Table 2. 1995 Soybean Plot Management

Soybean Sub-Treatments Within Tillage Systems

Tillage System	Sub Trt*	Planter	Row Cult	Fertilizer	Seed	Spring Tillage	Weed Control (ai)
No-Tillage	1	JD 4-row	None		Trt 1, 2, and 3 Parker 150,000/A	None	Sencor 0.31 lb/A
no fall tillage	2	JD 4-row	None				Lasso 3 lb/A
	3	JD 4-row	None	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/20/95	Trt 4 and 5 Parker 200,000/A planted 5/20/95		Roundup 1 lb/A 5/24/95
	4	JD 752	None				Select 8 oz/A 7/1/95
	5	JD 752	None				
Ridge-Tillage	1	JD 4-row	7/10/95		Parker 150,000/A planted 5/20/95	None	Sencor 0.31 lb/A
no fall tillage	2	JD 4-row	7/10/95				Lasso 3 lb/A 5/24/95
	3	JD 4-row	7/10/95	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/20/95			Select 8 oz/A 7/1/95
	4	JD 4-row	7/10/95				
	5	JD 4-row	7/10/95				
Conventional	1	JD 4-row	6/16/95		Trt 1, 2, and 3 Parker 150,000/A	Disc 5/20/95	Sencor 0.31 lb/A
Primary Tillage	2	JD 4-row	6/16/95				Lasso 3 lb/A 5/24/95
Moldboard plow	3	JD 4-row	6/16/95	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/20/95	Trt 4 and 5 Parker 200,000/A planted 5/20/95		Select 8 oz/A 7/1/95
Fall 94	4	JD 752	None				
	5	JD 752	None				
Reduced	1	JD 4-row	6/16/95		Trt 1, 2, and 3 Parker 150,000/A	Disc 5/20/95	Sencor 0.31 lb/A
Primary Tillage	2	JD 4-row	6/16/95				Lasso 3 lb/A 5/24/95
Chisel plow	3	JD 4-row	6/16/95	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/20/95	Trt 4 and 5 Parker 200,000/A planted 5/20/95		Select 8 oz/A 7/1/95
Fall 94	4	JD 752	None				
	5	JD 752	None				
Spring Tillage (95)	1	JD 4-row	6/16/95		Trt 1, 2, and 3 Parker 150,000/A	Disc 5/20/95	Sencor 0.31 lb/A
Flex Tillage (96)	2	JD 4-row	6/16/95				Lasso 3 lb/A 5/24/95
no fall tillage	3	JD 4-row	6/16/95	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/20/95	Trt 4 and 5 Parker 200,000/A planted 5/20/95		Select 8 oz/A 7/1/95
	4	JD 752	None				
	5	JD 752	None				

*Soybean Subtreatments Within Tillage Systems
1=with row cleaners, 30" rows
2=without row cleaners, 30" rows
3=with N fert (no row cleaner), 30" rows
4=with N fert, 7.5" rows
5=with no N fert, 7.5" rows

Table 3. Analysis of Variance

Corn - 1995	Source	DF	SS	MS	F	P
	Rep	3	184.10	61.37	1.45	0.2297
	Till	4	6900.57	1725.14	40.82	0.0001
	Rep*Till	12	3822.77	318.56	7.54	0.0001
	RowMgt	4	719.90	179.98	4.26	0.0027
	Till*RowMgt	16	836.48	52.28	1.24	0.2454
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	6900.57	1725.14	5.42	0.0100

Table 4. Corn Yields in 1995

Tillage System	Row Management 1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	115.1	115.4	118.6	121.9	116.1	8.5
Ridge-Tillage	117.8	121.8	118.0	121.3	123.3	5.1*
Conventional	130.8	136.6	138.5	134.4	131.8	5.9*
Reduced	121.2	123.9	125.4	132.2	128.1	6.1*
Spring	125.9	127.9	124.1	131.0	126.3	7.0
$LSD_{0.05}$	8.5	16.1	11.5	9.6	9.8	

*Significant treatment differences

Table 5. Analysis of Variance

Soybeans - 1995	Source	DF	SS	MS	F	P
	Rep	3	93.92	31.31	2.82	0.0409
	Till	4	356.38	89.10	8.03	0.0001
	Rep*Till	12	287.29	23.94	2.16	0.0166
	RowMgt	4	85.01	21.25	1.92	0.1108
	Till*RowMgt	14	570.08	40.72	3.67	0.0001
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	356.38	89.10	3.72	0.0342

Table 6. Soybean Yields in 1995

Tillage System	Row Management 1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	38.9	36.5	40.0	42.7	44.2	3.9*
Ridge-Tillage	36.4	39.6	40.7	nd	nd	3.7*
Conventional	44.5	42.1	44.0	40.7	40.6	3.2*
Reduced	39.5	40.1	40.0	40.3	41.7	2.9
Spring	42.0	45.8	40.5	43.1	45.1	3.3*
$LSD_{0.05}$	5.1*	5.2*	5.2	4.8	3.6*	

*Significant treatment differences

Table 7. 1986-1995 Corn Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Avg
	bu/A										
Notill	142.0	132.4	73.7	122.2	114.5	133.4	134.2	71.9	146.7	117.4	118.8
Ridge	145.4	125.4	82.2	132.6	118.4	128.9	145.3	72.0	162.2	120.4	123.3
Conv.	141.5	136.4	76.7	139.0	137.2	132.2	153.6	76.6	166.3	134.4	129.4
Reduced	139.8	124.8	70.1	128.1	120.5	133.6	130.7	75.1	162.7	126.2	121.2
Spr. till	132.4	119.8	65.4	131.8	122.8	132.6	136.6	73.4	164.5	127.0	120.6
$LSD_{0.05}$	11.7	6.7	6.7	6.9	6.0	6.2	10.2	4.3	6.9	5.8	3.6

Table 8. 1986-1995 Soybean Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Avg
	bu/A										
Notill	47.4	39.3	26.9	40.9	44.7	40.3	35.9	19.8	41.7	40.5	37.7
Ridge	47.2	38.7	26.7	49.2	48.7	41.3	35.3	31.5	42.6	38.9	40.0
Conv.	47.9	38.8	32.7	48.8	51.8	48.0	37.3	38.9	47.1	42.4	43.4
Reduced	46.7	39.5	26.3	45.8	51.6	46.2	37.7	34.5	43.1	40.3	41.2
Spr. till	48.9	37.0	26.2	47.1	45.4	44.4	36.5	33.1	41.6	43.3	40.4
$LSD_{0.05}$	1.5	1.4	1.5	2.6	2.6	3.5	2.0	2.9	1.9	1.5	1.8

VARIABLE INPUT CROP MANAGEMENT SYSTEMS AT THE SOUTHWEST EXPERIMENT STATION: 7-YEAR MANAGEMENT HISTORY AND 1995 YIELDS

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ABSTRACT

The development of methods to replace or supplement off-farm inputs and energy with on-farm resources is an important goal for agricultural sustainability. Cropping systems with minimum input, lower purchased input, higher purchased input, and organic input were established with two crop rotations and two prior levels of external inputs in 1989. In addition to results for 1995, this article outlines the actual management practices used in each of the seven years of the study.

INTRODUCTION

In 1988 the University of Minnesota gained access to a research site called the 'Koch Farm'. The Koch farm was a minimum input farm for at least 35 years prior to 1988. The overall objective of the Variable Input Crop Management Study (VICM) is 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. 1995 was the seventh year of crop production in the study.

METHODS AND MATERIALS

The study began in 1989 with treatments including two prior levels of external (off-farm) input: 1) VICM I located on the Koch Farm with 30 years of minimal inputs; and 2)VICM II located on the Southwest Experiment Station with 30 years of high external inputs. Each study evaluates four different management systems: 1) Minimum Input (MIN), 2) Lower Purchased Inputs (LPI), 3) High Purchased Inputs (HPI), and 4) Organic Inputs (ORG). Each study has two different crop rotations: 1) a four-year rotation of corn/soybeans/oat/alfalfa (CSOA) and 2) and a two-year corn/soybean (CS) rotation. Every crop is grown each year for every rotation.

Each of the four management systems is managed independently of the other three systems, and has the objective of maintaining good yields that are consistent with the philosophy of that system. The philosophies used for the four management systems are as follows:

MIN management systems receive no fertilizer or pesticides. Weed control is only through mechanical means (rotary hoe and row cultivation), and corn and soybeans are planted 1 to 2 weeks later than normal.

LPI management systems are planted as soon as possible to maximize yield potential. Phosphorus & K fertilizers are applied in a 2x2 band for corn and soybeans, N is applied in a 2x2 band in corn, and N, P and/or K fertilizer is broadcast on the oats and alfalfa. Fertilizer rates are based on soil tests, previous crop and realistic yield goals. Weed control includes rotary hoe and row cultivation, as well as moderate herbicide application - banded for corn and soybean, broadcast in oat and alfalfa. Generally this treatment has less intensive fall tillage than the other management strategies.

HPI management systems are planted as soon as possible to maximize yield potential. N, P and K are broadcast on all crops. Fertilizer rates are based on soil tests, previous crop and an optimistic yield goal (10% greater than realistic yield goal). Weed control is through row cultivation and herbicides.

ORG management systems are planted with untreated seed 1 to 2 weeks later than normal (corn and soybeans) to allow additional pre-planting tillage for weed control. The CSOA corn and oat crops rotation receive solid beef manure in the prior fall. Corn in the CS corn rotation receives liquid hog manure prior to planting in the spring. The rates are based on soil tests and previous manure application rates. Weed control is mechanical only, and includes rotary hoe and row cultivation.

Tables 1 and 2 show the details of plot management for 1995 for VICM I and VICM II respectively. Details of plot management for each year from 1989-1995 are given in Tables 5 and 6 for VICM I and VICM II respectively.

RESULTS

VICMS I crop yields for 1995 are summarized in Table 3. In VICM I, there was no difference in yield between the LPI and HPI management systems regardless of rotation (CSOA or CS). MIN had the lowest yield for all crops except oats and the SC-rotation soybean, in which case there were no significant differences between any of the management systems. ORG was never statistically different than LPI, though it was significantly less than HPI for CS corn and CSOA soybean.

VICM II crop yields for 1995 are summarized in Table 4. Patterns in yield with respect to management system are more complicated than for VICM I. Highest yields generally occurred in the HPI system, except for CSOA corn where the LPI system yielded significantly higher than HPI, and for oats where ORG and MIN yields were both significantly higher than HPI. Generally the MIN system had the lowest yields, however the lowest yields for soybean in both rotations was the ORG system, and for oats was the HPI system.

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Table 1. 1995 Plot management - Variable Input Crop Management System I (VICM I).

Mgt Level	Fall Tillage	Spring Tillage	Seed (rate:plants/ac)	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
CS-Rotation: CORN							
MIN	Chisel Fall 94	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31, 6/5	6/12,6/19. 6/29
LPI	none	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	0-65-0 Band 5/18	Buctril/Atrazine 6/12, Stinger 6/12, Accent 6/20 All POST,10" band	6/5	6/15, 6/19. 6/29
HPI	Chisel Fall 94	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	120-70-25 broadcast 5/17	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	229-269-80 manure 5/19	none	5/31, 6/5	6/12,6/19, 6/29
CS-Rotation: SOYBEAN							
MIN	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	*0-0-0*	Basagran, Pinnacle 6/19 Select 6/24 POST 10" band	6/5	6/16, 6/29, 7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Treflan 5/18 PPI	none	6/15, 7/13
ORG	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
CSOA-Rotation: CORN							
MIN	Chisel Fall 94	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31,6/2, 6/5	6/12
LPI	none	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	0-98-0 Band 5/18	Buctril/Atrazine 6/12, Stinger 6/12 All POST,10" band	6/5	6/15
HPI	Chisel Fall 94	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	15-105-0 broadcast 5/12	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	390-81-not an. manure Fall 94	none	5/31, 6/2, 6/5	6/12
CSOA-Rotation: SOYBEAN							
MIN	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Basagran, Pinnacle 6/19 Select 6/24 POST 10" band	6/5	6/16, 6/29, 7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Sonolan 5/18 PPI	none	6/15, 7/13
ORG	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
CSOA-Rotation: OAT							
MIN	Chisel Fall 94	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	none	none	none	none
LPI	none	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	50-50-0 5/1	Buctril 6/1 POST	none	none
HPI	Chisel Fall 1994	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	50-50-50 5/1	Buctril 6/1 POST	none	none
ORG	Chisel Fall 94	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	130-27-not an.	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none
LPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	Buctril 6/1 POST	none	none
HPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	Buctril 6/1 POST	none	none
ORG	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none

Table 2. 1995 Plot Management - Variable Input Crop Management System II (VICM II).

Mgt Level	Fall Tillage	Spring Tillage	Seed (rate:plants/ac)	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
CS-Rotation: CORN							
MIN	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31, 6/5	6/12,6/19. 6/29
LPI	none	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	197-0-0 band 5/18	Buctril/Atrazine 6/12, Stinger 6/12, Accent 6/20 All POST,10" band	6/5	6/19,6/29
HPI	Chisel Fall 1994	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	125-0-0 broadcast 5/17	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	229-269-80 manure 5/19	none	5/31, 6/5	6/12,6/19, 6/29
CS-Rotation: SOYBEAN							
MIN	Moldboard Fall 1994	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	none	Basagran, 6/19, Select 6/24 POST 10" band	6/5	6/29,7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	none	Treflan 5/18 PPI Basagran 6/24 POST	none	6/15, 7/13
ORG	Moldboard Fall 1994	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
CSOA-Rotation: CORN							
MIN	Moldboard Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31, 6/5	6/12
LPI	Moldboard Fall 1994	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	*0-98-0* Band 5/18	Buctril/Atrazine,Stinger 6/12 Accent 6/20 All POST,10" band	6/5	6/12
HPI	Moldboard Fall 94	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	20-15-25 broadcast 5/17	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Moldboard Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	130-27-not an. manure Fall 94	none	5/31, 6/5	6/12
CSOA-Rotation: SOYBEAN							
MIN	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/29, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Basagran 6/19, Select 6/24 POST 10" band	6/5	6/29, 7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Sonolan 5/18 PPI	none	6/15, 7/13
ORG	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/29, 7/12
CSOA-Rotation: OAT							
MIN	Chisel Fall 94	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	none	none	none	none
LPI	none	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	30-10-0 5/1	Buctril 6/1 POST	none	none
HPI	Chisel Fall 1994	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	50-20-0 5/1	Buctril 6/1 POST	none	none
ORG	Chisel Fall 94	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	130-27-not an.	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none
LPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	none	none	none
HPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	none	none	none
ORG	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none

Table 3. 1995 Yields - Variable Input Crop Management Systems (VICM I).

Rotation	Crop	Management Level				$LSD_{0.05}$
		MIN	LPI	HPI	ORG	
		bu/A				
CSOA	Corn	59.0	109	112	102	15.41
CS	Corn	37.6	95.3	103	88.2	13.49
SOAC	Soybeans	32.7	42.6	41.1	41.8	5.39
SC	Soybeans	36.7	41.0	38.8	36.7	7.83
ACSO	Alfalfa*	3.20	5.12	5.56	4.47	0.96
OACS	Oats	34.5	33.6	33.9	32.5	7.30

*Alfalfa yields are (T/A)

Table 4. 1995 Yields - Variable Input Crop Management Systems II (VICM II).

Rotation	Crop	Management Level				$LSD_{0.05}$
		MIN	LPI	HPI	ORG	
		bu/A				
CSOA	Corn	94.4	112	105	111	6.23
CS	Corn	54.0	70.2	104	89.6	12.05
SOAC	Soybeans	34.5	33.8	36.6	33.3	5.17
SC	Soybeans	34.4	25.5	38.4	24.4	5.63
ACSO	Alfalfa*	7.66	7.94	8.38	7.91	0.68
OACS	Oats	28.8	22.8	17.8	30.4	3.48

*Alfalfa yields are (T/A)

