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This 1997 edition of the soils "bluebook" compiles data collected and analyzed throughout Minnesota. Information is contributed by personnel of the University of Minnesota Department of Soil, Water, and Climate; by soil scientists at the Minnesota Agricultural Experiment Station branch stations at Crookston, Lamberton, Morris and Waseca, and at the Becker and Staples research farms; and by Soil and Crop area agents. Associated personnel from the Soil Conservation Service, and the Soil and Water Research group of the ARS-USDA, the Tennessee Valley Authority, and the Departments of Agriculture and Natural Resources also contribute.

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Table of Contents

Climate

Becker

Rosemount

Lamberton

Morris

Waseca

Off Station Research

Climate Summary - 1996

January brought an assortment of mild and frigid temperatures. A powerful storm sweeping through the Midwest on January 17 and 18 produced heavy snow in the north and west, and left southeastern Minnesota covered with ice. Throughout the State, schools and offices closed, travel was difficult, and power outages occurred.

Late January and early February brought a cold spell of historic proportions to the Upper Midwest. Various locations across Minnesota set all-time low temperature records. A location near Tower broke the all-time Minnesota low temperature record with minus 60 degrees F on February 2. Temperatures moderated by the second week of February and slowly melted the snow cover from southern Minnesota, easing flooding concerns in those areas. However, northern Minnesota lost relatively little snow cover. By late March, snow depths were still greater than 18 inches over large areas of the north..

After enduring one of the harshest winters of the century, northern Minnesota experienced a very cold spring. Significant snow cover persisted in the North well into mid-April. Spring runoff from the heavy snow cover led to flooding, with northwestern Minnesota experiencing the most serious flooding.

Southern Minnesota also experienced an unusually cold spring. Temperatures averaged three to five degrees below normal for April and May. The Twin Cities reached 67 degrees on April 10, the first time the temperature reached 60 or more for nearly six months. The cold temperatures suppressed soil warming and drying, leading to significant delays in spring planting.

Heavy rains in mid-May dropped two to six inches of water on the already saturated Red River Valley, further delaying agricultural field operations and leading to more flooding. May also brought the usual severe spring weather to western and southern Minnesota, leading to significant property damage in some areas.

The weather was highly variable across the state in June. Very dry weather for the first three weeks of the month led to forest fires in the north, especially northeastern Minnesota. Fortunately, late June rains quelled the fire potential. In contrast to the dryness of the north, some areas of southern Minnesota received torrential rains in mid-June. A slow moving low pressure system, plodding through the Upper Midwest produced a deluge in south central Minnesota on June 16 and 17. Rainfall totals exceeded six inches in portions of Nicollet and Blue Earth counties leading to small stream and urban flooding as well as mud slides.

Relatively dry weather was the major climate issue of July. As of late July, many areas of central and western Minnesota had received just 50 to 75 percent of normal precipitation for the season. However, there was a notable exception to this pattern. Extreme northwestern Minnesota received substantial rains in July and precipitation totals were well above normal for the season.

Dry and pleasant weather was the rule throughout the late summer and early fall across Minnesota. For some regions of the state, dry weather was a continuation of a very dry growing season. In a few communities, the precipitation deficit was similar to the worst droughts of the century. Fortunately, moderate summer temperatures led to reduced evaporation rates, mitigating the impact of the rainfall shortage. The Palmer Drought Severity Index indicated that southeastern Minnesota was in the "moderate drought" category in the fall. Northwestern, central, and east central Minnesota fell in the "moderate drought" category for much of the summer and early fall.

A notable exception to the dry late summer weather was in the Mankato area in early September. For the second time in 1996, the area received extremely heavy rains leading to urban flooding, mud slides and sewer backups. Rainfall totals exceeded six inches.

Agricultural production across Minnesota showed mixed results. Those areas receiving adequate rainfall reaped the benefits of stress-free temperatures. Meanwhile, those areas with precipitation deficits experienced significant yield reductions. Many communities saw their first light frost in mid September, and all of Minnesota experienced a hard freeze in the first week of October.

