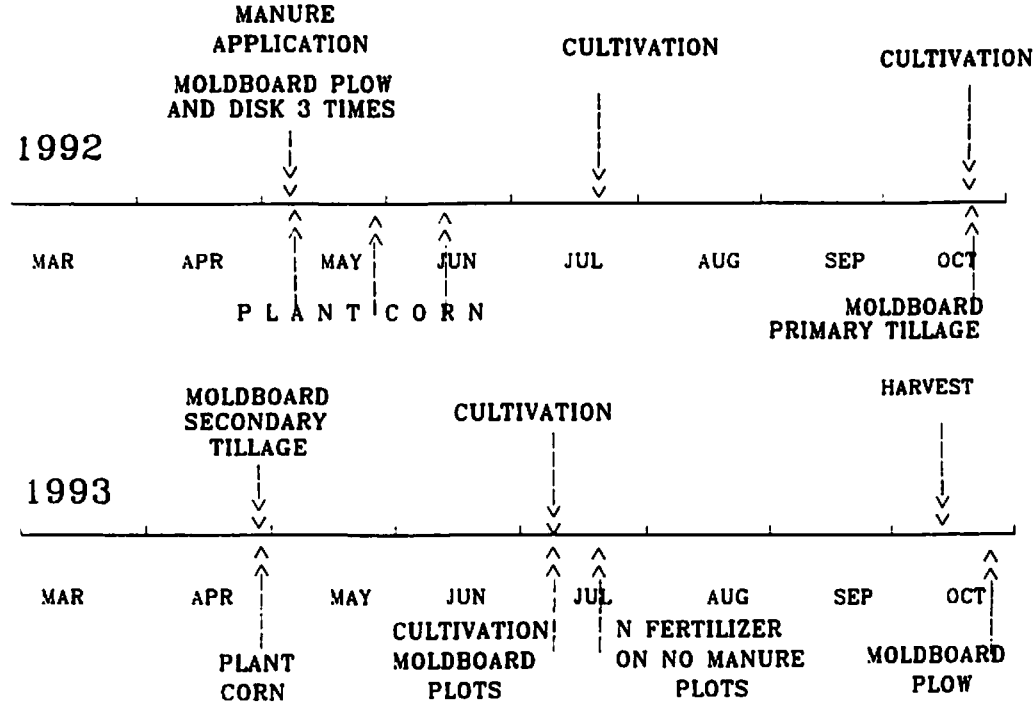


Fig. 2. Time line of cultural practices on runoff plots, Morris, MN.

Fig. 3. Tillage influence on cumulative runoff, sediment, total Phosphorus and Bioavailable Phosphorus at The West Central Experiment Station, Morris, MN