Table 5. Tillage and planting information for VICM I 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Seed Date	Row Cultiv	Fertilizer (N-P_2O_5-K_2O)	Herbicide§ type1(rate1), type2(rate2)
				# passes		plants/ac			# passes	lb/ac lb ai/ac
CS - Corn										
Min	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	0-0-0	none
	1990	Ch	FC 1x	3x	P3585	27700	5/8	3x	0-0-0	none
	1991	none	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	none	FC 1x	1x	P3585	29000	5/12	3x	0-0-0	none
	1993	none	FC 1x	3x	P3585	29000	5/14	4x	0-0-0	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	2x	0-0-0	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	0-0-0	none
LPI	1989	Ch	FC 1x	1x	P3585	26000	5/3	3x	75-50-50	Alac (3.0), 2,4-D (0.5)
	1990	none	FC 2x	5x	P3585	27700	4/23	3x	60-20-10	Alac (3.0), 2,4-D (0.5)
	1991	none	FC 1x	3x	P3585	27700	4/26	1x	60-30-15	Alac (3.0), 2,4-D (0.5)
	1992	none	FC 1x	1x	P3585	29000	5/1	2x	157-35-35	Alac (3.0), Nico (0.031)
	1993	none	FC 1x	1x	P3585	29000	5/14	2x	122-42-0	Alac (3.0)
	1994	none	FC 1x	1x	P3769	29000	5/9	1x	115-45-25	Nico (0.031), Clpy (0.25)
	1995	none	FC 2x	1x	P3769	30000	5/18	3x	0-65-0	[Brox&Atra](0.19&0.28),Clpy (0.09),Nico(.031)
HPI	1989	Ch	FC 2x	1x	P3585	26000	5/3	2x	150-100-100	[EPTC&R29148](4.0),Cyan(2.0),2,4-D(0.5)
	1990	Ch	FC 2x	none	P3585	27700	4/23	3x	120-40-20	[EPTC&R29148](2.5),Cyan(1.5),2,4-D(0.5)
	1991	Ch	FC 2x	none	P3585	27700	4/26	1x	120-60-30	[EPTC&R29148](2.5),Cyan(1.5),2,4-D(0.5)
	1992	Ch	FC 2x	none	P3585	29000	5/1	3x	197-50-50	[EPTC&R29148](2.5),Cyan(1.5)
	1993	SS	FC 2x	none	P3585	29000	5/14	2x	142-74-25	[EPTC&R29148](2.5),Cyan(1.5), Nico (0.031)
	1994	Ch	FC 3x	none	P3769	29000	5/9	1x	130-90-50	[EPTC&R29148](2.5),Cyan(1.5),Clpy (0.25)
	1995	Ch	FC 2x	none	P3769	30000	5/18	1x	120-70-25	[EPTC&R29148&Acet](4.2&1.2),Cyan(2),Clpy(0.25)
Org	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	352-3-158	none
	1990	Ch	FC 3x	3x	P3585	27700	5/8	3x	126-155-71	none
	1991	none	FC 2x	4x	P3585	27700	5/13	2x	263-244-76	none
	1992	none	FC 2x	1x	P3585	29000	5/12	4x	156-81-63	none
	1993	none	FC 2x	3x	P3585	29000	5/14	2x	228-137-87	none
	1994	Ch	FC 3x	3x	P3769	29000	5/13	2x	283-104-87	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	229-269-80	none
CS - Soybean										
Min	1989	Ch	disk 1x	1x	Hardin	150,000	5/25	3x	0-0-0	none
	1990	MB	disk/FC	2x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158.000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158.000	5/23	3x	0-0-0	none
LPI	1989	Ch	disk 2x	1x	Hardin	150,000	5/11	3x	0-50-50	Alac (3.0), Bent (0.75)
	1990	SS	disk 2x	3x	Hardin	150,000	5/10	3x	0-31-16	Alac (3.0), Seth+COC (0.2)
	1991	SS	FC 1x	3x	Hardin	150,000	5/14	2x	0-25-25	Alac (3.0), Seth+COC (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	2x	5-25-25	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	Alac (3.0)
	1994	SS	FC 1x	1x	Parker	158,000	5/12	2x	0-35-0	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158.000	5/19	3x	0-0-0	Bent (0.75), Thif (0.002), Clet (0.125)
HPI	1989	Ch	FC 2x	none	Hardin	150,000	5/11	2x	0-100-100	Bent (0.75), Seth+COC (0.2)
	1990	MB	disk2x/ FC	none	Hardin	150,000	5/10	2x	0-40-20	Trif (0.75)
	1991	MB	FC 2x	none	Hardin	150,000	5/14	2x	0-40-40	Trif (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/8	2x	11-50-50	Trif (0.75)
	1993	MB	disk/FC2x	none	Hardin	150,000	5/26	2x	0-50-0	Trif (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12	1x	0-50-0	Trif (0.75), Metr(0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	3x	0-0-0	Trif (0.75)
Org	1989	Ch	disk 1x	1x	Hardin	150,000	5/25	3x	127-1-57	none
	1990	MB	disk/FC	1x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	1x	Hardin	150,000	5/18	4x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 5 (con't). Tillage and planting information for VICM I 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage[†]	Spring Tillage[‡]	Rotary Hoe	Seed	Seed Rate	Seed Date	Row Cultiv	Fertilizer (N-P_2O_5-K_2O)	Herbicide[§] type1(rate1), type2(rate2)
				#passes		plants/ac			# passes	lb/ac (lb ai/ac)
CSOA - Corn										
Min	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	0-0-0	none
	1990	MB	FC 2x	3x	P3585	27700	5/8	3x	0-0-0	none
	1991	MB	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	MB	FC 1x	1x	P3585	29000	5/12	3x	0-0-0	none
	1993	MB	FC 1x	3x	P3585	29000	5/14	2x	0-0-0	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	2x	0-0-0	none
	1995	Ch	FC 2x	3x	P3769	30000	5/19	1x	0-0-0	none
LPI	1989	Ch	FC 1x	1x	P3585	26000	5/3	3x	75-50-50	Alac (3.0), 2,4-D (0.5)
	1990	none	FC 2x	5x	P3585	27700	4/23	3x	60-20-10	Alac (3.0), 2,4-D (0.5)
	1991	none	FC 2x	3x	P3585	27700	4/26	1x	40-20-20	Alac (3.0), 2,4-D (0.5)
	1992	none	FC 1x	1x	P3585	29000	5/1	2x	80-20-20	Alac (3.0), Nico (0.031)
	1993	none	FC 1x	1x	P3585	29000	5/14	3x	19-40-0	Alac (3.0)
	1994	none	FC 1x	2x	P3769	29000	5/9	1x	20-45-25	Nico (0.031), Clpy (0.25)
	1995	none	FC 2x	1x	P3769	30000	5/18	1x	0-98-0	[Brox&Atra](0.19&0.28),Clpy(0.09),Nico (.031)
HPI	1989	Ch	FC 2x	none	P3585	26000	5/3	1x	150-100-100	[EPTC&R29148](4.0), Cyan(2.0), 2,4-D(0.5)
	1990	Ch	FC 2x	none	P3585	27700	4/23	3x	120-40-20	[EPTC&R29148](2.5), Cyan(1.5), 2,4-D(0.5)
	1991	Ch	FC 2x	none	P3585	27700	4/26	1x	80-40-40	[EPTC&R29148](2.5), Cyan(1.5), 2,4-D(0.5)
	1992	SS	FC 2x	none	P3585	29000	5/1	3x	117-50-50	[EPTC&R29148](2.5), Cyan(1.5), 2,4-D(0.25)
	1993	Ch	FC 2x	none	P3585	29000	5/14	2x	37z-88-25	[EPTC&R29148](2.5), Cyan(1.5), Nico (0.031)
	1994	Ch	FC 3x	none	P3769	29000	5/9	1x	40-90-50	[EPTC&R29148](2.5), Cyan(1.5), Clpy (0.25)
	1995	Ch	FC 2x	none	P3769	30000	5/18	1x	15-105-0	[EPTC&R29148&Acet](4.2&1.2),Cyan (2),Clpy(0.25)
Org	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	162-10-185	none
	1990	Ch	FC 2x	3x	P3585	27700	5/8	3x	141-77-110	none
	1991	none	FC 2x	4x	P3585	27700	5/13	2x	275-88-132	none
	1992	Ch	FC 2x	1x	P3585	29000	5/12	3x	431-178-380	none
	1993	SS	FC 1x	3x	P3585	29000	5/14	2x	317-178-511	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	2x	177-76-125	none
	1995	Ch	FC 2x	3x	P3769	30000	5/19	1x	390-81-not an.	none
CSOA - Soybean										
Min	1989	Ch	disk 1x	1x	Hardin	150,000	5/25	3x	0-0-0	none
	1990	MB	disk/FC	3x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2	2x	Hardin	150,000	5/6	2x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none
LPI	1989	Ch	FC 2x	1x	Hardin	150,000	5/11	3x	0-50-50	Alac (3.0), Bent (0.75)
	1990	SS	disk 2x	3x	Hardin	150,000	5/10	3x	0-31-16	Alac (3.0), Seth (0.2)
	1991	SS	FC 1x	3x	Hardin	150,000	5/14	2x	0-25-25	Alac (3.0), Seth (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	3x	4-20-20	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	Alac (3.0)
	1994	SS	FC 1x	1x	Parker	158,000	5/12	2x	0-35-0	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158,000	5/19	3x	0-0-0	Bent(0.75), Thif (0.002), Clet (0.125)
HPI	1989	Ch	disk 2x	none	Hardin	150,000	5/11	2x	0-100-100	Etha (0.9), Bent (0.75), Seth (0.02)
	1990	MB	disk 2x	none	Hardin	150,000	5/10	2x	0-40-20	Etha (1.0)
	1991	MB	FC 2x	none	Hardin	150,000	5/14	2x	0-40-40	Etha (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/6	2x	8-40-40	Etha (0.75)
	1993	MB	disk/FC2x	none	Hardin	150,000	5/26	2x	0-50-0	Etha (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12	1x	0-50-0	Etha (1.0), Metr (0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	2x	0-0-0	Etha (1.0)
Org	1989	Ch	FC 1x	1x	Hardin	150,000	5/25	3x	68-4-77	none
	1990	MB	disk/FC	3x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	150-48-72	none
	1992	MB	disk/FC	1x	Hardin	150,000	5/18	2x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

[†] Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
[‡] Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

[§]Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 5 (con't). Tillage and planting information for VICM I, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage[†]	Spring Tillage[‡]	Rotary Hoe	Seed	Seed Rate	Planting Date	Row Cultiv	Fertilizer (N-P_2O_5-K_2O)	Herbicide[§] type1(rate1), type2(rate2)
				# passes		lb/ac		# passes	lb/ac	(lb ai/ac)
CSOA - Oat										
Min	1989	Ch	FC 2x	none	Don	64	4/18	none	0-0-0	none
	1990	Ch	FC 1x	none	Don	72	4/17	none	0-0-0	none
	1991	none	FC 1x	none	Don	72	4/24	none	0-0-0	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	0-0-0	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	0-0-0	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	0-0-0	none
	1995	Ch	FC 1x	none	Dane	85	5/2	none	0-0-0	none
LPI	1989	Ch	FC 2x	none	Don	64	4/18	none	40-40-40	*Seth (0.2)*
	1990	none	FC 1x	none	Don	72	4/17	none	40-40-80	none
	1991	none	FC 1x	none	Don	72	4/24	none	30-20-20	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	30-75-150	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	40-60-0	none
	1994	none	FC 1x	none	Dane	70	4/21	none	50-50-50	Brox (0.25)
	1995	none	FC 1x	none	Dane	85	5/2	none	50-50-0	Brox (0.25)
HPI	1989	Ch	FC 2x	none	Don	64	4/18	none	80-80-80	*Seth (0.2)*
	1990	Ch	FC 1x	none	Don	72	4/17	none	40-80-160	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	30-40-20	none
	1992	Ch	FC 1x	none	Don	*80*	4/28	none	30-100-200	none
	1993	SS	FC 1x	none	Don	*80*	5/4	none	40-40-0	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	50-50-50	Brox (0.25)
	1995	Ch	FC 1x	none	Dane	85	5/2	none	50-50-0	Brox (0.25)
Org	1989	Ch	FC 1x	none	Don	64	4/18	none	68-4-77	none
	1990	Ch	FC 1x	none	Don	72	4/17	none	0-0-0	none
	1991	none	FC 1x	none	Don	72	4/24	none	150-48-72	none
	1992	Ch	FC 1x	none	Don	80	4/28	none	299-124-264	none
	1993	SS	FC 1x	none	Don	80	4/44	none	317-178-511	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	172-75-126	none
	1995	Ch	FC 1x	none	Dane	85	5/2	none	130-27-not an.	none
CSOA - Alfalfa										
Min	1989	Ch	FC 2x	none	P5262	12	5/9/89	none	0-0-0	none
	1990	none	none	none	P5262	12	pr.yr.oats[¶]	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
LPI	1989	Ch	FC 2x	none	P5262	12	5/9/89	none	0-50-50	Bnfn (1.25)
	1990	none	none	none	P5262	12	pr.yr.oats	none	0-40-80	Bnfn (1.25)
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-50-100	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-75-150	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	*0-95-0*	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-100-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-65-15	none
HPI	1989	Ch	FC 2x	none	P5262	12	5/9/89	none	0-100-100	Bnfn (1.25)
	1990	none	none	none	P5262	12	pr.yr.oats	none	0-80-160	Bnfn (1.25)
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-50-100	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-100-200	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	*0-95-0*	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-100-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-65-15	none
Org	1989	Ch	none	none	P5262	12	5/9/89	none	68-4-77	none
	1990	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none

[†] Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
[‡] Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.
[§] Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.
[¶] Alfalfa planted previous year along with the oats.

Table 6. Tillage and planting information for VICM II, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Seed Date	Row Cultiv	Fertilizer ($N-P_2O_5-K_2O$)	Herbicide§ type1(rate1), type2(rate2)
				# passes		plants/ac		# passes	lb/ac	(lb ai/ac)
CS - Corn										
Min	1989	Ch	FC 2x	1x	P3585	26000	5/15	2x	0-0-0	none
	1990	Ch	FC/disk	3x	P3585	27700	5/7	2x	0-0-0	none
	1991	Ch	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	none	FC 1x	1x	P3585	29000	5/12	3x	0-0-0	none
	1993	none	FC 2x	3x	P3585	29000	5/14	3x	0-0-0	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	3x	0-0-0	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	0-0-0	none
LPI	1989	Ch	FC 1x	1x	P3585	26000	5/3	2x	75-50-50	Alac (3.0)
	1990	none	FC 2x	5x	P3585	27700	4/23	2x	60-0-0	Alac (*3.0*)
	1991	none	FC 1x	3x	P3585	27700	4/26	1x	60-0-0	Alac (3.0), 2,4-D (0.5)
	1992	none	FC 1x	1x	P3585	29000	5/1	3x	169-10-10	Alac (3.0)
	1993	none	FC 2x	1x	P3585	29000	5/14	2x	120-0-0	Alac (3.0),Nico (0.031)
	1994	none	FC 1x	3x	P3769	29000	5/9	2x	125-0-0	Brox (0.25)
	1995	none	FC 2x	1x	P3769	30000	5/18	2x	197-0-0	[Brox&Atr](0.19&0.28),Clpy(0.09),Nico(0.031)
HPI	1989	Ch	FC 2x	1x	P3585	26000	5/3	2x	150-100-100	[EPTC&R29148] (4.0), Cyan (2.0)
	1990	Ch	FC 2x	none	P3585	27700	4/23	2x	120-0-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1991	Ch	FC 2x	none	P3585	27700	4/26	1x	120-0-0	[EPTC&R29148] (2.5), Cyan (1.5),2,4-D(0.5)
	1992	Ch	FC 2x	none	P3585	29000	5/1	4x	183-0-0	[EPTC&R29148] (2.5), Cyan (1.5),2,4-D(0.25)
	1993	SS	FC 2x	none	P3585	29000	5/14	2x	132-0-0	[EPTC&R29148](2.5),Cyan (1.5),Nico(.031),Brox(.25)
	1994	Ch	FC 3x	none	P3769	29000	5/9	2x	145-35-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1995	Ch	FC 2x	none	P3769	30000	5/18	1x	125-0-0	[EPTC&R29148&Acet](4.2&1.2),Cyan(2.0),Clpy(0.25)
Org	1989	Ch	FC 2x	1x	P3585	26000	5/15	2x	352-3-158	none
	1990	Ch	FC/disk	3x	P3585	27700	5/8	2x	126-155-71	none
	1991	Ch	FC 2x	4x	P3585	27700	5/13	2x	263-244-76	none
	1992	none	FC 2x	1x	P3585	29000	5/12	3x	156-80-63	none
	1993	none	FC 2x	3x	P3585	29000	5/14	2x	312-186-119	none
	1994	Ch	FC 3x	2x	P3769	29000	5/13	3x	339-125-104	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	229-269-80	none
CS - Soybean										
Min	1989	Ch	FC 1x	1x	Hardin	150,000	5/25	2x	0-0-0	none
	1990	MB	disk 2x	3x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none
LPI	1989	Ch	disk 2x	1x	Hardin	150,000	5/11	2x	0-50-50	Alac (3.0)
	1990	SS	disk 2x	3x	Hardin	150,000	5/10	2x	0-0-0	Alac (*3.0*)
	1991	SS	disk/FC	3x	Hardin	150,000	5/14	2x	0-0-0	Alac (*3.0*), Seth (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	*Alac (3.0)*
	1994	SS	FC 1x	1x	Parker	158,000	5/12	3x	*0-0-0*	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158,000	5/19	2x	0-0-0	Bent (0.75), Clet (0.125)
HPI	1989	Ch	FC 2x	none	Hardin	150,000	5/11	2x	0-100-100	Trif (0.75)
	1990	MB	disk 2x	none	Hardin	150,000	5/10	1x	0-0-0	Trif (0.75)
	1991	MB	FC/disk	none	Hardin	150,000	5/14	2x	0-0-0	Trif (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/6	1x	*0-0-0*	Trif (0.75)
	1993	MB	disk/FC 2x	none	Hardin	150,000	5/26	2x	0-0-20	Trif (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12		*0-0-0*	Trif (0.75), Metr (0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	2x	0-0-0	Trif (0.75), Bent (0.75)
Org	1989	Ch	FC 1x	1x	Hardin	150,000	5/25	2x	127-1-57	none
	1990	MB	disk 2x	3x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk/FC	none	Hardin	150,000	5/18	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 6 (con't). Tillage and planting information for VICM II, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Planting Date	Row Cultiv	Fertilizer (N-P_2O_5-K_2O)	Herbicide§ type1(rate1), type2(rate2),...
				# passes		plants/ac		# passes	lb/ac	(lb ai/ac)
CSOA - Corn										
Min	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	2x	P3585	27700	5/8	2x	0-0-0	none
	1991	MB	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	MB	FC 1x	1x	P3585	29000	5/12	2x	0-0-0	none
	1993	MB	FC 2x	3x	P3585	29000	5/14	3x	0-0-0	none
	1994	MB	FC 2x	4x	P3769	29000	5/13	2x	0-0-0	none
	1995	MB	FC 2x	2x	P3769	30000	5/19	1x	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC 2x	3x	P3585	27700	4/23	2x	60-20-10	Alac (*3.0*)
	1991	MB	FC 2x	3x	P3585	27700	4/26	1x	40-0-0	Alac (*3.0*), 2,4-D (0.5)
	1992	MB	FC 1x	1x	P3585	29000	5/1	2x	89-10-10	Alac (3.0), Nico (0.031), 2,4-D (0.375)
	1993	MB	FC 2x	1x	P3585	29000	5/14	2x	58-0-0	Alac (3.0)
	1994	MB	FC 1x	3x	P3769	29000	5/9	2x	*25-0-0*	Brox (0.25)
	1995	MB	2x	1x	P3769	30000	5/18	1x	0-98-0	[Brox&Atra] (0.19&0.28),Clpy(0.09),Nico(0.031)
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC2x	none	P3585	27700	4/23	2x	120-0-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1991	MB	FC 2x	none	P3585	27700	4/26	1x	80-0-0	[EPTC&R29148] (2.5), Cyan (1.5), 2,4-D (0.5)
	1992	MB	FC 2x	none	P3585	29000	5/1	3x	130-0-0	[EPTC&R29148] (2.5), Cyan (1.5),2,4-D(0.25)
	1993	MB	FC 2x	none	P3585	29000	5/14	2x	43-41-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1994	MB	FC 3x	none	P3769	29000	5/9	2x	*40-50-0*	[EPTC&R29148] (2.5), Cyan (1.5)
	1995	MB	FC 2x	none	P3769	30000	5/18	1x	20-15-25	[EPTC&R29148&Acet](4.2&1.2),Cyan(2.0),Clpy(0.25)
Org	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	2x	P3585	27700	5/8	2x	141-77-110	none
	1991	MB	FC 2x	4x	P3585	27700	5/13	2x	150-48-72	none
	1992	MB	FC 2x	1x	P3585	29000	5/12	2x	431-178-380	none
	1993	MB	FC 2x	3x	P3585	29000	5/14	3x	*0-0-0*	none
	1994	MB	FC 2x	4x	P3769	29000	5/13	2x	59-25-42	none
	1995	MB	FC 2x	2x	P3769	30000	5/19	1x	130-27-not an.	none
CSOA - Soybean										
Min	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC	2x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	2x	Hardin	150,000	5/10	1x	0-0-0	Alac (*3.0*)
	1991	SS	disk/FC	3x	Hardin	150,000	5/14	2x	0-0-0	Alac (*3.0*), Seth (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-20-10	Alac (3.0)
	1994	SS	FC 1x	1x	Parker	158,000	5/12	2x	*0-0-0*	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158,000	5/19	2x	0-0-0	Bent (0.75), Clet (0.125)
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	none	Hardin	150,000	5/10	1x	0-0-0	Etha (1.0)
	1991	MB	FC/disk/FC	none	Hardin	150,000	5/14	2x	0-0-0	Etha (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/6	2x	0-0-0	Etha (0.75)
	1993	MB	disk/FC 2x	none	Hardin	150,000	5/26	2x	0-30-20	Etha (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12	none	*0-0-0*	Etha (1.0), Metr (0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	2x	0-0-0	Etha (1.0)
Org	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC	2x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk/FC	1x	Hardin	150,000	5/18	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 6 (con't). Tillage and planting information for VICM II, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage[†]	Spring Tillage[‡]	Rotary Hoe	Seed	Seed Rate	Planting Date	Row Cultiv	Fertilizer (N-P_2O_5-K_2O)	Herbicide[§] type1(rate1), type2(rate2)
				# passes		lb/ac		# passes	lb/ac	(lb ai/ac)
CSOA - Oat										
Min	1989	-	-	-	-	-	-		-	-
	1990	MB	disk 2x	none	Don	72	4/17	none	0-0-0	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	0-0-0	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	0-0-0	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	0-0-0	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	0-0-0	none
	1995	Ch	FC 1x	none	Dane	85	5/3	none	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	
	1990	MB	disk 2x	none	Don	72	4/17	none	40-0-80	none
	1991	none	FC 1x	none	Don	72	4/24	none	30-0-0	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	30-0-100	Brox (0.25)
	1993	none	FC 1x	none	Don	*80*	4/24	none	19-0-38	*Brox (0.25)*
	1994	none	FC 1x	none	Dane	70	4/21	none	*50-50-50*	Brox (0.25)
	1995	none	FC 1x	none	Dane	85	5/3	none	30-10-0	Brox (0.25)
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	none	Don	72	4/17	none	40-0-160	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	30-0-0	none
	1992	Ch	FC 1x	none	Don	*80*	4/28	none	30-0-150	Brox (0.25)
	1993	SS	FC 1x	none	Don	*80*	4/24	none	19-0-38	*Brox (0.25)*
	1994	Ch	FC 1x	none	Dane	70	4/21	none	50-50-50	Brox (0.25)
	1995	Ch	FC 1x	none	Dane	85	5/3	none	50-20-0	Brox (0.25)
Org	1989	-	-	-	-	-	-	-	-	
	1990	MB	disk 2x	none	Don	72	4/17	none	0-0-0	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	0-0-0	none
	1992	Ch	FC 1x	none	Don	*80*	4/28	none	299-124-64	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	*0-0-0*	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	59-25-42	none
	1995	Ch	FC 1x	none	Dane	85	5/3	none	130-27-not an.	none
CSOA - Alfalfa										
Min	1989	-	-	-	-	-	-	-	-	-
	1990	none	disk 2x	none	P5262	11	4/17/90	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr. oats[¶]	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	-
	1990	none	FC/disk	none	P5262	11	4/17/90	none	0-0-80	Bnfn (*1.25*)
	1991	none	none	none	P5262	11	pr.yr. oats	none	0-0-100	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-100	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	*0-20-0*	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	*0-40-0*	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-65-15	none
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	none	FC/disk	none	P5262	11	4/17/90	none	0-0-160	Bnfn (*1.25*)
	1991	none	none	none	P5262	11	pr.yr. oats	none	0-0-100	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-150	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	*0-20-0*	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	*0-40-0*	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-65-15	none
Org	1989	-	-	-		-	-	-	-	-
	1990	none	disk 2x	none	P5262	11	4/17/90	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none