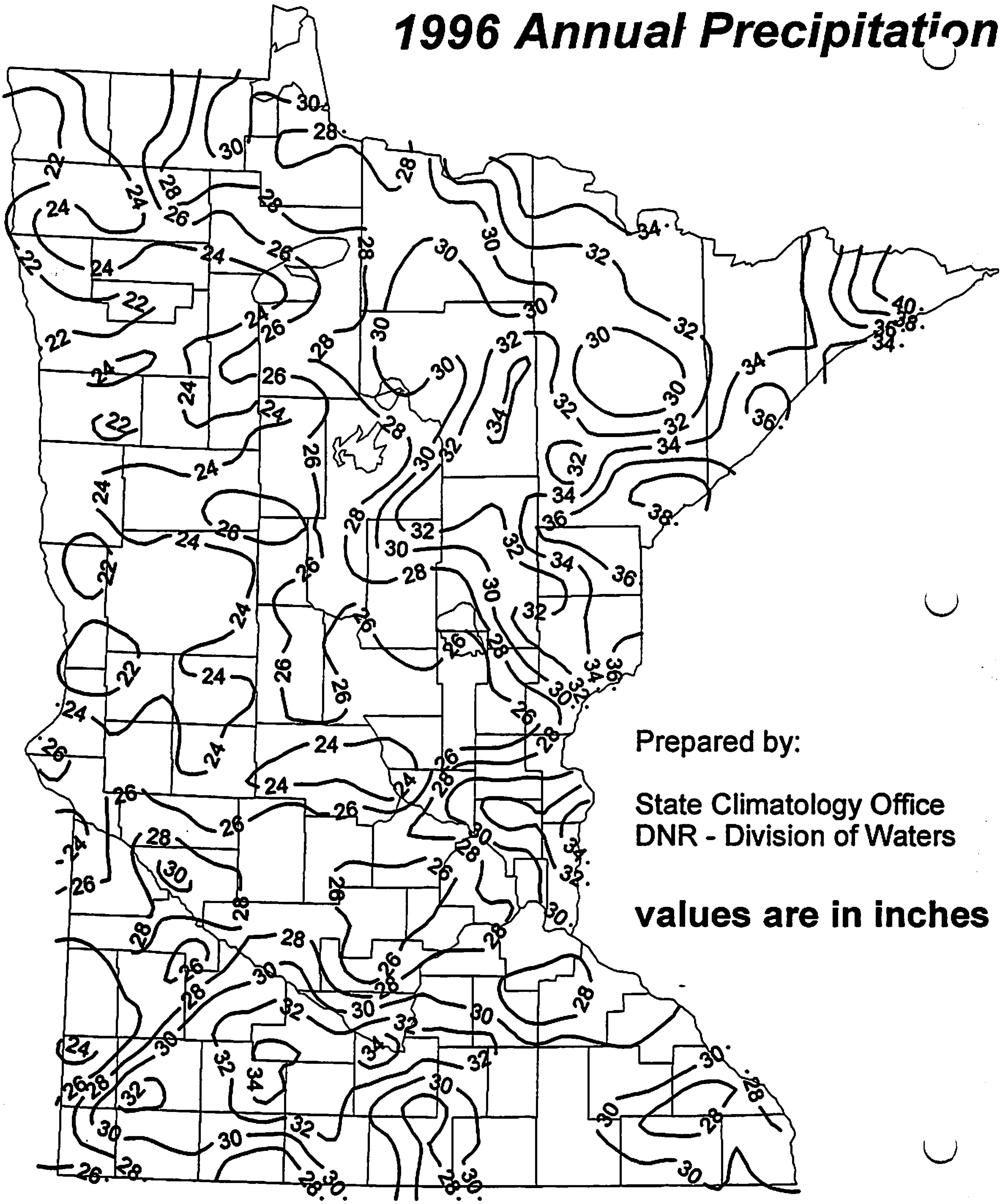
After a dry growing season, much of Minnesota experienced an extremely wet fall. For considerable areas of the state, precipitation totals for October and November ranged from four to eight inches. The October plus November precipitation totals ranked above the 95th percentile across large sections of Minnesota. Much of this precipitation fell before the soil froze and helped to replenish diminishing soil moisture reserves.

A major storm system passing through the central United States brought a wintry mess to the state in mid-November. Precipitation types included snow, rain, sleet and freezing rain. Some areas of northwestern Minnesota received over a foot of snow, making travel treacherous. Portions of eastern Minnesota reported nearly four inches of rain, dampening basements and causing minor urban flooding. Freezing rain in southwestern Minnesota brought down power lines, cutting electrical service to many. Southwestern Minnesota experienced yet another freezing rain event roughly one week later, hindering recovery from the first ice storm.

Mean November temperatures were considerably colder than normal. For many Minnesota communities it was one of the coldest Novembers of the century. November of 1996 was also one of the wettest this century, with a good deal of both freezing rain and snowfall.

Significant winter storms also occurred in December. Freezing rain events, snow storms, and full-fledged blizzards occurred throughout the month. Hardest hit was the western one third of Minnesota, where the prairie landscape did little to slow the arctic winds. Schools and offices closed across western Minnesota in mid-December. Christmas Day, 1996 will go down in history as the coldest and most snow-covered on record for many Minnesota communities. Cold temperature records fell across the state. Christmas Day snow depths over western and central Minnesota were at or near record levels for the date.