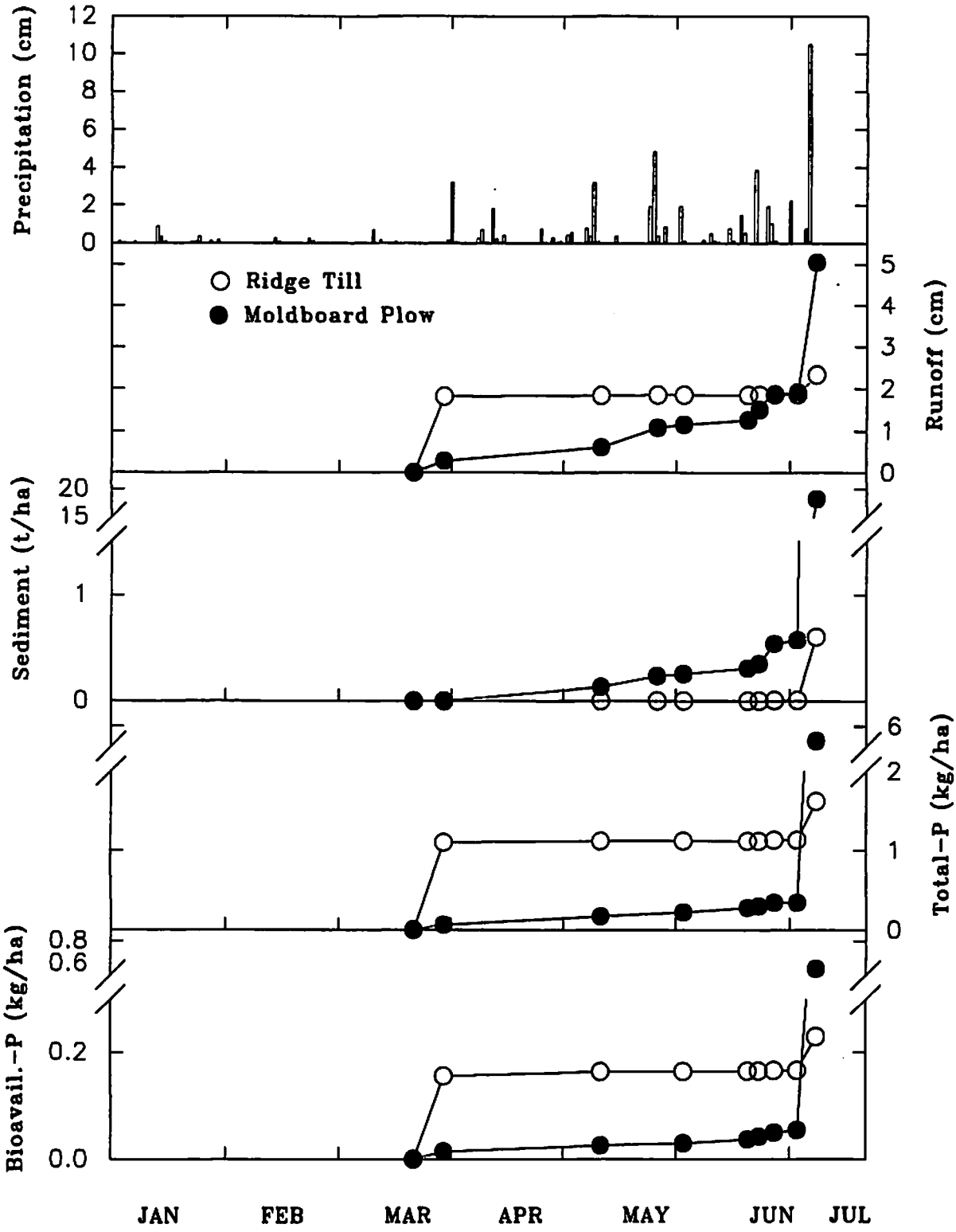
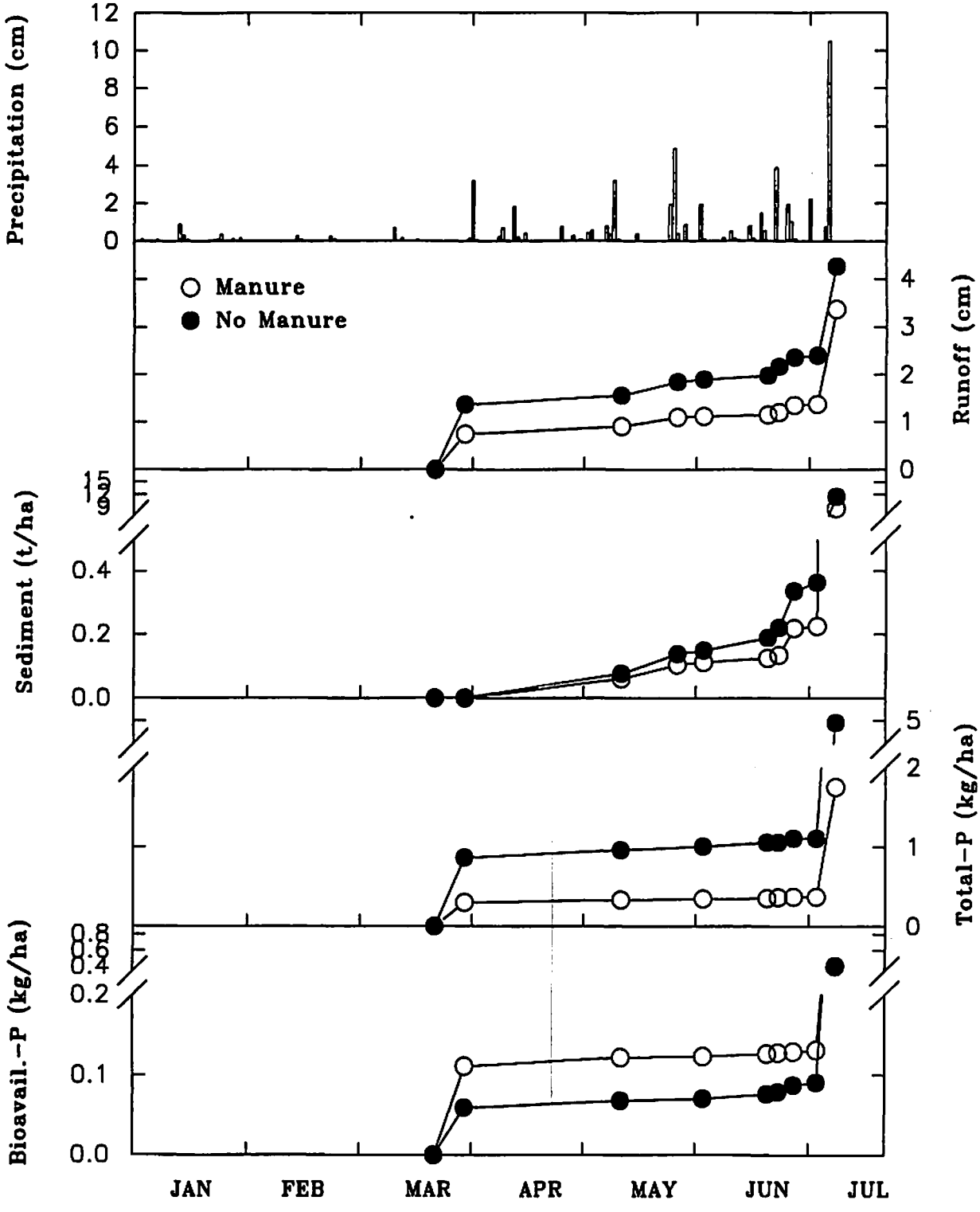