[†] Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
[‡] Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

[§]Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.
[¶] Alfalfa planted previous year along with the oats.

IMPACT OF RELATIVE MATURITY AND DATE OF PLANTING ON CORN YIELD AT LAMBERTON -- 1993-1995[1]

P.M. Porter, C.A. Perillo, D.R. Hicks, W.E. Lueschen, and J.H. Ford[2]

Abstract

Eight corn hybrids differing in relative maturity were planted on 5 dates from mid-April through early-June in 1993, 1994, and 1995 at Lamberton, Waseca and Morris. This article discusses only the yields obtained at Lamberton. The hybrids ranged in relative maturities from 115 to 80. The highest yielding hybrid was the 105 relative maturity DeKalb DK 512. The lowest yields were from the short-season 85 and 80 relative maturity hybrids. The data suggest there is no yield benefit to planting a short-season hybrid, even when planting is delayed to as late as early-June. Yields of the full-season 115 and 110 relative maturity hybrids were more adversely impacted by delayed planting (late-May or early-June) than the shorter-season hybrids.

Introduction

There is a need to better understand how corn hybrid relative maturity and planting date affect corn growth and development, date of physiological maturity, grain yield, and kernel moisture content at various times during the harvest period. A better understanding of the relationship between corn hybrid relative maturity and planting date will enable producers to make more informed decisions about what maturity hybrid to plant if conditions allow early planting or mandate a late planting to occur. Likewise, the effect of planting date and hybrid maturity on the dry-down rate of corn will influence when producers will want to harvest their crop.

This study was conducted at three branch station locations during the years 1993 through 1995. The data in this report are from the Southwest Experiment Station at Lamberton, and only involve selected yield and harvest moisture content.

Experimental Procedure

Eight corn hybrids ranging in relative maturity from 115 to 80 days were selected for this study (Ciba G4490, Northrup King N5220, DeKalb DK512, ICI 8777, Pioneer 3861, DeKalb DK401, Top Farm SX1184, and Pioneer 3963). Each corn hybrid was planted on five dates (late-April, early-May, mid-May, and late-May, and early June) in 1993, 1994 and 1995. The trial had a split-plot arrangement of a randomized complete block design with 4 replicates. Planting date was the main-plot variable and corn hybrid was the sub-plot variable. Sub-plot size was 10-ft wide (4 rows) by 28-ft long. Harvest area consisted of two rows, 25-ft long. Row width was 30 inches. The crop was managed for optimum production, and fertility was not limiting. Phosphorus and K were applied according to soil test such that high levels of each existed. Nitrogen rates were approximately 140 lb acre^{-1}. Seeding rates were 30,000 plants acre^{-1}. Weeds were controlled with herbicides and hand-weeding.

Tasseling, silking, and black layer dates were recorded for all treatments. After physiological maturity, 10 ears were hand harvested at regular intervals and kernel moisture contents were determined. Grain yields are reported at 15.5% moisture.

Results and Discussion

Averaged across all 8 hybrids, the 3-year average yields for corn planted in late-April and early-May were higher than for corn planted later in May or in early June (Table 1). Corn planted on the two earliest planting dates yielded 124 bushels acre^{-1}, and decreased 6, 19 and 35% as planting was delayed. Averaged over all hybrids, yields were highest in 1994 and lowest in 1993. The lower yields for the early-May planting compared to the late-April and mid-May planting in 1995 may have been due to unusually high temperatures near anthesis for the early-May planting or the impact of corn borer.

Averaged across all 5 planting dates, the 3-year average yields were highest for the 105 relative maturity corn hybrid DK 512 (Table 2). The hybrids with the next highest yields included those of 115, 100, 95 and 90 relative maturity (G4490, ICI 8777, and P 3861 and DK 401). The harvest moisture content declined as the relative maturity of the hybrids decreased (Table 2). Harvest moisture contents were quite high in 1993, which had below normal cumulative growing degree units during the growing season.

The impact of planting date on grain yield of each corn hybrid for the 3-years combined and each individual year is graphed in Figures 1 and 2, respectively. For the 3-year combined data the 105 relative maturity hybrid DK 512 yielded very well (compared to the other hybrids) regardless of planting date, while the 85 and 90 relative maturity hybrids (SX1184 and P3963) yielded relatively poorly regardless of planting date. Yields of specific hybrids did not respond in the same fashion as planting was delayed, especially when one compares numbers from one year to another. For example, NK N5220 yielded relatively poorly in 1993 for all but the first planting date, but yielded comparatively well the other two years. The hybrid DK 512 yielded extremely well in 1994, the highest yielding year, and tended to not drop off as fast in yield as the other hybrids as planting date was delayed. The yields of the 110 and 115 relative maturity hybrids (G 4490 and NK N5220) were most adversely impacted by delayed planting.

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[1] This project was funded in part by the Minnesota Corn Growers Association, Pioneer H-bred International, and the MN Ag. Expt. Stn.

[2] P.M. Porter (assistant professor) and C.A. Perillo (assistant scientist) are at the Southwest Experiment Station, Lamberton, MN 56152. D.R. Hicks and W.E. Lueschen (professors) are in the Department of Agronomy & Plant Genetics, and J.H. Ford (professor- retired) was at the Southwest Experiment Station.

Conclusions

In choosing a corn hybrid to plant, most producers will consider not only yield potential but also relative maturity, since relative maturity impacts when the hybrid reaches physiological maturity and to some extent when the corn will be at a desired moisture content for harvest. This study found that yields of full-season hybrids (with 115 and 110 relative maturities) were most adversely impacted as planting date was delayed. Yields of short-season hybrids (with 85 and 80 relative maturities) yielded the least, regardless of planting date. Not surprisingly, when harvested on the same date the full-season hybrids had higher moisture contents at harvest then the short-season hybrids. These data suggest there is no yield benefit to planting a short-season hybrid in southwest Minnesota, even when planting is delayed to as late as early-June.

Table 1. Corn yield for 5 planting dates, averaged across 8 hybrids ranging in relative maturity from 115 to 80 days, at Lamberton.

Planting date		Actual planting date			Yield (bushel acre^{-1})			
		1993	1994	1995	1993	1994	1995	Avg.
Date 1	late-April	April 24	April 21	April 28	106	162	104	124
Date 2	early-May	May 5	May 4	May 5	108	168	97	124
Date 3	mid-May	May 15	May 16	May 12	85	158	108	117
Date 4	late-May	May 28	May 31	May 26	87	128	89	101
Date 5	early-June	June 10	June 10	June 9	72	106	66	81
$LSD_{(0.10)}$					12	5	10	5

Table 2. Yield and harvest kernel moisture content for 8 corn hybrids, averaged across 5 planting dates, at Lamberton.

Corn hybrid	RM	Yield (bushel acre^{-1})				Harvest moisture content (%)			
		1993	1994	1995	Avg.	1993	1994	1995	Avg.
Ciba G4490	115	91	159	94	115	36	30	24	30
Northrup King N5220	110	71	150	92	104	30	25	21	25
DeKalb DK512	105	101	166	102	123	26	23	20	23
ICI 8777	100	103	151	92	115	24	20	18	21
Pioneer 3861	95	96	149	95	113	20	20	20	20
DeKalb DK401	90	100	142	99	114	22	19	19	20
Top Farm SX1184	85	90	120	87	99	19	19	18	19
Pioneer 3963	80	81	119	82	94	20	17	17	18
$LSD_{(0.10)}$		6	5	6	3	1	1	1	1

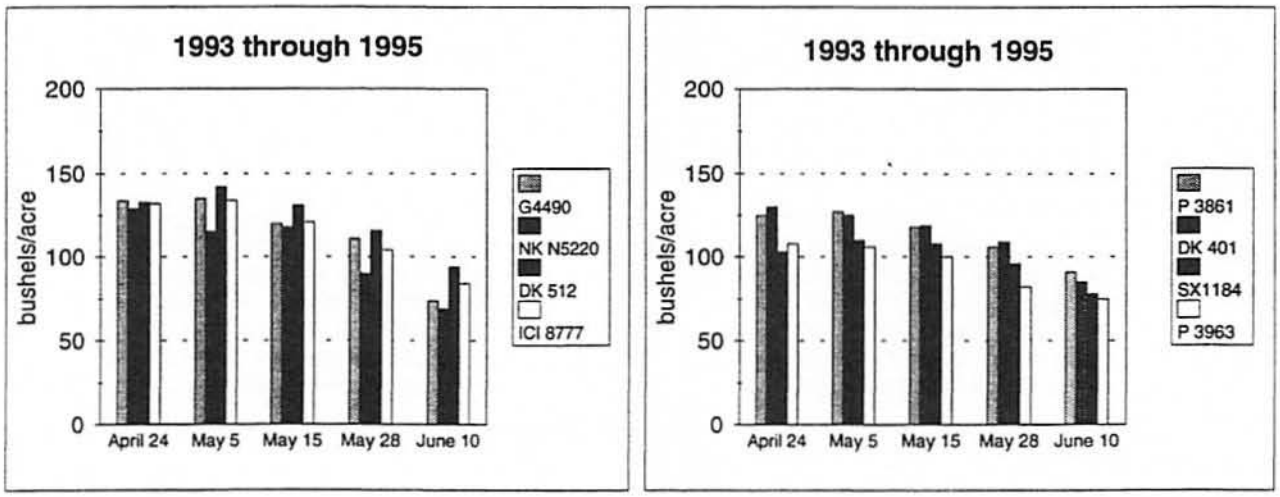

Figure 1. Three-year combined yield data for 8 corn hybrids planted on 5 dates at Lamberton.

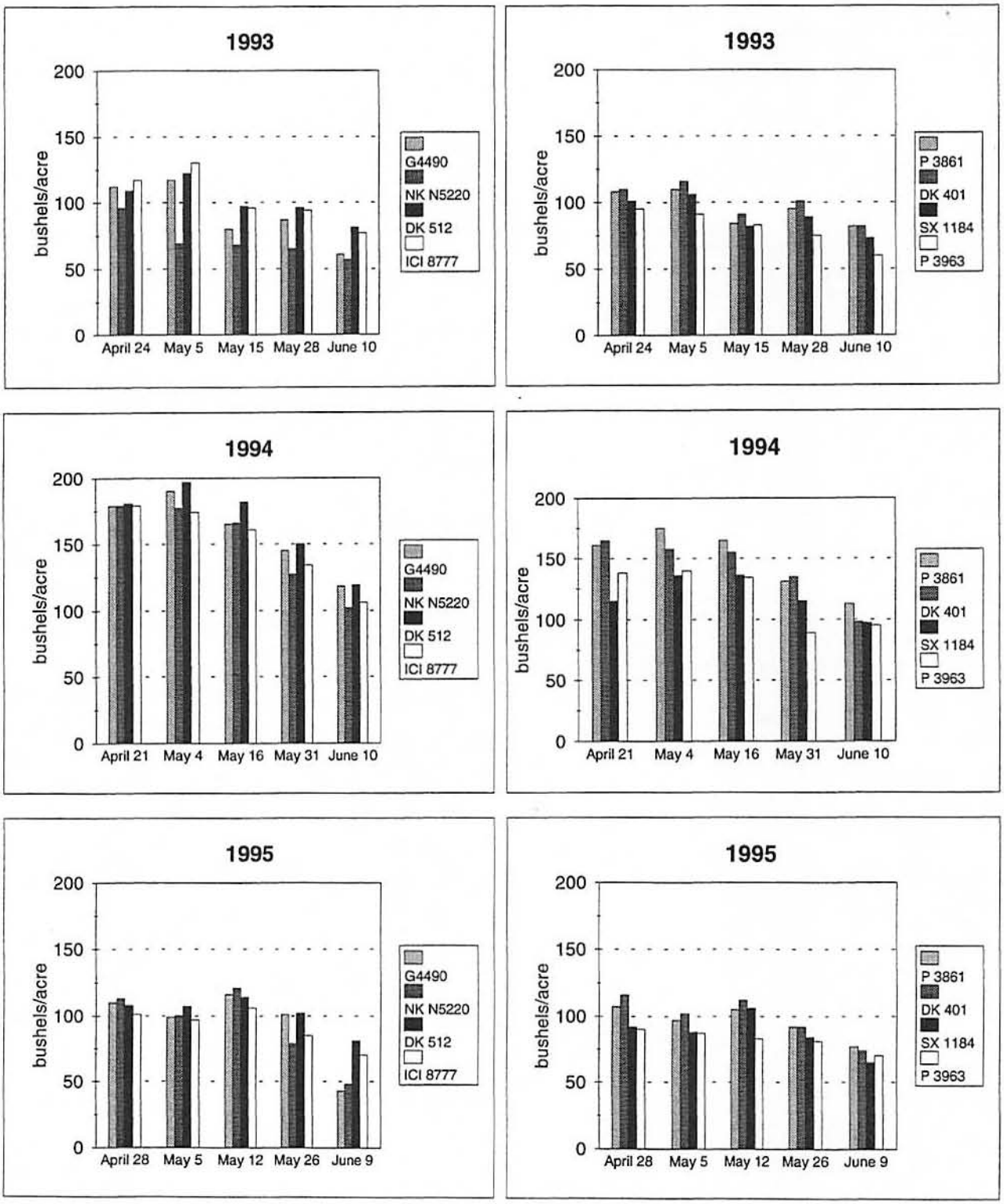

Figure 2. Effect of planting date on 8 corn hybrids in 1993, 1994 and 1995 at Lamberton.

EFFECT OF *RHIZOBIUM* INOCULANT ON SOYBEAN YIELD AT LAMBERTON – 1995[1]

P.M. Porter and C.A. Perillo[2]

Abstract

Rhizobium cause soybeans to form nodules on their roots where the bacteria fix large amounts of free nitrogen. This trial evaluated yield and other agronomic traits of soybeans that were treated with no inoculant, treated with a regular inoculant (532C), and treated with a USDA-patented inoculant. The presence or absence of an inoculant did not affect grain yield, moisture content at harvest, plant height or final plant stand. Results from several other states suggest there may be a slight yield increase when using the USDA-patented inoculant.