1996 Annual Precipitation

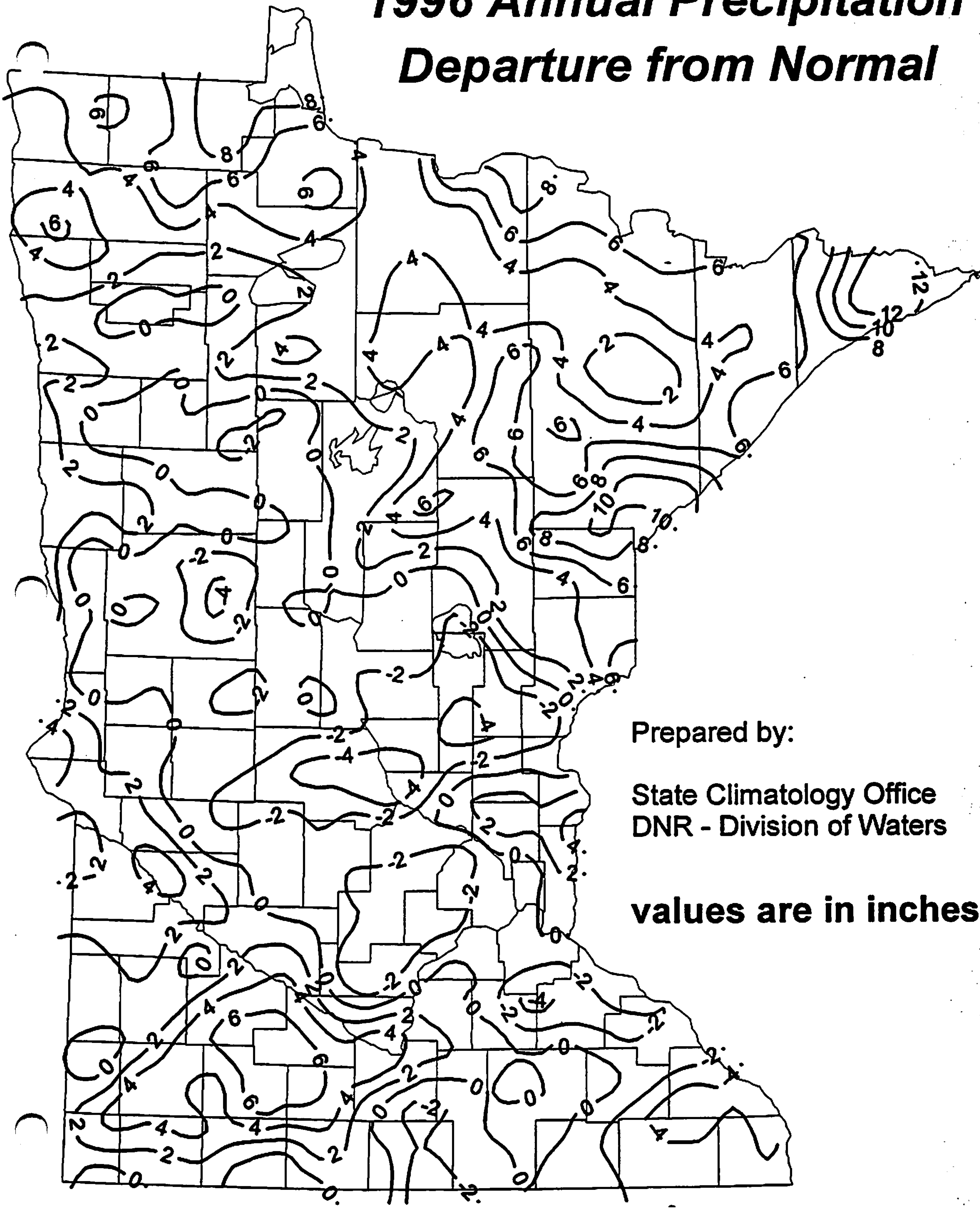


Prepared by:

State Climatology Office
DNR - Division of Waters

values are in inches

1996 Annual Precipitation Departure from Normal



Prepared by:

State Climatology Office
DNR - Division of Waters

values are in inches

LONG TERM EVAPORATION AND SOIL WATER RECORDS COMPARED TO 1996 RESULTS

By Donald G. Baker and David L. Ruschy

Evaporation is the loss of water from a moist surface into the atmosphere in the form of vapor. Except under unusual circumstances it is invisible. Because of this, the amount of water lost through evaporation is seldom appreciated. In Minnesota the loss is on the order of 20-30 inches per year. Evaporation estimates are ordinarily obtained by measuring the daily loss of water from a pan which measures 48 inches in diameter. Water depth in the pan is maintained at a depth of about 10 inches.

Unlike a lake the pan is extremely limited in area and, unlike a living leaf containing minute pores through which the water escapes to the atmosphere, the pan presents a free water surface to the atmosphere. As a result, the evaporation on a unit area basis from a pan is, under most circumstances, greatly in excess of that from a lake or an actively transpiring crop. In fact the evaporation from these two natural surfaces is in the neighborhood of only 50-70% of the pan. Nevertheless, in spite of the difference between the pan and natural surfaces the pan data do provide a reasonable estimate of the evaporation losses if the reduction factor is applied. The pan has the added advantages of being easy to measure as well as providing a uniform measurement. As a result, comparisons can be made between stations and between years.

Evaporation pans have been in place at the Agricultural Experiment Stations located at Lamberton, Morris, St. Paul, and Waseca for a number of years. It is that data which is shown in Table 1 and Fig. 1 and will be discussed. Due to the very limited evaporation between October 11-April 20, largely the winter period of little evaporation, the data shown in Fig. 1 represent the annual total.

Perhaps the most striking feature of Fig. 1 is the high evaporation centered around 1976 and 1988, the years of two well remembered droughts in Minnesota. The severity of the two droughts is evident in Fig. 1 as well as in the precipitation totals for those two years at St. Paul: 14.39 inches in 1976 and 20.36 inches in 1988 compared to a normal of 28.41 inches (1961-1990).

The evaporation from 1991 to the present, averaging 34.73 inches, has been considerably below the long term average, of 38.21 inches, Fig. 1, indicating relatively humid conditions and adequate precipitation.

Table 1. Mean total pan evaporation, inches, April 21-October 10, 1972-1996.

Station	Mean	Standard Deviation	Maximum/year	Minimum/year
Lamberton	40.21 in.	5.57 in.	56.95 in./1976	33.46 in./1972
Morris	39.33 in.	6.27 in.	58.22 in./1976	30.86 in./1996
St. Paul	38.21 in.	4.77 in.	51.41 in./1988	32.91 in./1993
Waseca	40.03 in.	4.59 in.	53.33 in./1988	32.99 in./1993

Lengthy soil water records are also available from the Lamberton and Waseca experiment stations. A comparison between the 1996 values and the long term average of plant available soil water under corn at the two stations is shown in Fig. 2 and 3. Except for a brief period in mid- to late June the soil water content at Lamberton was above average. Due to the relatively high end-of-season values it appears that the spring 1997 water content at Lamberton will be more than adequate.

The soil water at Waseca, Fig. 3, shows a market mid-season variation. First, there was an unusual low value which occurred in July, and second, it was followed by a temporary recovery in late August. The late fall values, Fig. 3 indicate that the soil water at Waseca will be quite adequate for the 1997 spring as it will be at Lamberton.