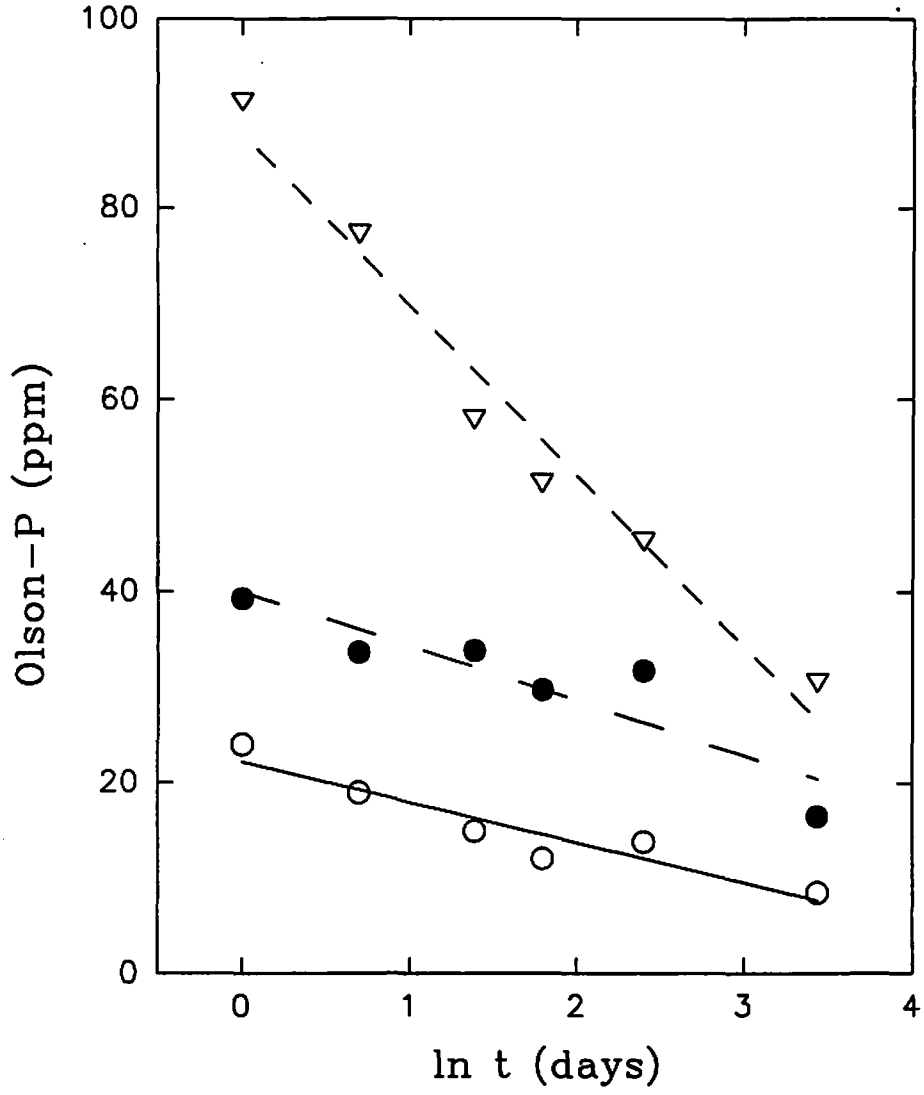