Introduction

Plants in the legume family such as soybeans have the potential to utilize atmospheric nitrogen indirectly through a symbiotic relationship with certain soil bacteria known as *Rhizobium*. If the proper strain of *Rhizobium* is present and nodules form, the soybean plants require little soil nitrogen. To encourage the formation of nodules, some producers add pure cultures of *Rhizobium* to soybean seed before planting . This process is known as inoculation. Effective strains of *Rhizobium* cause soybeans to produce large, pinkish nodules on their roots where the bacteria fix large amounts of free nitrogen.

Rhizobium are present in most Midwestern soils that have produced soybeans in the recent past, and on these soils inoculation is not commonly practiced. A company in the inoculation industry has developed a new strain of *Rhizobium* that they wanted to test across the upper Midwest. This study evaluated two strains of *Rhizobium* treated soybean seed and untreated soybean seed at the Southwest Experiment Station in 1995.

Experimental Procedure

The trial was conducted on a Ves loam soil (fine-loamy, mixed, mesic Udic Haplustolls) having high levels of P and K. The 3 treatments included soybean cultivar "Parker" treated with no inoculant, treated with a regular inoculant (532C), and treated with a USDA-patented *Bradyrhizobium japonicum* inoculant. The treatments were compared in a randomized complete block design with 12 replicates. Six of the replicates were planted no-till into corn residue, and 6 replicates were planted in an adjoining area where a Soil Saver was used to till the soil and corn residue the previous fall. The soybeans were planted on May 26, 1995 with a JD750 no-till drill. Plot size was 10 rows spaced 7.5 inches apart by 30 ft in length. The seeding rate was 680 seeds/plot or 158,000 seeds acre^{-1}. Weeds were controlled with Dual/Broadstrike on June 1.Plants were combined on September 28 with an Almaco plot combine. Harvest area was 5.0ft by 9.0ft. Plant height, plant stand, yield and % seed moisture were determined at harvest. Treatment mean comparisons were made using Fisher's protected least significant difference (LSD) test at $P \leq 0.05$.

Results and Discussion

The presence or absence of an inoculant did not affect grain yield, moisture content at harvest, plant height or final plant stand at the 5% (or 10%) level of significance (Table 1). This was true for both no-till soybeans as well as soybeans planted into corn that had been previously worked with a Soil Saver. Although not significant, the yield of the non-inoculated soybean was numerically lower than the yield of the two treatments where inoculant was used (3.1% in the case of the USDA-patented inoculant and 6.4% in the case of the 532C inoculant).

Our results were in agreement with other research conducted across the upper Midwest. According to the company that funded this research, the same trial was conducted at a total of 28 sites in 9 states. A positive response (but not necessarily a significant response) was observed at 20 of the 28 sites when comparing yields of the soybeans treated with the USDA-patented inoculant to the non-treated soybeans. Averaged over all 28 sites, the yield of the soybeans grown with the USDA-patented inoculant was 3.4% higher than the yield of the non-treated soybeans.

It is anticipated this trial will be repeated in 1996.

Conclusions

In this highly replicated field trial we could not detect a significant yield increase due to treating soybean seed with either of two types of inoculant compared to non-treated seed. Moisture content at harvest, plant height and final plant stand were also not significantly affected. Based on experimental results from other states the magnitude of the yield response, if actually present, would probably be less than 4%.

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[1] This project was funded in part by Urbana Laboratories and the MN Ag. Expt. Stn.

[2] P.M. Porter (assistant professor) and C.A. Perillo (assistant scientist) are at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. Soybean yield, plant height, plant stand and moisture content at harvest for two seed inoculant treatments and a non-inoculated control treatment conducted at Lamberton in 1995.

Treatment	Grain yield	Plant height	Plant stand	Harvest moisture
	bu/ac	in.	plants/ac	%
From all 12 replicates:				
No inoculant control	45.1	50.1	100,000	9.33
USDA patented inoculant	46.5	51.3	112,000	9.28
532C inoculant	48.0	50.7	107,000	9.23
Statistics				
C.V. (%)	9.0	7.8	20.0	1.3
Pr>F	0.24	0.74	0.38	0.15
$LSD^{1}_{(0.05)}$	3.5	3.3	18,000	0.11
From 6 replicates planted into no-till corn :				
No inoculant control	44.3	47.3	90,000	9.32
USDA patented inoculant	46.3	48.2	99,000	9.28
532C inoculant	47.0	48.0	92,000	9.27
Statistics				
C.V. (%)	10.0	2.4	17.2	0.9
Pr>F	0.58	0.44	0.63	0.60
$LSD^{1}_{(0.05)}$	5.9	2.4	21,000	0.11
From 6 replicates planted into corn tilled with a Soil Saver:				
No inoculant control	45.9	52.8	109,000	9.35
USDA patented inoculant	46.6	54.5	125,000	9.27
532C inoculant	49.1	53.3	121,000	9.20
Statistics				
C.V. (%)	8.6	5.9	15.4	1.2
Pr>F	0.39	0.66	0.34	0.13
$LSD^{1}_{(0.05)}$	5.2	4.1	23,000	0.15

[1] Note that in no instance was the $P \leq 0.05$, thus none of the LSD values presented are significant using Fisher's protected least significant difference.

SOYBEAN NO-TILL VARIETY PERFORMANCE TRIALS AT LAMBERTON -- 1994 & 1995[1]

P.M. Porter, J.H. Orf, and C.A. Perillo[2]

Abstract

There is some question whether soybean varieties grown in southwest Minnesota will yield as well under no-till conditions as under conventional production practices. Likewise, it is not known whether all varieties will respond similarly when grown under no-till and conventional systems. This study evaluated soybean varieties grown in side-by-side variety performance trials where the soybeans were planted either no-till into corn residue or on land worked by more conventional production practices. In 1995, the mean yield of 32 soybean varieties grown either no-till or conventionally was 46.0 and 48.2 bushels acre^{-1}, respectively. In 1994, the mean yield of 32 soybean varieties grown either no-till or conventionally was 48.3 and 54.8 bushels acre^{-1}, respectively. Two varieties that yielded very well in both tillage trials both years were Pioneer 9171 and Sturdy.

Introduction

Environmental concern with wind, water and soil erosion has led to increased pressure to re-evaluate traditional production practices that include primary fall tillage of corn residue prior to planting soybeans the following spring. Planting soybean no-till into corn residue is increasing in popularity, but questions concerning variety selection for no-till soybean production remain. This study was part of a 3-year multi-state program designed in part to evaluate the impact variety selection had on no-till soybean production. It involved side-by-side variety performance trials where soybean cultivars were planted either no-till into corn residue or on land worked by more conventional production practices. Results from 1994 and 1995 at Lamberton are reported here. The study will be repeated a third year in 1996.

Experimental Procedure

In 1995, 32 soybean varieties were grown on 2 adjacent sites where corn was planted in 1994. One site was tilled conventionally with a JD Soil Saver in the fall whereas the other was left un-tilled. On each site there were 3 replicates of each variety arranged in a randomized complete block design. The trial was conducted on a Ves loam soil (fine-loamy, mixed, mesic Udic Haplustolls).

The soybeans were planted on May 26, 1995 with a JD750 no-till drill. Plot size was 10 ft wide by 15 ft in length. Row width was 7.5 inches. The seeding rate was approximately 150,000 seeds acre^{-1}. Directly after planting it was estimated there was 85% residue cover following no-till and 30% following the Soil Saver. Weeds were controlled with Dual/Broadstrike on June 1. Plants were harvested on September 28 with an Almaco plot combine. Harvest area varied but averaged about 5.0ft by 9.0ft. Plant height, plant stand, and seed moisture at harvest were determined. Fisher's protected least significant difference (LSD) test at $P \leq 0.10$ was reported for these variables within for each of tillage regimes. It was not possible to calculate statistical comparisons between the tillage regimes since they were side-by-side trials. Seed oil and protein will be determined in Dr. Jim Orf's laboratory, and are not reported here.

A similar study was conducted in 1994, and those results are included. The trials were planted on May 16, 1994.

Results and Discussion

In 1995, the mean soybean yield for all 32 varieties when grown no-till and conventionally was 46.0 and 48.2 bushels acre^{-1}, respectively (Table 1 and 2). IA 2008 provided the highest yield (53.0 bu/A) in the no-till trial but Sturdy, Pioneer 9171, Archer, Bert, Parker, Hardin, Kasota, Dawson, Hendricks, Kenwood, Asgrow A1929, Asgrow A2234 and Corsoy 79 yields were not statistically different from IA 2008. Hardin provided the highest yield (55.8 bu/A) in the corresponding conventional tillage trial but Marcus BC, Northrup King S19-90, Glenwood, Pioneer 9171, Hardin 91, Asgrow A1929, and Kenwood yields were not statistically different from Hardin. Hardin, Pioneer 9171, Sturdy, and Bert produced superior yields in both tillage trials in 1995. No variety yielded 10 bushels acre^{-1} less under no-till conditions than with conventional tillage.

In 1994, the mean soybean yield for all 32 varieties when grown no-till and conventionally was 48.3 and 54.8 bushels acre^{-1}, respectively (Table 3). IA2014 provided the highest yield (58.8 bu/A) in the no-till trial but Asgrow A2234, DeKalb CX264, Hardin 91 IA 2008 Marcus, Marcus BC, Northrup King S19-90, Pioneer 9171, and Sturdy yields were not statistically different from IA 2014. IA 2008 provided the highest yield (64.0 bu/A) in the corresponding conventional tillage trial but DeKalb CX264, Kenwood, Parker, Pioneer 9171 and Sturdy yields were not statistically different from IA 2008. DeKalb CX264, IA2008, Pioneer 9171 and Sturdy produced superior yields in both tillage trials in 1994. Several varieties (Bert, Dawson, Faribault, Hodgson 78, Parker, IA2008 Kenwood, and DeKalb CX264) yielded at least 10 bushels acre^{-1} less under no-till conditions than with conventional tillage.

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[1] This project was funded in part by the North Central Soybean Research Program and the MN Ag. Expt. Stn.

[2] P.M. Porter (assistant professor) and C.A. Perillo (assistant scientist) are at the Southwest Experiment Station, Lamberton, MN 56152. J.H. Orf is Professor in the Department of Agronomy and Plant Genetics.

Conclusions

Although a direct statistical comparison was not possible, in both 1994 and 1995 the mean soybean yield for all 32 varieties when grown no-till was less than the mean soybean yield for all 32 varieties when grown conventionally. In 1994 the difference was 12% and in 1995 the difference was 5%. In 1994 several varieties yielded substantially less when grown no-till as compared to when grown conventionally, however this trend was not noted in 1995. Two varieties that yielded very well in both tillage trials both years were Pioneer 9171 and Sturdy.

Table 1. Soybean yields, yield ranking, plant stand and harvest moisture content for varieties in the no-till trial at Lamberton in 1995. Ranking for the conventional tillage variety performance trial are listed in parentheses.

Variety	Maturity group	No-till Yield	No-till Rank	Conv. rank	No-till Stand	No-till Rank	Conv. rank	No-till Moisture	No-till Rank	Conv. rank
		bu/ac			plants/ac			%		
Public varieties										
Glenwood	0.4	43.6	23	(4)	112000	17	(10)	8.9	27	(16)
Evans	0.6	42.8	25	(26)	127000	8	(15)	8.7	32	(13)
Dawson	0.7	48.3	9	(32)	124000	11	(18)	8.7	31	(32)
Hendricks	0.9	48.2	10	(23)	125000	9	(5)	8.9	29	(30)
Lambert	0.9	45.2	20	(16)	128000	7	(7)	8.9	28	(29)
Dassel	1.1	38.4	32	(30)	93000	27	(17)	9.1	22	(17)
Kasota	1.3	48.3	8	(12)	101000	21	(24)	9.0	24	(28)
Alpha	1.4	40.0	31	(31)	148000	2	(1)	9.1	21	(26)
Faribault	1.4	45.8	18	(27)	93000	28	(20)	9.5	11	(6)
Hodgson 78	1.4	42.9	24	(17)	128000	6	(8)	8.8	30	(25)
Kato	1.4	42.0	28	(19)	103000	20	(30)	9.1	20	(14)
Parker	1.4	49.5	6	(13)	113000	16	(26)	9.2	19	(9)
Bell	1.6	41.2	30	(22)	63000	32	(29)	9.9	7	(2)
Leslie	1.8	42.7	26	(20)	93000	29	(23)	9.5	13	(20)
Bert	1.9	50.1	5	(11)	115000	15	(12)	8.9	26	(31)
Hardin	1.9	49.3	7	(1)	142000	4	(11)	9.1	23	(23)
Hardin 91	1.9	46.7	15	(6)	116000	14	(9)	9.3	16	(27)
BSR 101	1.9	42.2	27	(15)	97000	23	(16)	9.4	14	(10)
Archer	1.9	50.9	4	(21)	98000	22	(13)	9.5	12	(19)
Sturdy	2.0	51.3	2	(9)	94400	26	(27)	9.7	8	(12)
IA 2008	2.1	53.0	1	(24)	139000	5	(4)	9.5	10	(18)
Corsoy 79	2.1	47.1	14	(18)	124000	10	(21)	10.1	6	(5)
Kenwood	2.1	47.9	11	(8)	82000	30	(31)	11.3	1	(3)
IA 2014	2.1	44.6	21	(28)	152000	1	(3)	10.3	5	(4)
Private varieties										
Asgrow A1929	1.9	47.7	12	(7)	107000	19	(25)	9.2	18	(21)
Asgrow A2234	2.2	47.2	13	(25)	94000	25	(19)	10.6	2	(1)
DeKalb CX 264	2.6	46.5	17	(29)	119000	13	(22)	10.4	4	(8)
Marcus	2.2	41.4	29	(14)	147000	3	(14)	9.4	15	(24)
Marcus BC	2.2	46.6	16	(2)	96000	24	(2)	10.6	3	(11)
Nor. King S1990	1.9	45.6	19	(3)	123000	12	(28)	9.6	9	(15)
Pioneer 9091	0.9	44.6	22	(10)	78000	31	(32)	9.0	25	(7)
Pioneer 9171	1.7	51.2	3	(5)	111000	18	(6)	9.3	17	(22)
Mean		46.0			112000			9.5		
CV (%)		9.7			16.5			3.4		
Probability		<0.05			<0.001			<0.001		
$LSD_{(0.10)}$		6.07			25300			0.4		

Table 2. Soybean yields, yield ranking, plant stand and harvest moisture content for varieties in the conventionally planted trial at Lamberton in 1995. Ranking for the no-till variety performance trial are listed in parentheses.

Variety	Maturity group	Conventional Yield	Conventional Rank	No-till rank	Conventional Stand	Conventional Rank	No-till rank	Conventional Moisture	Conventional Rank	No-till rank
		bu/ac			plants/ac			%		
Public varieties										
Glenwood	0.4	52.3	4	(23)	130000	10	(17)	9.4	16	(27)
Evans	0.6	46.0	26	(25)	125000	15	(8)	9.6	13	(32)
Dawson	0.7	41.6	32	(9)	121000	18	(11)	8.3	32	(31)
Hendricks	0.9	46.3	23	(10)	139000	5	(9)	9.0	30	(29)
Lambert	0.9	48.6	16	(20)	136000	7	(7)	9.1	29	(28)
Dassel	1.1	43.8	30	(32)	121000	17	(27)	9.4	17	(22)
Kasota	1.3	49.3	12	(8)	107000	24	(21)	9.1	28	(24)
Alpha	1.4	42.9	31	(31)	166000	1	(2)	9.1	26	(21)
Faribault	1.4	45.7	27	(18)	117000	20	(28)	10.4	6	(11)
Hodgson 78	1.4	48.4	17	(24)	135000	8	(6)	9.1	25	(30)
Kato	1.4	48.0	19	(28)	88000	30	(20)	9.5	14	(20)
Parker	1.4	49.2	13	(6)	104000	26	(16)	10.1	9	(19)
Bell	1.6	46.4	22	(30)	94000	29	(32)	10.5	2	(7)
Leslie	1.8	47.6	20	(26)	109000	23	(29)	9.3	20	(13)
Bert	1.9	49.4	11	(5)	130000	12	(15)	8.8	31	(26)
Hardin	1.9	55.8	1	(7)	130000	11	(4)	9.2	23	(23)
Hardin 91	1.9	50.7	6	(15)	131000	9	(14)	9.1	27	(16)
BSR 101	1.9	48.7	15	(27)	124000	16	(23)	10.0	10	(14)
Archer	1.9	46.7	21	(4)	127000	13	(22)	9.3	19	(12)
Sturdy	2.0	49.5	9	(2)	101000	27	(26)	9.7	12	(8)
IA 2008	2.1	46.3	24	(1)	142000	4	(5)	9.4	18	(10)
Kenwood	2.1	50.1	8	(11)	76000	31	(30)	10.5	3	(1)
Corsoy 79	2.1	48.3	18	(14)	117000	21	(10)	10.4	5	(6)
IA 2014	2.1	45.6	28	(21)	142000	3	(1)	10.5	4	(5)
Private varieties										
Asgrow A1929	1.9	50.6	7	(12)	104000	25	(19)	9.2	21	(18)
Asgrow A2234	2.2	46.1	25	(13)	120000	19	(25)	10.9	1	(2)
DeKalb CX 264	2.6	45.0	29	(17)	113000	22	(13)	10.2	8	(4)
Marcus	2.2	49.0	14	(29)	127000	14	(3)	9.1	24	(15)
Marcus BC	2.2	52.5	2	(16)	147000	2	(24)	9.8	11	(3)
Nor. King S1990	1.9	52.4	3	(19)	101000	28	(12)	9.5	15	(9)
Pioneer 9091	0.9	49.5	10	(22)	71000	32	(31)	10.3	7	(25)
Pioneer 9171	1.7	50.8	5	(3)	139000	6	(18)	9.2	22	(17)
Mean		48.2			119800			9.6		
CV (%)		8.8			17.5			6.5		
Probability		<0.10			<0.001			<0.001		
$LSD_{(0.10)}$		5.77			28600			0.8		

Table 3. Soybean yields, yield ranking and plant heights for varieties in the no-till and conventional trials at Lamberton in 1994.