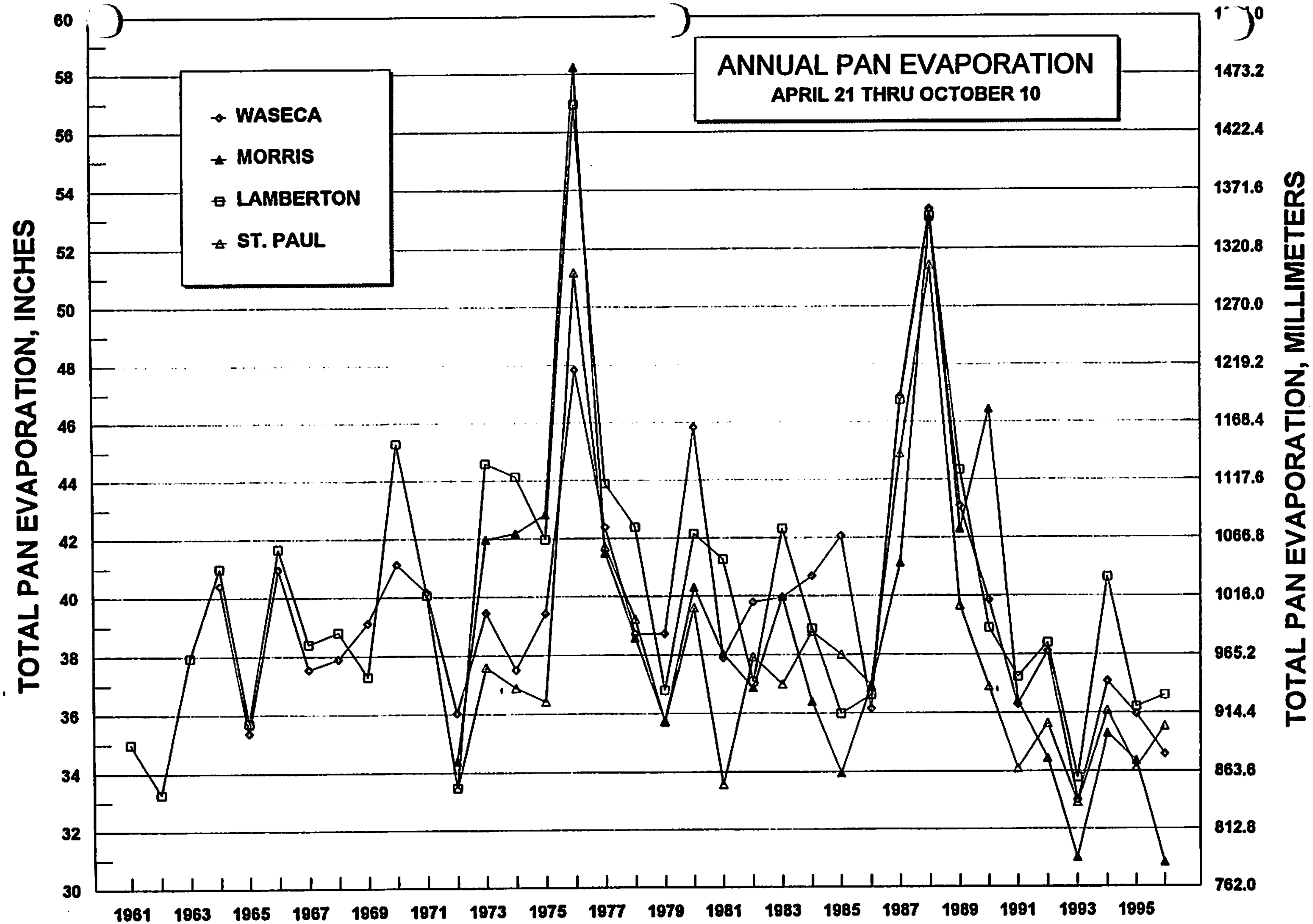


Fig. 1. Annual total pan evaporation for April 21 thru October 10.