Fig.4. Manure influence on cumulative runoff, sediment, total Phosphorus and bioavailable Phoshphorus at The West Central Experiment Station, Morris, MN, 1993.





○ = 0 Mg/ha Y=22.17−4.3 ln t (r^2 =0.95)

● = 28 Mg/ha Y=39.93−5.7 ln t (r^2 =0.90)

▽ = 84 Mg/ha Y=87.64−17.8 ln t (r^2 =0.98)

Fig. 5. Sodium bicarbonate extractable-P (Olson-P) and duration of incubation relationships of manured and non-manured soil (Barnes loam: fine-loamy mixed Udic Haploborolls).

POTASSIUM FERTILIZATION OF ALFALFA GROWN ON AN IRRIGATED SANDY SOIL

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

ABSTRACT: There was a need to evaluate potassium requirements for alfalfa grown on an irrigated sandy soil. Five rates of plowdown K_2O (0, 80, 160, 240, 320 lb./acre) were combined with five rates of annual K_2O (0, 60, 120, 180, 240 lb./acre) in a complete factorial design with four replications. Three cuttings were harvested in 1993. Yields were not affected by the rate of potash plowed down before planting. The application of K_2O in early spring produced small but significant increases in yield.

Introduction:

In recent years, some have questioned the potash recommendations for alfalfa currently used by the University of Minnesota. Alfalfa is a heavy user of K and removal or uptake is high. High yielding alfalfa can remove over 300 lb. K per acre. Stand longevity is also important for alfalfa production in north-central Minnesota. So, adequate potash fertilization is necessary for optimum production as well as stand longevity.

Objective:

This study was established to evaluate the effect of both plowdown and annual application of potash applied at several rates on alfalfa yield and stand longevity.

Experimental Procedure:

This study was initiated at the Irrigation Center at Staples in late spring of 1990. Soil samples (0-6 in.) were collected prior to seeding and the results are summarized in Table 1.

Table 1. Relevant soil test properties for the experimental site.

pH	6.5
P (Bray & Kurtz #1), ppm	43
K (ammonium acetate), ppm	63

Plowdown rates of K_2O (0, 80, 160, 240, 320 lb./acre) were combined with annual rates (0, 60, 120, 180, 240 lb./acre) in a complete factorial design with four replications. A split-plot arrangement of treatments was used. The plowdown rates of K_2O were the main plots. The annual rates of K_2O were the split plots. The K_2O was always supplied as 0-0-60.

The research site was planted to oats in the spring of 1990. The oats stubble was disced following grain harvest and lime as well as the plowdown rates of K_2O were applied at this time. Sulfur applied at a rate of 50 lb. S per acre as granular gypsum was also incorporated for each treatment at this time.

Alfalfa (Profit variety) was seeded at a rate of 16 lb. per acre on August 9, 1990. Irrigation water was applied as needed to insure a good stand and adequate growth before winter. The established stand was excellent.

The annual rates of K_2O were topdressed to the established stand in early spring of 1991, 1992, and 1993. Each year, the alfalfa in all plots was topdressed with 50 lb. S per acre supplied as granular gypsum. These cuttings were harvested each year. Whole plant samples were collected from each plot at each harvest and analyzed for K. Soil samples (0-6 in.) were taken from each plot in the fall of 1991, 1992, and 1993. These samples will also be analyzed for K.