Variety	Maturity group	No-till Trial Yield	No-till Trial Yield rank	Conventional Trial Yield	Conventional Trial Yield rank	No-till Trial Plant height	Conventional Trial Plant height
		bu/A		bu/A		inches	inches
Public varieties							
Glenwood	0.4	41.0	28	43.0	31	30	33
Evans	0.6	40.4	29	41.2	32	32	32
Dawson	0.7	37.6	32	49.4	26	33	34
Hendricks	0.9	39.9	30	47.8	29	29	31
Lambert	0.9	44.1	25	48.3	27	32	31
Dassel	1.1	41.7	27	46.9	30	31	30
Kasota	1.3	47.4	19	51.1	24	37	36
Alpha	1.4	44.2	23	50.1	25	40	37
Faribault	1.4	44.2	23	56.7	14	39	35
Hodgson 78	1.4	42.9	26	54.0	21	36	39
Kato	1.4	53.8	6	52.0	23	39	39
Parker	1.4	50.4	11	60.6	5	40	39
Bell	1.6	48.5	18	55.3	18	38	35
Leslie	1.8	49.8	14	58.9	8	38	40
Bert	1.9	45.1	22	57.9	11	44	41
Hardin	1.9	48.7	17	53.8	22	41	38
Hardin 91	1.9	55.7	4	54.1	20	40	35
BSR 101	1.9	46.4	21	55.9	16	41	39
Archer	1.9	46.9	20	55.7	17	41	42
Sturdy	2.0	53.6	7	62.2	3	41	40
IA 2008	2.1	53.4	8	64.0	1	45	42
Corsoy 79	2.1	49.3	15	57.6	12	44	39
Kenwood	2.1	49.2	16	63.8	2	38	41
IA 2014	2.1	58.8	1	58.4	9	39	38
Private varieties							
Asgrow A2234	2.2	52.4	9	59.4	7	39	38
Asgrow A1929	1.9	49.9	13	56.7	14	39	37
DeKalb CX 264	2.6	50.7	10	60.8	4	41	39
Marcus	2.2	50.4	11	58.4	9	37	37
Marcus BC	2.2	58.1	2	56.8	13	35	37
Nor. King S1990	1.9	57.1	3	55.3	18	39	36
Pioneer 9091	0.9	39.6	31	48.1	28	30	30
Pioneer 9171	1.7	54.0	5	60.6	5	36	36
Means		48.3		54.8		38	37
$LSD_{(0.10)}$		8.5		4.5		4	3

IMPACT OF ROW SPACING AND PLANT POPULATION ON CORN YIELDS -- 1992 through 1994

P.M. Porter, D.R. Hicks, W.E. Lueschen, D.D. Warnes, T.R. Hoverstad, and C.A. Perillo[2]

Abstract

This study was designed to investigate the relationships between row spacing, plant population, and hybrid at 3 Minnesota locations during the 1992, 1993, and 1994 growing seasons. At Lamberton and Waseca, row spacings were 10, 20 and 30 in.; target plant populations were 25000, 30000, 35000, and 40000 plants acre^{-1}; and hybrids were Ciba 'G4372,' DeKalb 'DK512,' and Pioneer Brand 'P3563.' At Morris, the same row spacings were evaluated but the plant populations were 22000, 27000 and 32000 plants acre^{-1} and the hybrids were Northrup King 'N3624,' DeKalb 'DK421,' and Pioneer Brand 'P3751.' At Lamberton and Waseca, the yield advantage for 10- and 20-in. rows compared with 30-in. rows was 7.2% when averaged over all hybrids and all plant populations, whereas at Morris the yield advantage was 8.5%. Choice of hybrid influenced grain yield, but had no interactive effect with row spacing or plant population at the 3 locations. There was a plant population by year interaction at Lamberton and Waseca: grain yields increased with greater plant populations in 1992 and 1994, but not in 1993 when yields were low due to climatic conditions. Analysis of yield versus harvest plant population showed yields were highest at harvest plant populations of about 35000 plants acre^{-1} in 1992 at Lamberton and 1994 at Waseca and Lamberton, but were unaffected by plant populations in 1992 at Waseca and in 1993 at both locations. At Morris, analysis of yield versus harvest plant population in 1993 and 1994 showed yields were highest at plant populations of 32000 plants acre^{-1}, the highest plant population studied at that location. These data show a yield advantage by narrowing row widths from 30 to 20 or 10 in., and that in some years maximum yields were obtained at plant populations substantially higher than the current average Minnesota harvest plant population of 26400 plants acre^{-1}.

Introduction

In the northern Corn Belt most corn is grown on 30 in. or wider row widths, and recommended plant densities range from 24000 to 28000 plants acre.$^{-1}$ The trend over time has been toward a narrowing of row width and an increase in plant density. There is a desire by some Minnesota producers to match row width of corn and soybean with that of sugarbeet, which is typically grown on less than 30-in. rows. That desire, coupled with the development of stronger-stemmed hybrids that seed companies say maintain high yields at higher plant populations, led to the need to address the question of how row spacing and plant population affect hybrid performance. The objectives of this study were to: (i) determine if popular corn hybrids responded similarly to row spacing of less than 30 in., and (ii) determine if the response differed over a range of plant populations.

Experimental Procedure

A 3-yr field study (1992-1994) was conducted at three Minnesota locations (Morris, Lamberton and Waseca) to examine the relationship between row spacing, plant population, and hybrid. At all three locations 3 row spacings were evaluated: 10, 20 and 30 in. At Lamberton and Waseca the plant populations were 25000, 30000, 35000, and 40000 plants acre^{-1} and hybrids were Ciba 'G4372,' DeKalb 'DK512,' and Pioneer Brand 'P3563' (relative maturities of 105). At Morris the plant populations were 22000, 27000 and 32000 plants acre^{-1}, and hybrids were Northrup King 'N3624,' DeKalb 'DK421,' and Pioneer Brand 'P3751' (relative maturities of 100). Fertilizer rates, weed control practices, previous crop, and planting and harvest dates varied with location, but recommended agronomic practices were followed for optimum production.

Planting dates were timely at all location all years. In 1993, rainfall was much above normal and early season temperatures were below normal. Growing season (April through June) precipitation and early season (May through June) growing degree day departures from average:

	Rainfall (in.)			Growing degree days in May and June		
	Lamberton	Waseca	Morris	Lamberton	Waseca	Morris
Average	19.8	22.7	17.9	890	842	769
1992	0.5	0.8	-1.1	47	46	48
1993	13.9	14.2	8.5	-162	-104	-95
1994	1.7	2.1	1.6	141	156	151

Results and Discussion

Does planting corn in rows narrower than 30 inches increase yield?
Each year of the study and at all locations corn planted on 20- and 10-in. rows yielded more than corn planted on 30-in. rows. At Lamberton and Waseca, the yield advantage for 10- and 20-in. rows compared with 30-in. rows was 7.2% when averaged over all hybrids and all plant populations, whereas at Morris the yield advantage was 8.5% (Table 1). The percentage yield increase (decrease) each year at each location associated with 20-in. rows compared to 30-in. rows are listed in Table 2.

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Should plant population be changed if corn is planted at narrower than 30-inch row spacings?
At Lamberton and Waseca, there was no interaction between row spacing and plant population, meaning that plant population should not be changed when planting in row widths narrower than a 30-in. row width. At Morris, the yields were unaffected by plant population for the narrower rows evaluated, but declined at the intermediate plant population for the 30-in. row width.

There was a plant population by year interaction at Lamberton and Waseca: grain yields increased with greater plant populations in 1992 and 1994, but not in 1993 when yields were low due to climatic conditions. Regression analysis of yield versus harvest plant population showed yields were highest at plant populations at or above 35000 plants/acre in 1992 at Lamberton and 1994 at Waseca and Lamberton, but were unaffected by plant populations in 1992 at Waseca and in 1993 at both locations. At Morris, regression analysis of yield versus harvest plant population in 1993 and 1994 showed yields were highest at plant populations of 32000 plants/acre, the highest plant population studied at that location.

Do hybrids to differ in response to row width and plant population?
Choice of hybrid influenced grain yield, but had no interactive effect with row spacing or plant population at the three locations. It is important to note that the hybrids evaluated were planted in a timely fashion and were considered to be the proper maturity for the locations where they were grown. Choice of hybrid and climatic conditions had a greater effect on grain moisture content at harvest, test weight, and ear length than row spacing or plant population (data not shown).

Conclusions

Thirty-in. rows consistently yielded less that 20- or 10-in. rows. The yield advantage of the narrower rows averaged about 7% across nine site-years. All hybrids evaluated responded similarly, and the yield advantage occurred regardless of plant population. At Lamberton and Waseca grain yields increased with greater plant populations in 1992 and 1994, but not in 1993 when yields were low due to climatic conditions. In some years of the study, especially when growing conditions were good, higher yields were obtained at plant populations higher than currently recommended by the Extension Service. Regardless of growing conditions, yields did not decline at the highest plant populations evaluated. These data show a yield advantage by narrowing row widths from 30 to 20 or 10 in., and that in some years maximum yields were obtained at plant populations substantially higher than the currently recommended harvest plant population of 29000 plants/acre.

Table 1. Corn grain yields for year, row spacing, plant population, hybrid main effects for the 3-year study.

	Lamberton and Waseca†					Morris			
	bushels acre^{-1}					bushels acre^{-1}			
Year:	1992	1993	1994		$LSD_{(0.05)}$	1992	1993	1994	$LSD_{(0.05)}$
	155b	82c	193a		4.6	111b	73c	153a	5.9
Row spacing:	10-in.	20-in.	30-in.			10-in.	20-in.	30-in.	
	146a	146a	136b		3.9	116a	114a	106b	5.9
Hybrid:	DK512	P3563	G4372			DK421	P3751	N3624	
	148a	144b	137c		3.1	106b	122a	109b	5.9
Plant Population:	25000	30000	35000	40000		22000	27000	32000	
(plants acre^{-1})	140	143	144	145	NS	112	112	112	NS

† Since the hybrids and plant populations were similar, data from Lamberton and Waseca were combined.

Table 2. Percentage yield increase (decrease) when planting corn in row widths of 20-in. rows compared to 30-in. rows.

Location	Yield increase with 20" vs. 30" rows				3-yr average Yield
	1992	1993	1994	AVG.	
	%				bushels acre^{-1}
Lamberton	7	15	5	7.1	136 vs. 127
Waseca	10	10	4	7.5	157 vs. 146
Morris	7	(-2)	11	7.5	114 vs. 106

THE CORN AND SOYBEAN ROTATION EFFECT: IMPORTANCE OF CROP ROTATION

P.M. Porter, R.K. Crookston, W.E. Lueschen, D.R. Huggins, J.H. Ford, and T.R. Hoverstad[1]

Abstract

Ongoing research begun in the early 1980s at Lamberton and Waseca clearly demonstrates the importance of crop rotation in a study specifically designed to evaluate the effect of crop rotation. Corn grown in an annual rotation with soybeans out-yielded continuous corn by 12% (138 vs. 122 bu/ac). Soybeans grown in an annual rotation with corn out-yielded continuous soybean by 14% (40.7 vs. 35.9 bu/ac). First-year corn following five consecutive years of soybean yielded 13% more than continuous corn. First-year soybean following five consecutive years of corn yielded 22% more than continuous soybeans. Soybean yields increased when grown on land that was not planted to soybeans in the previous five years as compared to when grown on land planted every other year with corn (43.7 vs. 40.7 bu/ac). This was not observed for corn: corn yields were the same whether corn was planted on land where soybeans were grown the previous five years or on land where soybeans were grown every other year. The relative increase in yields of both corn and soybean in annual rotation compared to continuous monoculture were two-fold greater in low yielding environments than in high yielding environments. In low yielding environments, the yield advantage of an annual rotation of corn and soybean compared to continuous monoculture was frequently greater than 25%

Introduction

Corn and soybean are the backbone of Midwest crop production. Alternating corn and soybeans results in increased yields for both crops as compared to growing either crop continuously. Yield increases associated with crop rotation have been referred to as the "rotation effect." Researchers have tried to pinpoint the cause of the rotation effect, but to date there is not a definitive explanation for the phenomenon. The objective of this study were to determine the impact of various corn and soybean cropping patterns on the yield of both crops, and to evaluate the impact of environment on the rotation effect.

Experimental Procedure

The study was established on the Southwest Experiment Station at Lamberton, MN in 1981 and on the Southern Experiment Station at Waseca, MN in 1982. Details of the soil types, soil fertility, and fertilizers and pesticides used through 1989 are described by Crookston et al. (Agron. J. 83:108-113). Recommended practices for optimum production were followed.

The original study design consisted of 16 treatments arranged in a randomized complete block replicated four times. This paper will discuss 14 of those treatments with the following general cropping sequences: (i) 5 years of consecutive corn alternated with 5 years of consecutive soybean, arranged so that during each year of the study there occurred a first-, second-, third-, fourth-, and fifth-yr of each crop following 5 years of the other crop; (ii) continuous monoculture of each crop; and (iii) an annual rotation of each crop. Data from the initial 4 years, when the rotation sequences were being established, were not included in the analysis. At Lamberton, 11 years of yield data were analyzed. At Waseca, 9 years of corn and 8 years of soybean yield data were analyzed.

Results and Discussion

Averaged over all the years and both the Lamberton and Waseca locations, annually rotated corn yielded 12% better, and first-year corn yielded 13% better than a continuous corn monoculture. Annually rotated soybean yielded 14% better, and first-year soybean yielded 22% better than a continuous soybean monoculture (Table 1).

There were differences in the response of the two crops to increasing years of consecutive planting. Second- to fifth-year corn yields following five consecutive years of soybeans were not different from continuous corn yields. Second-year soybeans yielded 11% better and third- to fifth-year soybeans following five consecutive years of corn yielded 5% better than continuous soybeans. These results suggest that the commonly practiced annual rotation of corn and soybean optimized corn yields, but not soybean yields, relative to the other sequences studied.

The relative increase in yields of both corn and soybean in annual rotation compared to monoculture (continuous corn or continuous soybeans) were twofold greater in low yielding environments than in high yielding environments (Tables 2 and 3). In low yielding environments, the yield advantage of an annual rotation compared to continuous corn or continuous soybeans was frequently greater than 25%. Low-yielding environments included seasons of drought (1988) as well as seasons of too much moisture (1993).

Conclusions

We conclude that the rotation effect observed for both corn and soybean was more pronounced in low-yielding environments than in high-yielding environments. Under our conditions, the commonly practiced annual rotation of corn and soybean optimized corn yields, but not soybean yields, relative to the other sequences studied.

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Table 1. Combined Lamberton and Waseca corn (C) and soybean (SB) yield when grown with seven 6-year cropping sequences. The data were averaged over an 11 year period from 1985 through 1995.

Corn			Soybean		
Cropping sequence last 6 years		Yield	Cropping sequence last 6 years		Yield
		(bu/ac)			(bu/ac)
Continuous corn	C-C-C-C-C-C[1]	122	Continuous soybean	SB-SB-SB-SB-SB-SB	35.9
Alternating C-SB	SB-C-SB-C-SB-C	136 (12%)[2]	Alternating C-SB	C-SB-C-SB-C-SB	40.7 (14%)[2]
1st-yr corn	SB-SB-SB-SB-SB-C	138 (13%)	1st-yr soybean	C-C-C-C-C-SB	43.7 (22%)
2nd-yr corn	SB-SB-SB-SB-C-C	123 (1%)	2nd-yr soybean	C-C-C-C-SB-SB	40.0 (11%)
3rd-yr corn	SB-SB-SB-C-C-C	123 (1%)	3rd-yr soybean	C-C-C-SB-SB-SB	37.7 (5%)
4th-yr corn	SB-SB-C-C-C-C	123 (1%)	4th-yr soybean	C-C-SB-SB-SB-SB	37.7 (5%)
5th-yr corn	SB-C-C-C-C-C	122 (0%)	5th-yr soybean	C-SB-SB-SB-SB-SB	37.6 (5%)

[1] Yield is listed for the crop on the left of the sequence (in bold). For example, 1st-yr corn refers to the yield of the corn crop following 5 years of soybean, SB-SB-SB-SB-SB-C.
[2] Numbers in parentheses indicate the percentage yield increase over the continuous monoculture.

Table 2. Continuous corn yield and the yield advantage (disadvantage) when corn was grown the first-year following 5 years of soybean or in a corn-soybean rotation at Lamberton and Waseca.

Location	Cropping sequence	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	'85-'95
Lamberton	Continuous corn (bu/ac)	121	140	128	84	143	134	111	122	58	111	118	115
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr corn	6	23	5	19	12	7	5	21	41	10	12	13
	Corn-soybean rotation	11	21	0	2	15	8	7	15	29	30	11	13
Waseca	Continuous corn (bu/ac)	--	120	174	76	169	145	--	147	65	148	121	129
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr corn	--	9	6	30	18	9	--	17	13	15	12	13
	Corn-soybean rotation	--	(-9)	(-3)	34	16	6	--	12	33	12	11	10

[1] See Table 1 for the combined Lamberton and Waseca data.

Table 3. Continuous soybean yield and the yield advantage (disadvantage) when soybean was grown the first-year following 5 years of corn or in a corn-soybean rotation at Lamberton and Waseca.

Location	Cropping sequence	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	'85-'95
Lamberton	Continuous soybean (bu/ac)	38.2	37.3	41.9	27.8	27.8	40.1	44.5	24.4	28.4	37.8	41.0	35.3
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr soybean	14	28	13	12	33	25	13	36	43	5	10	20
	Corn-soybean rotation	12	15	12	19	33	21	7	25	43	(-2)	5	16
Waseca	Continuous soybean	--	34.3	42.5	27.7	36.6	42.7	--	27.1	--	41.8	40.7	36.7
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr soybean	--	38	13	20	16	28	--	35	--	27	21	24
	Corn-soybean rotation	--	13	5	(-8)	13	17	--	32	--	6	9	11

[1] See Table 1 for the combined Lamberton and Waseca data.