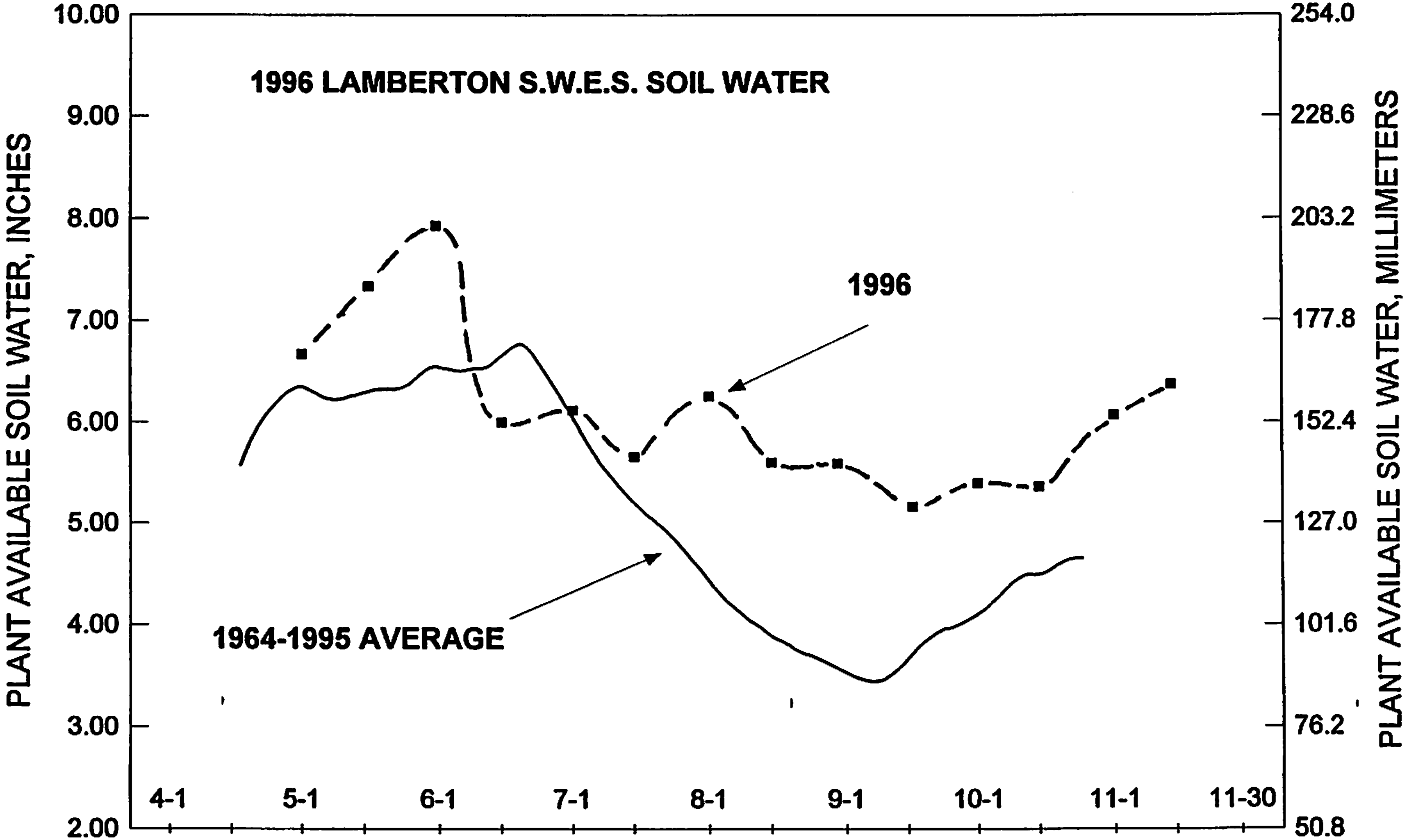


Fig. 2. Total plant available soil water in a 5-foot column of soil at the Lamberton S.W.E.S. in 1996 shown against the 1964-1995 average.

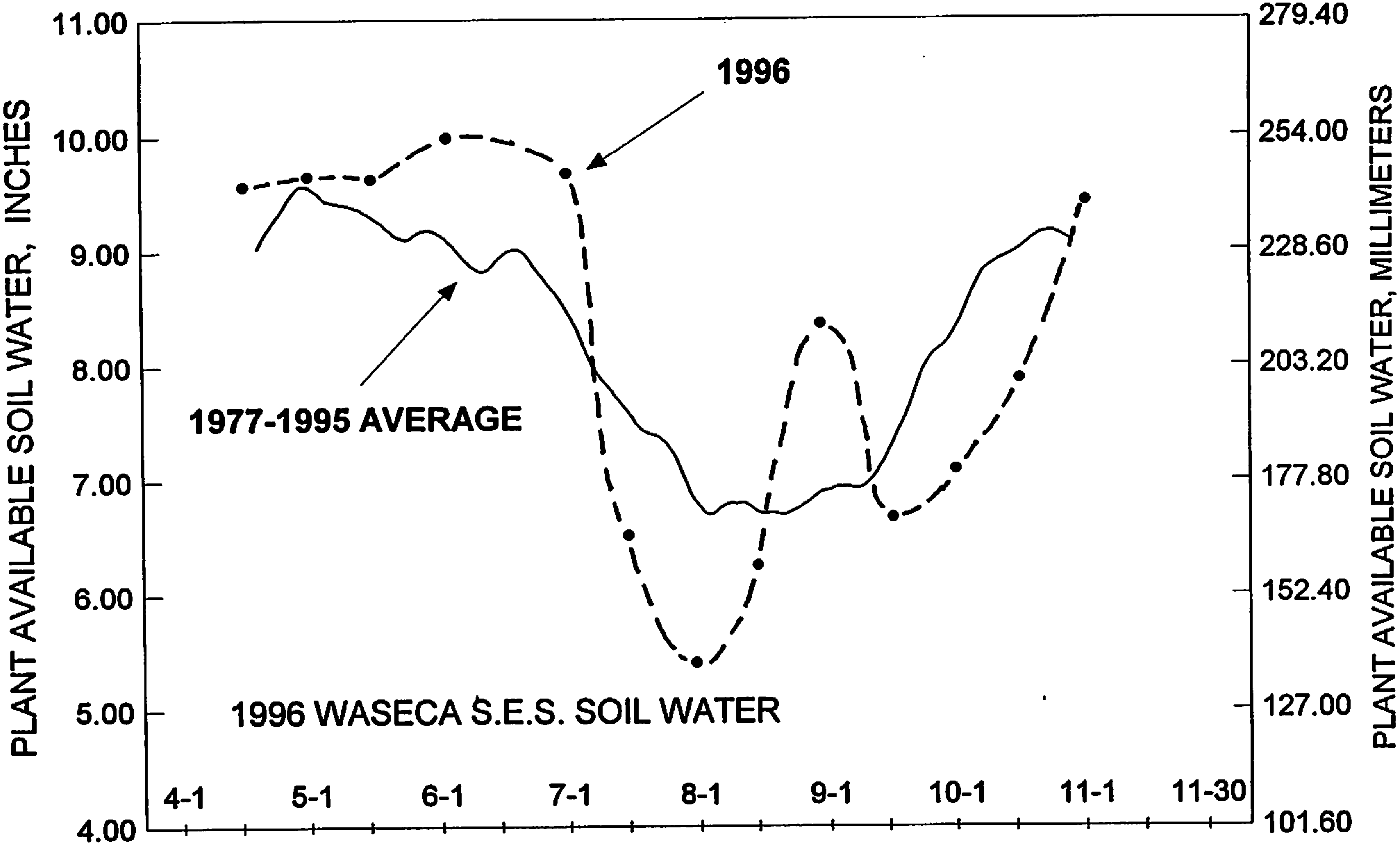


Fig. 3. Total plant available soil water in a 5-foot column of soil under corn at the Waseca S.E.S in 1996 shown against the 1977-1995 average.