Results and Discussion:

The total dry matter yields for the 1993 growing season are summarized in Table 2. The analysis of soil and plant samples for K is not complete at the time of preparation of this report.

[1/] Extension Soil Scientist, Junior Scientist, and Assistant Scientist, respectively.

Table 2. The effect of plowdown and annual rates of K_2O on yield of alfalfa grown on an irrigated sandy soil. 1993.

Plowdown K_2O	Cutting	0	60	120	180	240
lb./acre		ton dry matter/acre				
0	1	.89	1.02	.96	.97	.98
	2	.82	.90	1.03	1.10	1.10
	3	1.19	1.19	1.35	1.30	1.37
	Total	2.68	3.11	3.34	3.37	3.45
80	1	.80	.87	.90	.87	.82
	2	.89	.90	1.04	1.01	1.04
	3	1.11	1.26	1.22	1.33	1.24
	Total	2.79	3.03	3.16	3.21	3.10
160	1	.90	.99	.90	.92	.97
	2	1.13	1.12	1.46	1.02	1.17
	3	1.24	1.30	1.25	1.36	1.38
	Total	3.27	3.41	3.60	3.30	3.52
240	1	.61	.94	.94	.98	.84
	2	.84	.97	1.07	1.00	1.04
	3	1.18	1.24	1.36	1.21	1.40
	Total	2.63	3.14	3.37	3.19	3.27
320	1	.93	.77	.91	.94	.91
	2	.90	.92	1.08	1.10	1.10
	3	1.20	1.09	1.35	1.30	1.32
	Total	3.03	2.79	3.34	3.34	3.33

The rate of K_2O plowed down before planting had no significant effect on alfalfa yield. Yields were significantly increased by the rate of K_2O applied on an annual basis. Although total yields were relatively low for alfalfa production, the annual rate of 60 lb. K_2O per acre appeared to be optimum in 1993. The alfalfa at this site had not responded to K_2O fertilization prior to 1993. Apparently, the K supplied by the soil decreased in 1993 and there was a response to potash fertilization.

ESTABLISHMENT OF FORAGE LEGUMES ON SANDY SOILS IN NORTH-CENTRAL MINNESOTA

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ABSTRACT: This study was conducted from 1991 through 1993 to evaluate the effect of various methods of establishment on yield of legumes in the year of establishment and subsequent production years. The 1992 yield of legumes established in 1991 was affected by both the legume and the method of establishment that was used. The same was true for the legumes seeded in 1992. The method of establishment also had a significant effect on the density of stand measured in early September of 1992.

There are legumes other than alfalfa that are adapted to the climate and soils of North-Central Minnesota. These legumes may be used for pastures or for hay production. As with alfalfa, establishment of an acceptable stand is a major problem in the region. Therefore, this study is being conducted to evaluate the effect of various methods of establishment. Four forage legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, red clover) are involved.

Experimental Procedure:

This study was initiated at the Irrigation Center at Staples in 1991, and repeated at an adjacent location at the Center in 1992. Prior to seeding, adequate rates of lime, phosphate, potash, and sulfur were broadcast and incorporated with a disk. The experimental area was disked and packed prior to seeding.

Five establishment methods were evaluated. These are described below:

A. Clean Seedbed: With this method, Balan Herbicide was applied at a rate of 3 qts. per acre at two weeks before seeding and incorporated with a rototiller. The Balan restricts the growth of grassy weeds as well as volunteer small grain. The legumes were seeded into the prepared seedbed.

B. Conventional: Oats is used as a companion or nurse crop. Oats was seeded into a prepared seedbed approximately two weeks before seeding of the legumes. The legumes were then seeded into the emerging oats crop. The oats crop was harvested as oatlage when it reached the milk to soft dough stage of development.

C. Companion Oats Plus Herbicide: The sequence of seeding oats and legumes was identical to that used for method B described above. The oats crop was killed when 10-15 inches tall by spraying with Poast (1.5 pints per acre) plus Dash (1 qt. per acre).

D. Late Summer Companion Crop: For this method, oats was planted in early spring and allowed to mature and the grain was harvested. A new seedbed was prepared by rototilling the stubble. A second oats crop was planted in mid-July. The legumes were seeded into the emerging oats in early August. Freezing temperatures in the fall killed the established oats.

E. No-Till Establishment: The legumes were seeded into existing oats stubble in early August. The initial oats crop was planted in early spring, allowed to mature, and was harvested for grain.