INTERRUPTING THE CONTINUOUS CORN YIELD DEPRESSION: COMPARATIVE EFFECTIVENESS OF SEVERAL CROP ROTATIONS

P.M. Porter, R.K. Crookston, J.H. Ford, D.R. Huggins, and W.E. Lueschen[1]

Abstract

It has been well documented that monoculture corn yields less than corn grown in certain rotations. This field study investigated several agronomic crops, rotated with corn, for their relative effectiveness at interrupting the yield depression associated with corn monoculture. The study was conducted on a Webster clay loam soil near Lamberton, MN. Corn grain yields were increased ($P \leq 0.05$) by a single-year cropping of either alfalfa or sunflower prior to planting corn for each of 4 years, with the exception of the corn-sunflower rotation in 1992. Averaged across 4 years, corn yields were increased by 19 and 17% when corn followed a single-year of either alfalfa and sunflower, respectively. A single-year of either sorghum, sorghumXsudangrass, or fallow prior to planting corn did not improve corn yields compared to corn monoculture; this was true for each year and when averaged across 4 years, with the exception of the corn-fallow rotation in 1995. Averaged across 4 years, a two-year interruption of sunflower followed by alfalfa increased corn yield by 22% compared to corn monoculture. A 2-year interruption of sorghum followed by sorghumXsudangrass increased the following corn yield by 6% compared to corn monoculture. We conclude that the closely-related grasses were relatively ineffective rotation crops at interrupting the monoculture corn yield depression. Both dicots, however, improved corn yields; leguminous alfalfa being no better than the non-legume sunflower.

Introduction

In the northern U.S. Corn Belt, it has been well documented that corn grain yields are improved when annually rotated with soybean compared to monoculture. Yield decline associated with corn monoculture has been referred to as a "monoculture yield decline" or the rotation effect. While there have been numerous studies involving the monoculture corn yield depression in comparison to a soybean-corn rotation, only a limited number of studies involve other crops rotated annually with corn.

The purpose of this study was to investigate the nature of the corn monoculture yield decline by evaluating several 2- and 3-year rotations. One of our hypotheses was that "corn is bad for corn," and that any other crop (or a fallow), when rotated annually with corn, would benefit corn yields. We hypothesized all alternate crops (and a fallow) would be equally effective in interrupting the corn monoculture yield decline. To test this hypothesis we compared the yield of continuous corn to corn alternated with 1) fallow; 2) two grass species closely related to corn; and 3) two dicot species, one a nitrogen fixing legume and the other not. With the selected dicots we tested the sub-hypothesis that, with adequate nitrogen supplied to the corn, alfalfa (the nitrogen fixer) would provide no more effective yield benefit to corn than sunflower (not a nitrogen fixer). Another hypothesis was that, for either the selected grasses or dicots, a rotation sequence where corn was grown once every third-year would result in greater corn yield than a 2-year rotation sequence where corn was grown every other year. In testing this hypothesis, we compared the corn yield in either a 3-year grass-grass-corn or dicot-dicot-corn rotation to that of either a 2-year grass-corn or dicot-corn rotation.

Experimental Procedure

The study was established on the Southwest Experiment Station at Lamberton, MN in 1990 on a Webster clay loam (fine, loamy, mixed, mesic Typic Haplaquoll). Soil tests made during the study indicated a medium (3.1 to 4.5%) organic matter level, and high P and K levels (17 to 28 and 113 to 159 ppm, respectively). Fertilizer P and K were applied according the University of Minnesota Soil Testing Service recommendations. Over the course of the study, N rates ranged from 80 to 140 lbs acre^{-1} for corn and sorghum. Sunflower and sorghumXsudangrass received lower N rates ranging from 50 to 130 lbs acre^{-1}, and no N was applied to alfalfa or the fallow. These N rates were chosen to ensure N was not a limiting factor in this study. Weeds were controlled with herbicides, cultivation, and hand-weeding.

Study design consisted of 18 treatments arranged in a randomized complete block design replicated four times. The treatments consisted of the following sequences: (i) continuous corn; (ii) five 2-yr rotations of corn with fallow, sorghum, sorghumXsudangrass, sunflower, or alfalfa; and (iii) two 3-yr rotations of sorghum-sorghumXsudangrass-corn or sunflower-alfalfa-corn. The experimental design was such that corn was grown each year with each cropping sequence. In order to have an even number of treatments so that the trial would utilize the space available, there were two continuous corn treatments.

During the course of the study, corn hybrids were Pioneer Brands '3615' and '3563'; the sorghum hybrids were Northrup King '1210' and Pioneer Brand '894'; sorghumXsudangrass hybrids were Northrup King 'Sordan 79' and Pioneer Brand '877F'; sunflower hybrid was Pioneer Brand '594'; and alfalfa varieties were Pioneer Brand '5262,' 'Nitro,' and 'Saranac.' Grain was harvested from the corn, sorghum, and sunflower. Alfalfa and sorghumXsudangrass were cut 1 to 3 times annually, and only the alfalfa residue was removed from the plots. Primary tillage consisted of fall moldboard plowing, which was followed in the spring by either disking or field cultivation.

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Planting and harvest dates varied according to seasonal conditions. Planting of all crops took place between 18 April and 30 May. Corn was harvested between 30 September and 27 October. Corn, sorghum, sorghumXsudangrass and sunflower were planted in 30-inch rows, whereas alfalfa was broadcast seeded. Plots were 15ft wide (12 rows) and 35ft long; corn harvest for yield determination was from 30ft of 4 center rows. Plots were harvested with field-plot equipment.

Grain yield data were analyzed using the general linear model (GLM) procedure. Treatment mean comparisons were made using Fisher's protected LSD at $P \leq 0.05$.

Results and Discussion

Growing conditions were near excellent during the 1994 growing season, and corn yields were 19, 132 and 33% higher that year than in 1992, 1993, and 1995 respectively. Cool and wet conditions during the growing season in 1993 resulted in very poor corn yields (Tables 1 and 2). Each of the four years, cropping sequence had an effect on corn yields. For the 4-year combined data there was no cropping sequence by year interaction.

Corn yields averaged across 4 years were increased by 19% for the 2-year alfalfa-corn rotation compared to continuous corn (Table 2). Each year, corn in the alfalfa-corn rotation yielded more than continuous corn: 10, 45, 20, and 13% in 1992 through 1995, respectively. Corn yields averaged across 4 years were 17% greater for the 2-year sunflower-corn rotation than for continuous corn. The sunflower-corn rotation yielded 26, 26, and 15% more corn than continuous corn in 1993 through 1995, respectively. Only in 1993 was the corn yield of the 2-year alfalfa-corn rotation greater than the corn yield of the 2-year sunflower-corn rotation.

For the 4-year combined data there was no difference in corn yield between the two 2-year dicot rotations: annually rotating corn with alfalfa or sunflower resulted in 19 and 17% greater corn yields, respectively, than corn monoculture. It is probably not realistic to expect this level of yield advantage over time. In a corn-soybean rotation study conducted on a site directly adjacent to this study, researchers found annual rotation of soybean with corn resulted in a 20% corn yield advantage averaged over the same 4-year period (corn yielded 15, 29, 30, and 11% more when grown in annual rotation with soybean compared to monoculture in 1992 through 1995, respectively). In that study, however, corn yields were only 12% higher when corn was grown in annual rotation with soybean compared to monoculture when comparing 18 location by yr environments, and in low yielding environments the relative magnitude of the rotation effect increased.

Corn yields from the 2-year sorghum-corn and the 2-year sorghumXsudangrass-corn rotations were not different from yields of continuous corn in any of the 4 years of the study, or for the 4-year combined data (Table 2). Only in 1995 did corn yield from the 2-year fallow-corn rotation yield more than continuous corn. In the other 3 years of the study, and for the 4-year combined data, there was no difference in yield between continuous corn and corn in the fallow-corn rotation.

Corn yield averaged across 4 years for the 3-year sunflower-alfalfa-corn rotation was 22% greater than the continuous corn yield (Table 2). Each year corn in the sunflower-alfalfa-corn rotation yielded more than continuous corn: 15, 41, 24, and 17% in 1992 through 1995, respectively. Averaged across 4 years, the 3-year sorghum-sorghumXsudangrass-corn rotation resulted in a 6% increase in corn yield compared to continuous corn, however, corn yields from the 3-year sorghum-sorghumXsudangrass-corn rotation were not different than continuous corn yields in any of the 4 years of the study. Averaged across 4 years, corn yielded 15% more in the 3-year sunflower-alfalfa-corn rotation than in the 3-year sorghum-sorghumXsudangrass-corn rotation (Table 2). Corn in the sunflower-alfalfa-corn rotation yielded 10, 34, and 12% more than corn in the sorghum-sorghumXsudangrass-corn rotation in 1992, 1993 and 1995, respectively. In 1994, there was no difference in corn yield between the two 3-year rotations.

Averaged across 4 years, there was no significant difference in corn yield between the 3-year rotation involving the monocots and the two 2-year rotations involving monocots (Table 2). Likewise, there was no significant difference in corn yield between the 3-year rotation involving the dicots and the two 2-year rotations involving dicots.

With dicots as the alternate crop, corn yields were not affected whether the interruption of the corn monoculture occurred annually or two of three yr; both rotations improved yields. With grasses as the alternate crop, corn yields were not affected by an annual interruption of the corn monoculture, but increased slightly when grasses other than corn were grown two of three years in a 3-year rotation. However, corn yielded more for the 3-year sunflower-alfalfa-corn rotation compared to the 3-year sorghum-sorghumXsudangrass-corn rotation, again suggesting dicots were more effective at interrupting the corn monoculture yield depression.

These results show sorghum and sorghumXsudangrass, grasses closely related to corn, grown in annual rotation with corn had no effect on yields relative to monoculture. The results also show that the dicots alfalfa and sunflower grown in annual rotation with corn improved corn yields relative to monoculture. Whether it is true that all dicots interrupt the monoculture yield depression is uncertain, and warrants further research.

Since the dicots selected for this study effectively alleviated corn monoculture yield decline while the selected grasses and fallow did not, our hypothesis that all alternate crops (and a fallow) would be equally effective in interrupting the corn monoculture yield decline was incorrect. The concept that "corn is bad for corn" needs to be expanded to include that certain grasses, when alternated with corn, are bad for corn.

Our sub-hypothesis that, under conditions where nitrogen was not limiting, alfalfa alternated with corn would provide no more effective corn yield benefit than sunflower alternated with corn was correct.

With dicots as the rotation crop, we did not detect a corn yield advantage when comparing corn grown every other yr to corn grown every third year. Likewise, with grasses as the rotation crop, we did not detect a corn yield advantage when comparing corn grown every other year to corn grown every third year. These data suggest corn yields would not be increased if corn were grown once every third year as compared to every other year. Thus, the hypothesis that a rotation sequence where corn was grown once every third-year would result in greater corn yield than a 2-year rotation sequence where corn was grown every other year was not true.

Conclusion

These results show sorghum and sorghumXsudangrass, grasses closely related to corn, grown in annual rotation with corn had no effect on corn yields relative to continuously grown corn. The results also show that the dicots alfalfa and sunflower grown in annual rotation with corn improved corn yields relative to continuously grown corn, The yield increase from a 2-year rotation of corn with the leguminous alfalfa was not significantly different than that observed for the non-legume sunflower. Whether it is true that all dicots interrupt the monoculture yield depression is uncertain, and warrants further research.

Table 1. Corn planting and harvest dates, seasonal rainfall, and growing degree days at Lamberton MN during the 1992 through 1995 growing seasons.

	Year								35-year average	
	1992		1993		1994		1995			
Plant date	May 4		May 20		May 10		May 5		early-May	
Harvest date	Oct. 17		Oct. 27		Oct. 21		Oct. 6		mid-Oct.	
Monthly rainfall (inches) and growing degree days (GDD)[†]										
Month	in.	GDD	in.	GDD	in.	GDD	in.	GDD	in.	GDD
May	1.61	450	7.09	281	1.34	430	4.17	270	3.19	342
June	4.09	487	11.14	447	4.45	601	1.69	571	3.86	548
July	4.80	470	5.24	600	2.68	577	6.93	631	3.90	661
August	5.12	480	5.28	594	4.06	520	3.35	659	2.99	588
September	2.09	370	2.36	262	3.74	429	2.20	371	3.19	369
Total	17.72	2257	31.10	2184	16.26	2557	17.56	2502	17.13	2508

[†] Growing degree days were calculated with a base of 50° and 86°F.

Table 2. Grain yield of corn grown from 1992 to 1995 at Lamberton, MN for continuous corn and seven cropping sequences involving five 2-year and two 3-year rotations.

Sequence description	Year 1992	1993	1994	1995	4-year average
	Corn yield bushels/acre				
Continuous corn	145	66	162	124	124
2-yr sorghum-corn rotation	146	73	165	134	130
2-yr sorghumXsudangrass-corn rotation	143	71	170	125	127
2-yr fallow-corn rotation	139	72	170	139*	130
2-yr alfalfa-corn rotation	160*[†]	96*	195*	140*	148*
2-yr sunflower-corn rotation	154	84*	203*	143*	146*
3-yr sorghum-sorghumXsudangrass-corn rotation	152	70	178	129	132*
3-yr sunflower-alfalfa-corn rotation	167*	94*	201*	145*	152*

[†] In each column, a * indicates that cropping sequence was significantly greater in yield than continuous corn.

ORGANIC CROP ROTATION STUDY AT LAMBERTON -- 1995

P.M. Porter, C.A. Perillo, and D.R. Huggins[1]

Abstract

In 1995, manure application in an on-going organically managed study employing no herbicides or synthetic fertilizer increased corn yields, but not soybean yields, regardless of rotation length. Corn yields in the manured and non-manured treatments averaged 112 and 51 bushels acre^{-1}, respectively. Soybean yields in the manured and non-manured treatments averaged 24.6 and 30.4 bushels acre^{-1}, respectively. Length of rotation had no effect on corn yields in the manured treatments, but impacted yields in the non-manured treatments with continuous corn yielding less than corn in 2- and 4-year rotations. For soybeans, highest yields were obtained with the 4-year rotation compared to the 2- and 3-year rotations, with the increase especially pronounced in the manured treatments. Oat yields were unaffected by rotation length or manure application. The high coefficients of variations, particularly in the non-manured treatments, were probably due in part to high and variable weed pressure.

Introduction

This on-going study evaluates various crop rotations managed organically under both high and low fertility levels. The crop rotations include 1) continuous corn, 2) a 2-year corn-soybean rotation, 3) a 3-year corn-soybean-oat rotation, and 4) a 4-year corn-soybean-oat-alfalfa rotation. The site of the study (Koch Farm adjacent to the Southwest Experiment Station) had a 30+ year history of no synthetic fertilizer use and minimal pesticide use. The study began in 1990, and at that time the Bray 1 phosphorus level was 10 ppm and the potassium level was 171 ppm. All the crop rotations have been grown both with and without poultry manure applications. There were no chemical weed control practices used, only mechanical weed control methods. The 1995 yield results are reported here. Previous results were presented in last year's edition of this publication.

Experimental Procedure

The study involved a randomized complete block design with a split-plot arrangement and 4 replicates. Rotation length was the main plot variable, and fertility management was the sub-plot variable. Main plot size was 60 ft by 155 ft, and sub-plot size was 30 ft by 155 ft. The composted poultry manure rate was based on the soil test results from the previous fall sampling and University of Minnesota Extension recommendations. The rate used was expected to meet the crop requirement of the most limiting nutrient (P or N). The manure was broadcast and incorporated prior to secondary tillage in the spring (Table 1). Soil samples for phosphorus and potassium were taken on Nov. 21 to a depth of 1 ft with 8 composite cores per sub-plot. Soil nitrate samples were taken on Nov. 16 in 1 ft increments to a depth of 5 ft with 2 composite cores per sub-plot.

After oat and oat/alfalfa treatments were planted, the plots were harrowed and packed in an effort to increase weed control and improve soil to seed contact. Corn and soybean plots were rotary-hoed and cultivated in an effort to better control weeds. Tillage and rotary hoeing in like crops in all rotations were treated the same, but row-cultivation in corn varied depending on fertility level. As in the past, all plots except those with oats under-seeded with alfalfa were moldboard plowed in the fall.

Total weed counts were taken in all plots. All weed species were identified and counted in each sample. In corn and soybean three samples 4-ft long and 2.5-ft wide were collected for grassy weeds, and three samples 150 ft by 2.5 ft were collected for broadleaf weeds. In oats and alfalfa five 1-ft squares per plot were collected for both grassy and broadleaf weeds.

Results and Discussion

In 1995, corn yields were increased with the addition of manure regardless of rotation length: manured and non-manured treatments averaged 112 and 51 bushels acre^{-1}, respectively (Table 2). Length of rotation had no effect on corn yields in the manured treatments, but impacted yields in the non-manured treatments. Without manure the continuous corn yield substantially less than corn in the 2- and 4-year rotations. Weed pressure in the 3-year rotation may have contributed to the corn yield of that rotation being no different than the continuous corn yield. In the 3-year rotation the crop preceding corn was oats, and weeds were more difficult to manage in oats than in either the soybeans or the alfalfa - crops which preceded corn in the 2- and 4-year rotations.

In 1995, as in 1994, soybean yields were higher when grown without manure as compared to with manure (24.6 and 30.4 bushels acre^{-1}, respectively), as weeds were more of a problem in the manured treatments (Table 2). Soybean yields responded favorably to increasing rotation length in treatments receiving manure. Oat yields were unaffected by rotation length or manure application, but in general were low. There was no difference between the manured and non-manured alfalfa treatments. The high coefficients of variations, particularly in the non-manured treatments, were probably due in part to high and variable weed pressure.

[1] P.M. Porter (assistant professor - Department of Agronomy and Plant Genetics), C.A. Perillo (assistant scientist), and D.R. Huggins (assistant professor- Department of Soil, Water, and Climate) are at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. 1995 management information for the organic crop rotation study at Lamberton.