RESPONSE OF SNOWDEN AND GOLDRUSH POTATO CULTIVARS TO NITROGEN ON AN IRRIGATED SOIL - 1996[1]

Carl Rosen and Dave Birong[2]

ABSTRACT: The second year of a three year field study was conducted at the Sand Plain Research Farm at Becker to determine the effects of nitrogen rate and timing on yield of Snowden and Goldrush potatoes. For Snowden, increasing N rate from 125 lb N/A to 285 lb N/A had no effect on total yield, but increased tuber size. Post-hilling applications of N had no effect on yiled, but tended to reduce hollow heart incidence. Increasing N rate increased total yield of Goldrush and tended to decrease tubers in the 3-6 oz category and increase tubers in the greater than 12 oz category. Post-hilling N application tended to decrease yield of Goldrush. The petiole nitrate test on both a dry weight and sap basis was useful for measuring the N status of the crop. For Snowden, petiole nitrate-N concentrations greater than 0.6% on a dry weight basis and 1000 ppm on a sap basis in mid-July were associated with the highest yields. For Goldrush, highest yields were associated with a petiole nitrate-N concentration of 1.0% on a dry weight basis and 1100 ppm on a sap basis during tuber bulking.

Potatoes are a relatively shallow rooted crop, often supplied with high rates of nitrogen to promote growth and yield. High rates of nitrogen are used because of the potential for increased yield and a high rate of return compared to the cost of nitrogen applied. Shortage of nitrogen during the growing season can seriously limit yield and tuber size. The shallow root system of potatoes, high nitrogen requirement, and production on sandy soils greatly increase the potential of nitrate contamination of shallow aquifers under irrigated potato production. This environmental concern has prompted research to identify management practices that will minimize nitrate losses to groundwater. Recent studies with Russet Burbank have shown that timing of nitrogen application can have a dramatic effect on nitrogen use efficiency by the potato crop. Delaying most of the nitrogen until after emergence decreased nitrate concentrations in the soil water below the root zone by over 50%. Use of the petiole nitrate sap test to schedule N application after hilling for late season varieties has also shown promise for improving nitrogen use efficiency. While great strides have been made in understanding the nitrogen requirement of potatoes and reducing nitrate losses, improvements in N use efficiency can still be made. Areas that need attention are: determining N response and calibrating the sap test for varieties other than Russet Burbank. The overall objective of this study was to characterize the nitrogen response and calibrate the petiole nitrate sap test for Snowden and Goldrush potato cultivars grown under irrigated conditions.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand. Selected chemical properties in the 0-6" depth were as follows: pH, 6.4; Bray P1, 49 ppm; and NH_4OAc K, 129 ppm. An average of 11 lb nitrate-N was available in the top. Prior to planting, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. Each cultivar was evaluated in adjacent strips. At planting, phosphate (11-48-0) and potash fertilizer (0-0-60 and 0-0-22) were banded 3 inches to the side and 2 inches below each tuber to supply 25 lb N/A, 110 lb P_2O_5/A, 200 lb K_2O/A, 20 lb Mg/A, and 34 lb S/A. Six nitrogen treatments were tested. For each cultivar, five of the six nitrogen treatments were: 125, 165, 205, 245, and 285 lb N/A. All nitrogen was applied in three split applications: 25 lb N/A at planting (banded as described above) and the remainder split equally between emergence (May 22 for Snowden and May 23 for Goldrush) and hilling (June 11). The sixth treatment was a post-hilling treatment where 165 lb N/A was applied through hilling as described above, followed by 80 lb N/A post-hilling applied as urea-ammonium nitrate at 40 lb N/A on June 22 and 40 lb N/A on July 6.

For each variety, treatments were replicated 4 times in a randomized complete block design. Spacing was 10" in the row and 36" between rows for all varieties. Each plot was 4 rows wide and 20 feet in length. Goldrush and Snowden "A" size cut seed potatoes were planted by hand on April 23, 1996. Admire was applied in furrow for Colorado potato beetle control. Emergence N was sidedressed on May 23 for Snowden and May 23 for Goldrush, and hilling N was applied on June 11. Petioles were sampled at two week intervals starting June 20. Half of the petioles collected were crushed to express the sap for quick nitrate determination using a Cardy meter, and the remainder were dried for conventional nitrate determination. Snowden vines were killed September 4 and tubers harvested September 12. Goldrush vines were killed September 5 and tubers were harvested September 12. At harvest, total yield, graded yield, tuber specific gravity, and internal disorders were recorded. Total dry matter and nitrogen content of vines and tubers were also determined to calculate total nitrogen uptake by the crop. Irrigation was provided according to the checkbook method.

Results

Snowden: Yield of Snowden tuber and vines is presented in Table 3. Increasing N rate from 120 lb N/A to 280 lb N/A did not significantly affect total yield; however, yield of the largest sized tubers (greater than 3") increased with increasing N rate.

Vine growth increased with increasing N rate. At equivalent N rates, post-hilling N did not significantly affect tuber yield or vine growth. Although numerically, the highest yield was obtained with a post-hilling application of nitrogen. Hollow heart incidence was lowest with the post-hilling treatment. Specific gravity was not affected with increasing N rate or post-hilling N application.