In the year of establishment, legumes were harvested when growth appeared to be adequate. Late harvest was avoided so that the potential of winter-kill would be reduced. Adequate rates of phosphate, potash, and sulfur were broadcast to the established stands in the spring of 1992 and 1993. Both sites were irrigated as needed in 1991, 1992, and 1993.

The legumes established in 1991 were harvested in 1992 and 1993. Three cuttings of alfalfa were taken each year. All other legumes were harvested twice each year. The legumes seeded in 1992 were harvested in 1993 following the harvest schedule for the legumes seeded in 1991.

The stand density for each legume in all establishment methods at both sites was measured in early September 1992. For this measurement, plants were dug from a 3 ft^2 area and the number of plants in that area was counted.

Results and Discussion:

The 1993 forage yields for the legumes seeded in 1991 are summarized in Table 1. The establishment method used had a significant effect on the yield of the first and second cutting of alfalfa and the first cutting of red clover. Otherwise, yields were not affected by method of establishment. In general, there was a substantial amount of variability in yield which was due, in part, to the consistent and sometimes heavy rainfall throughout the summer.

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Table 1. The effect of method of establishment used in 1991 on yield of four legumes in 1993.

Legume	Cutting	Method of Establishment A	B	C	D	E
		- - - - - - - - ton dry matter/acre - - - - - - - -				
alfalfa	1	1.33	1.18	1.22	1.08	1.22
	2	1.76	1.73	1.58	1.62	1.81
	3	1.28	1.27	1.08	1.27	1.16
	Total	4.37	4.17	3.88	3.97	4.20
birdsfoot trefoil	1	1.94	1.55	1.60	1.66	1.88
	2	1.79	1.75	1.20	1.64	1.23
	Total	3.73	3.20	2.80	3.30	3.11
cicer milkvetch	1	1.73	1.47	1.33	1.46	1.53
	2	1.46	1.29	1.32	1.11	1.19
	Total	3.19	2.77	2.65	2.56	2.72
red clover	1	1.41	1.41	1.44	1.75	1.73
	2	1.93	1.75	1.90	1.94	1.87
	Total	3.34	3.16	3.34	3.69	3.60

For alfalfa, the lowest yield of the first cutting was associated with establishment method D. The highest yield was associated with method A (clean seedbed). Other establishment methods produced intermediate yields. For red clover, the highest first cutting yields were associated with methods D and E. The effects of the differences in first cutting yields were reflected in total yield.

The total yields for the 1992 and 1993 growing seasons for the legumes seeded in 1991 are summarized in Table 2.

Table 2. Effect of establishment method used in 1991 on total dry matter production for 1992 and 1993.

Legume	Establishment Method A	B	C	D	E
	- - - - - - - - - ton dry matter/acre - - - - - - - - - -				
alfalfa	10.50	9.75	9.50	7.62	8.65
birdsfoot trefoil	8.16	7.15	7.89	6.35	6.89
cicer milkvetch	7.05	4.40	5.03	3.62	4.16
red clover	8.56	8.26	8.75	8.17	8.79

In evaluating these yields, it's important to recognize that 1st year yields (1991) were not measured for methods D and E which were seeded in August of that year. For red clover, yields resulting from these establishment methods were higher in 1992 and 1993. This was not the case for the other three legumes.

Yields from the study established in 1992 are summarized in Table 3. Except for the first cutting of alfalfa and cicer milkvetch, method of establishment that was used in 1992 had no significant effect on forage yield measured in 1993. For the alfalfa, the lowest yields resulted from the use of methods A and E. For cicer milkvetch, the lowest yield of the first cutting resulted from the use of method D. For this legume, all other establishment methods had an equal effect on yield.

Stand counts were taken from a 3 ft^2 area in September of 1992 by digging and counting whole plants. These stand counts are summarized in Table 4.

As would be expected, stand counts were lower if the legumes were seeded in 1991 instead of 1992. This reflects a natural decrease in legume stands with age.

Measured stand varied with legume and method of establishment. For example, no-till produced the lowest stand for alfalfa seeded in 1991. Yet, this method of seeding produced the highest stand for birdsfoot trefoil that was seeded in 1992. The method of establishment had no consistent effect on measured stand throughout the study.