Rotation	Spring tillage and dates	Seed, rate, and planting date †	Rotary hoeing dates	Cultivation dates	Fertilizer rates and dates
Continuous corn	Field cultivator	Pioneer P3769	5-31	6/13, 6/22, 7/7 (N)‡	
	5/18 (N)	30000 seeds acre^{-1}	6/02	6/13, 6/22 (Y)	289-361-289
	5/18, 5/19 (Y)	5/20	6/05		on 5/19
Corn-soybean	Field cultivator	Pioneer P3769	5-31	6/13, 6/22, 7/7 (N)	
	5/18 (N)	30000 seeds acre^{-1}	6/02	6/13, 6/22 (Y)	249-315-252
	5/18, 5/19 (Y)	5/20	6/05		on 5/19
Corn-soybean-oats	Field cultivator	Pioneer P3769	5-31	6/13, 6/22, 7/7 (N)	
	5/18 (N)	30000 seeds acre^{-1}	6/02	6/13, 6/22 (Y)	252-315-252
	5/18, 5/19 (Y)	5/20	6/05		on 5/19
Corn-soybean-oats-alfalfa	Field cultivator	Pioneer P3769	5-31	6/13, 6/22, 7/7 (N)	
	5/18 (N)	30000 seeds acre^{-1}	6/02	6/13, 6/22 (Y)	40-50-40
	5/18, 5/19 (Y)	5/20	6/05		on 5/19
Corn-soybean	Field cultivator	Parker	5/31	6/13, 6/22, 7/10 (N)	
	5/18, 5/22 (N)	158,000 seeds acre^{-1}	6/05	6/13, 6/22, 7/10 (Y)	24-30-24
	5/18, 5/20, 5/22 (Y)	5/22			on 5/20
Corn-soybean-oats	Field cultivator	Parker	5/31	6/13, 6/22, 7/10 (N)	
	5/18, 5/22 (N)	158,000 seeds acre^{-1}	6/05	6/13, 6/22, 7/10 (Y)	24-30-24
	5/18, 5/20, 5/22 (Y)	5/22			on 5/20
Corn-soybean-oats-alfalfa	Field cultivator	Parker	5/31	6/13, 6/22, 7/10 (N)	
	5/18, 5/22 (N)	158,000 seeds acre^{-1}	6/05	6/13, 6/22, 7/10 (Y)	24-30-24
	5/18, 5/20, 5/22 (Y)	5/22			on 5/20
Corn-soybean-oats	Field cultivator and	Dane	none	none	
	harrow / packer	85 lbs acre^{-1}			40-50-40
	5/02 (N and Y)	5/02			on 5/20
Corn-soybean-oats-alfalfa	Field cultivator and	Dane and Pioneer P5262	none	none	
	harrow / packer	85 and 15 lbs acre^{-1}			40-50-40
	5/02 (N and Y)	5/02 and 5/02			on 5/20
Corn-soybean-oats-alfalfa	none	Planted previous year	none	none	52-65-52
					on 5/20

† Hybrid or variety is listed, followed by seeding rate in seeds acre^{-1} and planting date.
‡ N refers to non-fertilized treatments, Y refers to fertilized treatments. Analysis of the composted manure was 4-5-4% N-P_2O_5-K_2O.

Table 2. Rotation length and fertility effects on corn, soybean, oats and alfalfa yields in an organically-managed study at Lamberton, 1995.

Rotation	With manure	Without manure
Corn yield	---- bushels acre^{-1} -----	
Continuous corn	112.8	34.1 c
Corn-soybean	119.7	56.9 ab
Corn-soybean-oats	110.5	44.8 bc
Corn-soybean-oats-alfalfa	106.6	66.2 a
Mean	112.4	50.5
CV (%)	5.0	21.5
Pr> F	0.051	0.011
$LSD_{(0.05)}$	9.0	17.3
Soybean yield	---- bushels acre^{-1} -----	
Soybean-corn	17.0 b	29.5
Soybean-oats-corn	20.7 b	29.5
Soybean-oats-alfalfa-corn	36.0 a	32.3
Mean	24.6	30.4
CV (%)	27.0	26.0
Pr> F	0.015	0.85
$LSD_{(0.05)}$	11.4	13.7

Rotation	With manure	Without manure
Oat yield	--- bushels acre^{-1} ---	
Oats-corn-soybean	34.6	34.0
Oats-alfalfa-corn-soybean	36.4	32.7
Mean	35.5	33.4
CV (%)	4.2	18.7
Pr> F	0.18	0.80
$LSD_{(0.05)}$	3.35	14.0
Alfalfa yield	--- ton acre^{-1} ----	
Alfalfa-corn-soybean-oats	5.90	4.23
With vs. without manure		
CV (%)	20.3	
Pr>F	0.11	
$LSD_{(0.05)}$	2.31	

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1995

Month/ Period	Dates/ Period	Precipitation 1995	Precipitation 100-yr. average	Precipitation Dev. from av.	Air Temperature 1995	Air Temperature 100-yr. average	Air Temperature Dev. from av.	Soil Temperature (10 cm depth) 1995	Soil Temperature 10-yr. average
January	1-31	0.91	0.68	+0.23	12.1	8.0	+4.1	25.6	20.7
February	1-28	0.55	0.67	-0.12	14.4	12.8	+1.6	25.4	23.9
March	1-31	3.77	1.13	+2.64	28.7	26.7	+2.0	32.1	29.2
April	1-10	0.16	0.57	-0.41	32.7	38.0	-5.3	36.0	
	11-20	1.98	0.64	+1.34	38.0	44.4	-6.4	35.8	
	21-30	0.36	1.05	-0.69	43.9	48.3	-4.4	43.6	
Total/av.		2.50	2.26	+0.24	38.2	43.6	-5.4	38.4	41.4
May	1-10	0.75	0.77	-0.02	52.0	52.0	–	50.2	
	11-20	1.25	0.95	+0.30	55.4	55.8	-0.4	54.0	
	21-31	1.10	1.25	-0.15	56.9	60.0	-3.1	57.2	
Total/av.		3.10	2.97	+0.13	54.8	56.1	-1.3	53.9	57.1
June	1-10	1.21	1.29	-0.08	66.3	63.0	+3.3	67.5	
	11-20	0.41	1.30	-0.89	73.5	66.3	+7.2	73.0	
	21-31	0.48	1.37	-0.89	71.8	68.1	+3.7	74.3	
Total/av.		2.10	3.96	-1.86	70.5	65.8	+4.7	71.6	69.3
July	1-10	5.06	1.44	+3.62	66.5	70.1	-3.6	69.0	
	11-20	0.56	1.06	-0.50	73.2	71.4	+1.8	77.7	
	21-31	1.12	1.01	+0.11	69.7	71.4	-1.7	75.5	
Total/av.		6.74	3.51	+3.23	69.8	70.9	-1.1	74.0	76.7
August	1-10	0.71	1.04	-0.33	70.2	70.4	-0.2	76.3	
	11-20	2.97	0.93	+2.04	72.0	69.0	+3.0	76.5	
	21-31	2.58	1.04	+1.54	71.8	66.9	+4.9	76.2	
Total/av.		6.26	3.01	+3.25	71.4	68.7	+2.7	76.3	73.9
September	1-30	2.68	2.20	+0.48	58.6	59.0	-0.4	64.7	61.5
October	1-31	3.35	1.74	+1.61	44.7	47.2	-2.5	48.5	47.8
November	1-30	0.44	0.97	-0.53	23.2	29.7	-6.5	30.1	33.6
December	1-31	1.04	0.68	+0.36	15.4	15.2	+0.2	22.4	23.4
Growing Season	4/1-8/31	20.70	15.71	+4.99	60.9	61.0	-0.1	63.9	63.8
Annual	1/1-12/31	33.44	23.78	+9.66	41.8	42.0	-0.2	46.9	46.7

ANHYDROUS AMMONIA - KNIFE SPACING STUDY[1]

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

Abstract

A field study was initiated in Morris, MN in 1994 and repeated in 1995 to study the effects of 2 anhydrous ammonia applicator knife spacings at sidedress on corn grain yield. Nitrogen was sidedressed at 0, 36, 72, 108, and 144 lb/A using 30- and 60-inch applicator knife spacings. In 1994 and 1995 there was an increase in grain yield up to 72 lb N/A but no difference in yield due to knife spacing.

Objectives

Anhydrous ammonia is the dominant source of inorganic nitrogen used in corn production. Normally anhydrous ammonia is injected into the soil through knives that run 6 to 10 inches deep. Horse-power requirements and fuel consumption are high during this process. It would be advantageous to space anhydrous ammonia knives 60 inches apart, rather than the conventional 30-inch spacing, to reduce horse-power and fuel requirements during the anhydrous ammonia application process. At the 60-inch spacing no ammonia is applied in the tractor wheel tracks. This study was designed to evaluate corn grain yield response due to spacing of anhydrous ammonia applicator knives at 30-inch intervals versus 60-inch intervals. The anhydrous ammonia was applied sidedress at the V5 stage of corn with a conventional ammonia applicator.

Experimental Procedures

The 1995 experiment was established on a Nutley clay soil. For 1994 experimental procedures see 'Blue Book' Miscellaneous Publication 88-1995, page 55. The experimental design was a randomized complete block with 4 replications. The experimental site was in Oats in 1994 and fall chisel plowed. Initial soil tests are shown in Table 1. The 1995 individual plots were 6 rows (15ft) wide and 45 feet long. The experimental site was field cultivated and seeded to Ciba Geigy 4172 corn at 30,000 seeds per acre on May 1, 1995. Force 1.5G was band applied at 10 lb/A at seeding. A 6-row J.D. Maxemerge planter was used for seeding. Lasso @ 3.0 lb/A a.i. + Bladex @ 2.2 lb/A a.i. was applied pre-emergence broadcast on May 2. Basagran @ 0.75 lb/A a.i. + 1 qt/A COC was applied on June 12 for Canada thistle control. Anhydrous ammonia was sidedress applied on June 21. Nitrogen was applied at rates of 36, 72, 108, and 144 lb/A at 30- and 60-inch knife spacings. A check treatment was also included by running knives at 30- and 60-inch spacings through the check plots without applying any nitrogen. Corn was in the V5 stage, 4-5 collars visible at the time of nitrogen application. The study was row cultivated prior to nitrogen application on June 21. Corn tasseling and silking dates were recorded and occurred between July 24-29. The study was harvested with a plot combine on October 12. Grain yield and grain moisture were recorded.

Results

There were significant differences in grain yield due to nitrogen rate (Table 2) in 1994 and 1995. Grain yield was maximized at about 72 lb/N in both years. Grain moisture at harvest was highest and tasseling and silking were latest for the 0 lb/N treatment in both years (data not shown). There were no significant effects on grain yield due to knife spacing in 1994 or 1995. The knife spacing x treatment interaction was not significant in 1994, but was significant in 1995. Examination of data for the 1995 interaction indicated that most of the effects were attributed to nitrogen rate. Two years of results show no differences in grain yield due to 30- and 60-inch anhydrous ammonia knife applicator spacings at sidedress.

Table 1. Analysis of site soil samples taken in the fall of 1994.

Organic Matter	pH	Olsen P	K	0-2 ft NO_3-N	2-5 ft NO_3-N
%	–	ppm	ppm	lb/A	lb/A
5.2	7.3	22	246	22	16

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

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

Table 2. Effect of applicator knife spacing on corn grain yield, Morris 1994 and 1995.

Nitrogen Rate	Knife Spacing	1994 Grain Yield	1995 Grain Yield
lb/A	inches	bu/A	bu/A
0	30	80.5	103.6
36	30	106.9	115.7
72	30	150.3	162.6
108	30	142.7	162.8
144	30	159.3	163.2
0	60	80.5	89.5
36	60	113.5	139.0
72	60	148.9	155.7
108	60	153.3	158.7
144	60	159.8	162.4
Nitrogen Rate			
Sig. Level (%)		99	99
BLSD (.05)		20.5 bu	7.6 bu
Knife Spacing			
Sig. Level (%)		34	12
N Rate x Knife Spacing			
Sig. Level (%)		2	99
C.V. (%)		16.7	5.8

Continuous Corn Silage, 1965-1995[1]

S.D. Evans[2]

Abstract

In 1965 an experiment was initiated on a McIntosh silt loam soil to determine the effects of removal of continuous corn silage or continuous corn grain on corn silage yields and soil fertility levels under low- and high-fertility regimes. 1995 was the last year of the study. A 30-year analysis shows no silage yield differences due to the removal of continuous corn silage versus continuous corn grain. A significant difference in yield exists between the low- and high-fertility regime. Significant soil test P and K differences exist due to fertility regime but the K soil test and not the P soil test was affected by above ground silage removal compared to removing only the grain.

Objective

This the 30th and final year of a corn silage study initiated in 1965 on a McIntosh silt loam soil. The study was initiated to determine the effects of removal of continuous corn silage and continuous corn grain on corn silage yields and soil fertility level. Yields were assessed under low (74+48+48, $N+P_2O_5+K_2O$ in lbs/a) and high (148+96+96, $N+P_2O_5+K_2O$ in lbs/a) fertilizer regimes.

Experimental Procedures

The experiment was designed as a latin square with 4 treatments: (1) silage-low fertility, SLF (2) silage-high fertility, SHF (3) grain-low fertility, GLF and (4) grain-high fertility, GHF. Silage yields were recorded from 1966 to 1995 except in 1993 when the corn failed to reach maturity and was chopped down and incorporated back into the soil. From 1965 to 1994 the plots were fertilized each fall with specific plots receiving a 74+48+48 or a 148+96+96 fertilizer blend. Each fall after fertilization the plots were moldboard plowed. The study was seeded at optimum rates to established corn hybrids usually in early to mid May as soil temperature and moisture conditions allowed. A rootworm insecticide was applied at planting. Weed control was normally achieved through pre-emergence or post-emergence applications of grass and broadleaf herbicides and through row cultivation once or twice a year depending on soil conditions and weed pressure. Designated plots were either harvested as corn silage or had only the grain harvested. Silage yields were obtained by hand chopping and weighing 3 10-foot rows from each plot. Ears and stover were separated and weighed separately. Ear moisture was obtained by removing the center 3/4 inch section of 10 ears and forage moisture was obtained by running 5 stalks through a forage chopper. Ear and forage samples were weighed wet, dried for 48 hours at 150°F, and weighed dry for moisture determination. On "silage" plots the remaining bulk of the corn was harvested with a conventional forage harvester as corn silage. On the "grain" plots corn grain was harvested with a combine. Silage yields were also taken on an adjacent unfertilized (check) area. This check was not a part of the experimental design.

Results

Silage Yields

There were significant differences in silage yields after 30 years of continuous corn in low- versus high-fertility regimes, (Table 1). The difference in silage yields between the low- and high-fertility regime was 0.63 tons/A for the continuous silage plots and 0.48 tons/A for the continuous grain plots. The 30-year average silage yield for the check treatment adjacent to the study was 3.39 tons/A compared to 5.57 tons/A for the low- and 6.13 tons/A for the high-fertility regime. There was no significant difference in corn silage yield when silage was removed versus when only the grain was removed at the low- or high-fertility regime. This would indicate that continuous corn silage removal had no effect on silage yield if an adequate fertility regime is maintained. In Fig.1 silage yields are presented in 5 year intervals. The high fertility treatments and low fertility treatments performed similarly throughout the life of the study.

Soil Fertility

The results of soil analysis for the initial year of the study in 1965, and for 1985 and 1991, as well as results for the final year of the study in 1995 are given in Table 2. The P soil test differs significantly in 1985 between low- and high-fertility regimes 20 years after initiation of the study. P soil test levels continued to increase from 1985 to 1995. It appears that initial low P soil test levels were increased to high and very high P soil test levels and maintained at low 48-lb P and high 96-lb P fertility regimes respectively. Corn silage removal had no appreciable effect on P soil test levels, but K soil test levels were substantially affected. K soil test levels were unchanged from 1965 to 1995 on the SLF treatment, but raised by 24, 51, and 107 ppm on the SHF, GLF, and GHF treatments respectively. Corn silage removed more K than grain only but soil test levels were still maintained by the SLF treatment.

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

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

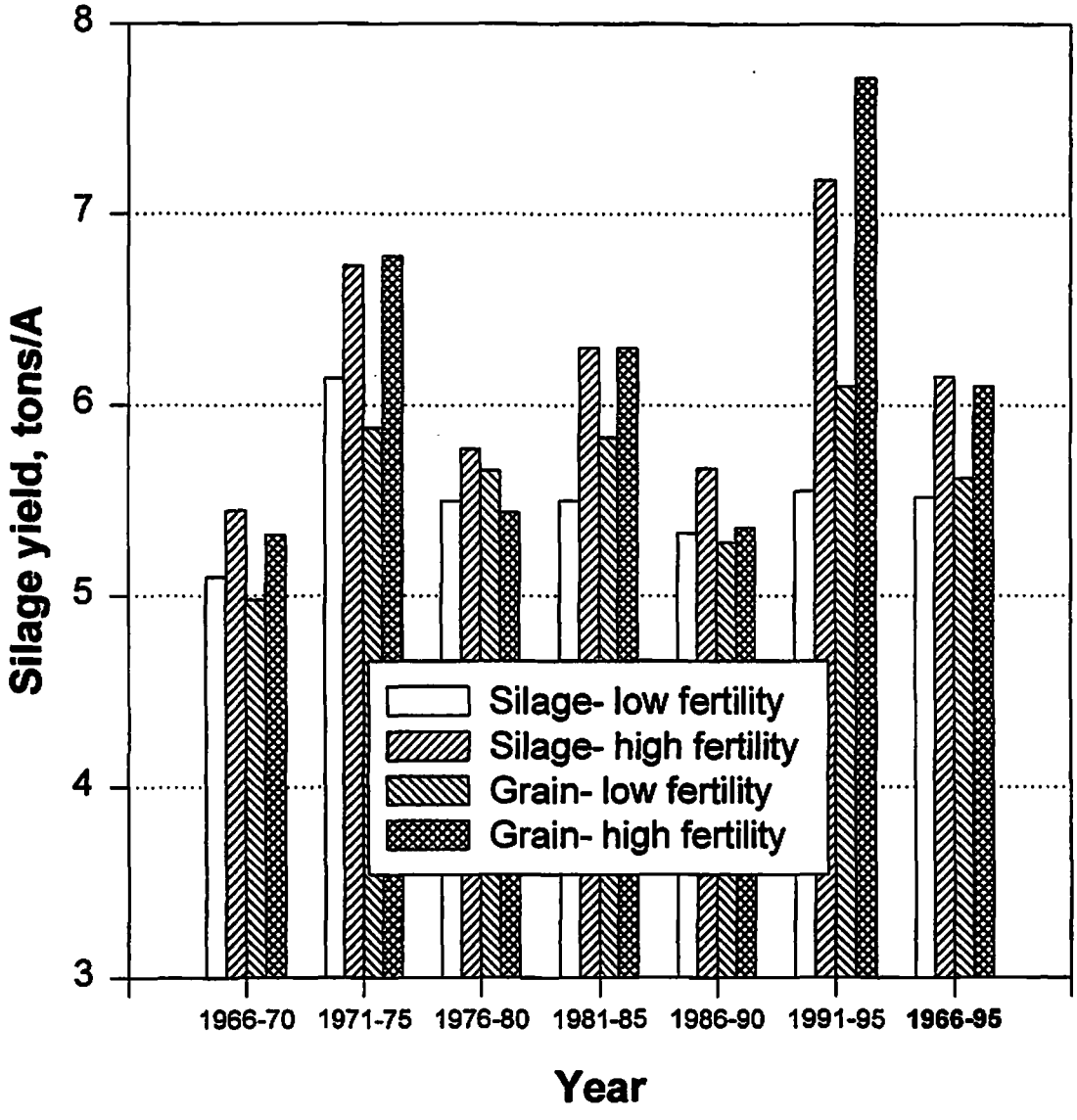
Table 1. Effect of removal of continuous silage or grain only on silage yields.