[1]Funding for this research was provided by a grant from the Area 2 Potato Research Council.
[2]Extension Soil Scientist and Assistant Scientist, Dept. of Soil, Water and Climate.

Nitrogen uptake increased with increasing N rate (Table 2). The highest N uptake was obtained with the posthilling N treatment, which was primarily due to more N in the vines at harvest. Tuber N concentrations and dry matter production were not affetced by treatment while vine dry matter and concentrations at harvest increased with increasing N rate. On the first sampling date petiole nitrate-N was not affected by N treatment (Table 3). On all subsequent sampling dates petiole nitrate-N increased with increasing N rate. Highest yield and quality were associated with nitrate-N concentrations during tuber bulking greater than 0.6% on a dry weight basis and 1000 ppm on a sap basis. Posthilling N application significantly increased petiole nitrate-N from July 15 on.

Goldrush: Goldrush tuber and vine yield is presented in Table 4. Increasing N rate significantly increased total tuber yield and yield of tubers greater than 6 oz. Tubers less than 6 oz increased with increasing N rate. Post-hilling N application tended to decrease total yield as well as yield of 6-12 oz tubers. The practice of applying N after hilling for Goldrush seems questionable based on results from the past two years. Vine growth increased with increasing N rate. Hollow heart incidence increased and specific gravity decreased with increasing N rate.

Nitrogen uptake increased with increasing N rate (Table 5). The posthilling N treatment did not improve nitrogen uptake and tended to lower tuber dry matter production at harvest. Tuber and vine N concentrations increased with increasing N rate. Dry matter porduction was not affected by increasing N rate. On the first sampling date petiole nitrate-N was not affected by N treatment (Table 6). On all subsequent sampling dates petiole nitrate-N increased with increasing N rate. Highest yield and quality were associated with nitrate-N concentrations during tuber bulking greater than 1.0% on a dry weight basis and 1100 ppm on a sap basis. Posthilling N application significantly increased petiole nitrate-N from July 15 on.

Table 1. Effect of nitrogen treatments on Snowden tuber quality and fresh weight of vines and tubers - Becker, MN.

Treatment	N total	N timing	Vine	<1⅞"	1⅞-2½"	2½-3"	>3"	Total	Specific Gravity	Hollow Heart-% incidence
			Tons/A	cwt/A						
1.	125	(25,50,50)[1]	2.70	34.5	125.2	186.2	53.0	398.9	1.0905	2.0
2.	165	(25,70,70)	2.97	29.2	122.1	168.9	84.4	404.6	1.0906	4.0
3.	205	(25,90,90)	3.37	22.9	101.7	195.2	119.1	438.9	1.0903	2.0
4.	245	(25,110,110)	4.10	25.8	112.6	171.5	111.9	421.8	1.0928	5.0
5.	285	(25,130,130)	5.42	24.1	108.1	170.2	133.0	435.4	1.0913	4.0
6.	245	(25,70,70)+80[2]	4.40	30.5	106.1	195.6	118.8	451.0	1.0906	0.0
Significance			**	NS	NS	NS	*	NS	NS	NS
BLSD (0.05)			0.64	--	--	--	58.9	--	--	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			**	*	NS	NS	**	NS	NS	NS
Quad Rate N (1, 2, 3, 4, 5)			*	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			NS	NS	NS	NS	NS	NS	NS	*

Fresh weight columns: Vine through Total.

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 2. Effect of nitrogen treatments on Snowden nitrogen content, nitrogen concentration, and dry matter production - Becker, MN.

Treatment	N total	N timing	Nitrogen content Vine	Nitrogen content Tuber	Nitrogen content Total	N concentration Vine	N concentration Tuber	Dry matter Vine	Dry matter Tuber	Dry matter Total
			lbs/A			% N		Tons/A		
1.	125	(25,50,50)[1]	6.8	108.1	114.9	1.29	1.14	0.26	4.72	4.98
2.	165	(25,70,70)	8.5	118.0	126.5	1.28	1.29	0.33	4.63	4.96
3.	205	(25,90,90)	9.1	124.9	134.0	1.37	1.27	0.34	4.94	5.28
4.	245	(25,110,110)	9.8	127.0	136.8	1.21	1.29	0.42	4.96	5.38
5.	285	(25,130,130)	15.4	131.7	147.1	1.50	1.26	0.52	5.22	5.74
6.	245	(25,70,70)+80[2]	18.2	130.9	149.1	1.80	1.26	0.51	5.21	5.72
Significance			**	NS	NS	*	NS	**	NS	NS
BLSD (0.05)			3.5	--	--	0.35	--	0.09	--	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			**	++	*	NS	NS	**	NS	++
Quad Rate N (1, 2, 3, 4, 5)			++	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			**	NS	NS	**	NS	++	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3. Effect of nitrogen treatments on Snowden nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment	N total	N timing	June 20 dry weight Petiole-N	June 20 sap Horiba	July 1 dry weight Petiole-N	July 1 sap Horiba	July 15 dry weight Petiole-N	July 15 sap Horiba
			ppm NO_3-N					
1.	125	(25,50,50)[1]	26218	1650	14906	1450	899	355
2.	165	(25,70,70)	26578	1675	22000	1875	2316	553
3.	205	(25,90,90)	26737	1725	24460	1950	6636	1018
4.	245	(25,110,110)	27119	1775	24422	1925	11135	1250
5.	285	(25,130,130)	25811	1700	27842	2025	14691	1500
6.	245	(25,70,70)+80[2]	26194	1700	26315	1975	16630	1575
Significance			NS	NS	**	**	**	**
BLSD (0.05)			--	--	5026	218	1740	114
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			NS	NS	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	*	++	NS
Post-hilling (4) vs (6)			NS	NS	NS	NS	**	**