Treatment	1966-1995 Silage Yield
	dry matter, tons/A
Silage, low fertility	5.52
Silage, high fertility	6.15
Grain, low fertility	5.62
Grain, high fertility	6.10
Signif. Levels (%)	
Treatment	>99
Year	>99
Treatment x Year	>99
BLSD, Treatment (.05)	0.16
C.V. (%)	11.8

Table 2. Effect of removal of continuous silage or grain at 2 fertility regimes on P and K soil tests at four intervals over a 30 year period.

Treatment	1965	1985	1991	1995
Silage-low fertility				
pH	7.8	8.1	8.2	8.2
O.M. %	4.5	–	–	4.0
P Soil test-ppm	6	13	14	16
K Soil test-ppm	129	131	119	120
Silage-high fertility				
pH	7.9	8.1	8.2	8.2
O.M. %	4.3	–	–	4.1
P Soil test -ppm	6	21	33	31
K Soil test -ppm	127	146	139	151
Grain-low fertility				
pH	7.9	8.1	8.1	8.2
O.M. %	4.4	–	–	3.9
P Soil test -ppm	5	9	17	15
K Soil test -ppm	123	166	158	174
Grain-high fertility				
pH	7.9	8.1	8.1	8.2
O.M. %	4.2	–	–	4.0
P Soil test -ppm	6	24	37	38
K Soil test -ppm	119	199	199	236
P Signif. Level (%)	NS	99	>99	>99
P BLSD (.05)	–	8	9	5
K Signif. Level (%)	NS	>99	>99	>99
K BLSD (.05)	–	17	15	16

Fig.1. Effect of removal of continuous corn silage or grain only on silage yields with low and high fertility treatments in 5 year increments, 1966 - 1995.



SOUTHERN EXPERIMENT STATION
35838 120th STREET
WASECA, MINNESOTA 56093-4521

WEATHER DATA - 1995

Month	Period	Precipitation 1994	Precipitation Normal[1/]	Avg. Air Temp. 1994	Avg. Air Temp. Normal[1/]	Growing Degree Units 1994	Growing Degree Units Normal[1/]
		---- inches ----		----- °F -----			
January	1 - 31	0.40	0.98	16.1	10.2		
February	1 - 28	0.21	0.97	19.0	16.1		
March	1 - 31	3.28	2.28	33.2	29.1		
April	1 - 30	3.73	2.97	40.7	43.1		
May	1 - 10	0.47		52.5		61.0	
	11 - 20	1.40		57.2		99.0	
	21 - 31	1.52		58.2		105.0	
	Total	3.39	3.65	56.0	57.7	265.0	327
June	1 - 10	0.88		65.8		166.5	
	11 - 20	0.03		71.2		211.0	
	21 - 30	2.28		74.6		229.0	
	Total	3.19	4.11	70.8	67.1	606.5	515
July	1 - 10	0.27		66.1		164.5	
	11 - 20	2.65		76.4		241.5	
	21 - 31	2.34		72.3		242.5	
	Total	5.26	4.21	71.6	71.3	648.5	646
August	1 - 10	3.56		71.7		217.0	
	11 - 20	0.65		74.4		234.5	
	21 - 31	0.35		74.6		263.5	
	Total	4.56	4.20	73.6	68.4	715.0	567
September	1 - 30	4.08	3.56	59.2	59.9	277.5	316
October	1 - 31	4.98	2.45	47.1	47.9	-	31
November	1 - 30	1.17	1.72	25.9	32.3		
December	1 - 31	1.28	1.35	18.6	16.2		
Year	Jan-Dec	35.53	32.45	44.3	43.4	2512.5[2/]	2402
Growing Season	May-Sep	20.48	19.73	66.3	64.9	2512.5	2371

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

Notes:
1) Highest 24-hour precipitation on August 5 --- 1.92"
2) Growing degree units 5% above normal for season.
3) Highest temperature on July 14 --- 101°F.
4) Last spring frost --- April 28.
5) First fall frost --- September 22.

1995 Soil Moisture

0-5' Profile, Webster Clay Loam

Continuous Corn

Southern Experiment Station, Waseca, MN 56093

Depth	4/14	5/1	5/15	6/1	6/16	6/30	7/17	7/31	8/17	8/31	9/15	10/4	10/16	11/2
inches	inches available water in zone													
0 - 6[1]	1.03	1.21	1.17	1.14	1.12	0.93	0.40	0.90	1.11	0.66	0.75	1.21	1.14	1.23
6 - 12	1.02	1.05	0.95	0.88	0.84	0.68	0.11	0.64	0.61	0.42	0.56	0.81	0.80	0.98
12 - 18	1.00	1.09	0.79	0.96	0.83	0.72	0.29	0.70	0.66	0.42	0.67	0.95	0.95	1.05
18 - 24	0.69	0.82	0.74	0.78	0.63	0.58	0.33	0.53	0.57	0.37	0.39	0.74	0.72	0.75
24 - 36	1.79	1.69	1.88	2.12	1.57	1.85	1.28	1.44	1.54	1.15	1.21	1.46	1.66	1.83
36 - 48	2.49	2.52	2.51	2.71	2.42	2.58	2.05	2.36	2.34	2.13	2.15	2.00	2.29	2.54
48 - 60	1.92	2.12	2.18	2.23	2.01	2.08	1.90	1.98	2.00	1.88	1.88	1.64	2.03	2.07
Total available water in 0-5' profile (inches)	9.93	10.50	10.22	10.82	9.42	9.43	6.38	8.55	8.84	7.03	7.61	8.81	9.60	10.45
% of Capacity[2]	90	95	92	98	85	85	58	77	80	64	69	80	87	95

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

[2] Assuming 11.05" field moist capacity.

Above average rainfall resulted in plentiful soil moisture in the five-foot profile throughout the 1995 growing season. Lowest soil moisture levels occurred in mid-July and again in late August following two-week dry periods with very hot conditions when peak ET occurred. Soil moisture in early November was at 95% of field capacity and reflects the abnormally wet October. With any snow melt or early spring rainfall, soil moisture will likely be at field capacity in April and could delay field operations.

NITROGEN AND MANURE MANAGEMENT FOR CORN AFTER ALFALFA IN WINONA COUNTY

G. W. Randall and J. A. Vetsch

1995

ABSTRACT: Semi-solid dairy manure was applied at rates of 10, 20, and 30 T/A (wet basis) to a 3-yr old stand of alfalfa in October, 1993 and chisel plowed in immediately. After growing corn in 1994 and removing it for silage, liquid dairy manure was applied and immediately incorporated at rates of 7500, 10000, and 13800 gal/A to plots which both received and did not receive manure for first-year corn. The manure treatments were compared to urea applied at rates from 0 to 160 lb N/A. Grain yields were improved above the control by all of the manure and most of the fertilizer N treatments. Responses were greater for manure, especially when applied for two consecutive years, compared to fertilizer N. Yields were not improved by applying more than 7500 gal/A. Nitrate-N concentrations in the soil water at a 5-ft depth were consistently higher throughout the season when manure or fertilizer N had been applied for first-year corn after alfalfa. Due to dry conditions in 1995, manure applied in October 1994 did not affect the NO_3-N concentration at this depth. Although these data show a slight yield advantage for applying manure to both first and second-year corn after alfalfa, the environmental consequence is substantial - - greatly elevated concentrations of residual soil NO_3 at the end of the season and NO_3 concentrations in the soil water leaching out of the soil profile.

Surveys of land owners in Winona County indicate a substantial acreage of corn is planted following alfalfa. Previous studies have shown little or no corn yield response to fertilizer N for first-year corn after alfalfa. Yet many farmers often add some fertilizer N and dairy farmers without an adequate land base for manure often apply manure following alfalfa for corn. The result of these fertilizer and manure additions is an abundant supply of N, which is in excess of plant use and which can contribute significantly to nitrates in the ground water. Nitrogen management for second year corn after alfalfa can be impacted by the N inputs to the previous corn crop. The purposes of this study were to determine: (1) the effect of dairy manure and fertilizer N applied to first and second-year corn following alfalfa on corn production, nitrate-N in the soil profile, and nitrate-N in the soil water at the 5' and 7.5' depths and (2) the "available" N to corn in an animal-based cropping system by evaluating various soil N tests from samples taken periodically during the season.

MATERIALS AND METHODS

The site is located on a Seaton silt loam at the Robert and Eugene Kalmes farm in Winona County. Alfalfa was companion seeded with oats in May 1991 following five years of continuous corn. After removing three cuttings of alfalfa in 1993, semi-solid dairy manure was applied on Oct. 27 at rates of 10, 20, and 30 T/A (wet) to plots that were replicated four times. Three manure samples were taken and analyzed. Average values were: 18.7% dry matter, 10.8 lb total N/ton, 4.0 lb NH_4-N/ton, 10.9 lb P_2O_5/ton, and 14.4 lb K_2O/ton. All plots were chisel plowed to an 8 - 9" depth within 6 hours. Corn was then grown in 1994. After grain and silage yields were measured, all of the corn was removed from the plots as silage.

Liquid dairy manure was applied to selected treatments on October 25, 1994. The manure was broadcast applied on the surface and incorporated with a chisel plow within 3 hours. Two manure samples were analyzed. Average values were 8.1% dry matter, 27.6 lb total N/1000 gal, 14.1 lb NH_3-N/1000 gal, 18.5 lb P_2O_5/1000 gal, and 30.0 lb K_2O/1000 gal.

Corn (Pioneer 3861) was planted on May 5 after field cultivation. Weeds were controlled well with herbicides. No mechanical cultivation was practiced. Urea was broadcast applied and incorporated on May 5. Soil water samples were taken periodically during the season from porous cup samplers installed at a depth of 5'. Grain and silage yields were taken by hand-harvesting 60' of row from each plot on Oct. 3.

Soil samples consisting of six random cores/plot were taken at the V-5 stage (June 23) when corn was about 12" tall. After harvest (October 13) three random cores/plot were taken in 1-foot increments to a depth of 5 feet. Cores from each plot were composited by depth, placed in paper bags, forced-air dried at 125 degrees F., ground, and analyzed for NO_3-N.

RESULTS AND DISCUSSION

Grain yields obtained in this study were much poorer than expected due primarily to the hybrid used, dry weather, severe root lodging caused by strong winds on Aug. 13, and very high levels of European corn borer. Yields were improved by the fertilizer N treatments but especially by the manure treatments (Table 1). The highest second-year corn yields were obtained where some manure had been applied for both first and second-year corn. Yields were slightly lower (6 bu/A) when manure was applied only for second-year corn. When no manure was applied and only fertilizer N was used, yields were about another 6 bu/A lower. The response to manure was easily visibly seen in June as the manure plots produced taller and darker green corn. Rate of manure application had no effect on grain yield; yields with 7500 gal/A were as good as with 13800 gal/A.

Table 1. Grain, stover, and silage yields, grain and stover N content, and total N removal in the grain, stover, and silage as affected by manure and fertilizer applied to second-year corn following alfalfa.

'93-94 Treatments		'94-95 Treatments		Yield			N Concentration		N Removal		
Manure[1/]	Nitrogen	Manure[1/]	Nitrogen	Grain	Stover	Silage	Grain	Stover	Grain	Stover	Silage
T/A(wet)	lb/A	gal/A	lb/A	bu/A	T DM/A	T DM/A	--- % ---		----- lb N/A -----		
0	0	0	0	97	1.91	4.21	1.21	0.62	55	24	79
10	0	7500	0	124	2.44	5.37	1.32	0.72	77	35	112
20	0	10000	0	126	2.54	5.51	1.42	0.68	84	35	119
30	0	13800	0	124	2.30	5.23	1.40	0.70	82	32	114
0	75	0	160	113	2.25	4.92	1.45	0.66	78	31	109
0	0	7500	0	118	2.69	5.49	1.34	0.70	75	38	112
0	0	10000	0	118	2.64	5.42	1.31	0.67	73	35	108
0	0	13800	0	124	2.68	5.60	1.43	0.68	84	36	120
0	0	0	40	112	2.16	4.81	1.35	0.71	72	30	102
0	0	0	80	114	1.98	4.67	1.35	0.71	72	28	101
0	0	0	120	112	2.24	4.90	1.40	0.75	78	34	111
0	0	0	160	102	2.10	4.53	1.43	0.80	69	33	102
Statistical Analysis of Treatments											
P > F:				<0.01	<0.01	<0.01	0.02	0.23	<0.01	0.03	<0.01
LSD (0.05):				11	0.36	0.55	0.12		10	7	12
C.V. (%):				7	11	8	6	11	9	15	8
Contrast Statistics											
P > F: 'Manure vs Fertilizer N'				<0.01	<0.01	<0.01	0.27	0.17	0.01	0.01	<0.01
P > F: '2-yr Manure vs 1-yr Manure'				0.20	0.03	0.39	0.59	0.51	0.18	0.26	0.70

[1/] Manure rates applied 10/27/93 as semi-solid dairy manure and 10/25/94 as liquid dairy manure.

Nitrate-N concentrations in the soil water at a 5' depth also were affected significantly by the manure and N treatments (Table 2). Treatments 2 - 5, which received either manure or urea for first-year corn, gave consistently higher NO_3-N concentrations throughout the season than did those manure and urea treatments that were applied only for second-year corn. Due to the dry weather, which severely limited leaching, no impact of the manure applied in the fall of 1994 or urea applied in the spring of 1995 was observed at this depth in 1995.

Table 2. Nitrate-N concentrations in the soil water at 5' in July, August, and September, 1995 as affected by manure and fertilizer N applied for second-year corn after alfalfa.

'93-94 Treatments		'94-95 Treatments		Nitrate-N Concentration in Soil Water at 5'		
Manure	Nitrogen	Manure	Nitrogen	June	August	September
T/A(wet)	lb/A	gal/A	lb/A	---------- mg/l ----------		
0	0	0	0	12	10	10
10	0	7500	0	17	18	–
20	0	10000	0	40	35	34
30	0	13800	0	33	--	30
0	75	0	160	32	31	26
0	0	7500	0	12	12	11
0	0	10000	0	12	13	12
0	0	13800	0	24	--	16
0	0	0	40	19	20	19
0	0	0	80	16	16	16
0	0	0	160	15	16	16

Soil NO_3-N at the V-5 stage was surprisingly high at this site for all treatments, and it was increased further above the control by the high rate of manure and by fertilizer N rates ≥ 80 lb/A (Table 3). The 19 ppm concentration found in the control plots was very close to the critical level of 21 ppm which has been established in several research studies as the value above which a yield response to N will not occur. This may partially explain the small yield response (< 30 bu/A) to N in this study.

Residual soil NO_3-N (RSN) in the 0-5' profile was increased significantly over the control by the treatments where manure and fertilizer N were applied to both first and second year corn after alfalfa (Table 3). Manure applications caused increased soil NO_3-N primarily in the top 3 to 4' while the 75-lb fertilizer N rate applied in 1994 followed by 160 lb N/A in 1995 showed elevated RSN levels throughout the profile. Application of either manure or fertilizer only for second year corn resulted in somewhat higher RSN levels compared to the control, primarily in the top 2 feet. This accumulation near the surface was likely due to the dry weather in 1995. Contrast statistics showed higher RSN levels in the top 3 feet for the fertilizer N treatments compared to the manure treatments and for the second year manure applications compared to the single year applications.

Table 3. Nitrate-N concentrations in the 0-1' layer at the V-5 stage (June 23) and in the 0-5' soil profile after harvest (Oct. 13) as influenced by manure and fertilizer N rates.

'93-94 Treatments		'94-95 Treatments		Nitrate-N Concentration						
				June 23	October 13					
Manure	Nitrogen	Manure	Nitrogen	0-1'	0-1'	1-2'	2-3'	3-4'	4-5'	0-5'
T/A(wet)	lb/A	gal/A	lb/A	ppm						lb/A
0	0	0	0	19	4.6	1.9	1.6	2.2	2.6	52
10	0	7500	0	26	7.6	6.6	3.9	4.2	3.3	102
20	0	10000	0	25	8.1	7.6	5.9	4.1	3.9	118
30	0	13800	0	31	8.1	8.4	6.2	4.4	3.7	123
0	75	0	160	36	15.4	19.0	9.5	6.4	4.4	219
0	0	7500	0	21	5.5	3.7	2.7	2.9	2.9	70
0	0	10000	0	25	6.6	5.4	3.2	3.1	2.7	84
0	0	13800	0	30	5.0	3.5	3.7	5.5	4.5	89
0	0	0	40	20	6.1	4.8	3.1	3.1	2.4	78
0	0	0	80	30	6.2	5.2	4.1	3.4	4.5	94
0	0	0	120	42	9.6	12.4	5.7	3.5	2.8	136
0	0	0	160	50	11.9	15.8	5.7	3.4	3.0	159
Statistical Analysis of Treatments										
P > F:				<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
LSD (0.05):				13	3.4	5.7	3.0	1.9	1.5	40
LSD (0.10):				10	2.9	4.7	2.5	1.6	1.2	33
CV (%):				29	30	50	45	35	30	25
Contrast Statistics										
P > F: 'Manure vs Fertilizer N'				<0.01	<0.01	<0.01	0.04	0.81	0.88	<0.01
P > F: '2-yr Manure vs 1-yr Manure'				0.53	0.03	0.05	0.02	0.43	0.60	<0.01

SUMMARY

- Grain yields were higher where dairy manure had been applied compared to only fertilizer N (urea).
- Increasing the manure rate from 7500 gal/A to 13800 gal/A did not improve second-year corn yields.
- Applying manure or fertilizer N for first-year corn gave substantially higher NO_3-N concentrations in the soil profile and in the soil water at a 5' depth 12 to 24 months after application. Moreover, first-year corn yields were not affected by the manure or fertilizer N treatments (data not shown).
- Based on these data liquid dairy manure is a superb source of N for second year corn but should not be applied and is not a BMP for first-year corn after alfalfa.