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3 cont. Effect of nitrogen treatments on Snowden nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date: July 25 dry weight Petiole-N	July 25 sap Horiba	August 6 dry weight Petiole-N	August 6 sap Horiba
	N total	N timing	ppm NO_3-N			
1.	125	(25,50,50)[1]	263	158	37	140
2.	165	(25,70,70)	991	185	397	193
3.	205	(25,90,90)	1313	443	537	228
4.	245	(25,110,110)	4143	838	1497	335
5.	285	(25,130,130)	9576	1200	3860	463
6.	245	(25,70,70)+80[2]	13242	1450	6322	593
Significance			**	**	**	**
BLSD (0.05)			1692	121	1857	104
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			**	**	++	NS
Post-hilling (4) vs (6)			**	**	**	**

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 4. Effect of nitrogen treatments on Goldrush tuber quality and fresh weight of vines and tubers - Becker, MN.

Treatment			Fresh weight: Vine	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Specific Gravity	Hollow Heart-% incidence
	N total	N timing	Tons/A	cwt/A							
1.	125	(25,50,50)[1]	0.71	15.3	59.6	150.5	183.5	21.1	430.0	1.0823	4.0
2.	165	(25,70,70)	0.84	5.4	51.7	143.0	186.4	39.6	426.1	1.0805	7.0
3.	205	(25,90,90)	1.04	14.3	47.7	117.5	194.5	48.4	422.4	1.0792	4.0
4.	245	(25,110,110)	1.35	15.1	39.0	106.4	219.6	79.0	459.1	1.0769	9.0
5.	285	(25,130,130)	1.95	16.3	31.7	99.5	207.0	107.7	462.2	1.0776	10.0
6.	245	(25,70,70)+80[2]	1.75	18.6	38.9	100.8	177.1	76.8	412.2	1.0755	7.0
Significance			**	*	**	**	NS	**	NS	*	NS
BLSD (0.05)			0.40	8.1	13.1	24.3	--	26.1	--	0.0043	--
Contrasts											
Lin Rate N (1, 2, 3, 4, 5)			**	NS	**	**	++	**	++	**	++
Quad Rate N (1, 2, 3, 4, 5)			++	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			++	NS	NS	NS	++	NS	++	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, and ** = significant at 10%, 5%, and 1%, respectively.

Table 5. Effect of nitrogen treatments on Goldrush nitrogen content, nitrogen concentration, and dry matter production, Becker, MN.

Treatment			Nitrogen content: Vine	Tuber	Total	N concentration: Vine	Tuber	Dry matter: Vine	Tuber	Total
	N total	N timing	lbs/A			% N		Tons/A		
1.	125	(25,50,50)[1]	5.8	100.2	106.0	1.51	1.11	0.20	4.50	4.70
2.	165	(25,70,70)	9.3	122.0	131.3	1.53	1.49	0.33	4.14	4.47
3.	205	(25,90,90)	9.9	122.5	132.4	1.84	1.42	0.27	4.30	4.57
4.	245	(25,110,110)	12.0	143.5	155.5	2.37	1.57	0.26	4.56	4.82
5.	285	(25,130,130)	11.4	152.0	163.4	2.23	1.76	0.26	4.33	4.59
6.	245	(25,70,70)+80[2]	12.4	120.3	132.7	2.46	1.52	0.25	3.95	4.20
Significance			NS	**	**	**	**	NS	++	NS
BLSD (0.05)			--	24.5	24.0	0.50	0.31	--	0.49	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			*	**	**	**	**	NS	NS	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			NS	++	NS	NS	NS	NS	**	*

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 6. Effect of nitrogen treatments on Goldrush nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			June 20 dry weight Petiole-N	June 20 sap Horiba	July 1 dry weight Petiole-N	July 1 sap Horiba	July 15 dry weight Petiole-N	July 15 sap Horiba
	N total	N timing	ppm NO_3-N					
1.	125	(25,50,50)[1]	22878	1450	12136	1225	2130	385
2.	165	(25,70,70)	23767	1525	18097	1650	324	568
3.	205	(25,90,90)	25163	1575	22227	1700	7104	750
4.	245	(25,110,110)	24473	1525	26415	1950	10378	1175
5.	285	(25,130,130)	23665	1475	27688	2000	16049	1450
6.	245	(25,70,70)+80[2]	24382	1525	24051	1900	14864	1450
Significance			NS	NS	**	**	**	**
BLSD (0.05)			--	--	2562	146	2815	293
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			NS	NS	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			++	++	*	*	*	NS
Post-hilling (4) vs (6)			NS	NS	++	NS	**	++

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 6 cont. Effect of nitrogen treatments on Goldrush nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			July 25 dry weight Petiole-N	July 25 sap Horiba	August 7 dry weight Petiole-N	August 7 sap Horiba
	N total	N timing	ppm NO_3-N			
1.	125	(25,50,50)[1]	304	143	450	145
2.	165	(25,70,70)	636	240	255	150
3.	205	(25,90,90)	864	353	994	210
4.	245	(25,110,110)	4130	740	2062	380
5.	285	(25,130,130)	7247	853	2575	493
6.	245	(25,70,70)+80[2]	12759	1250	5566	703
Significance			**	**	**	**
BLSD (0.05)			1979	211	1687	119
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			**	NS	NS	++
Post-hilling (4) vs (6)			**	**	**	**

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, ** = significant at 10% and 1%, respectively.

EVALUATION OF ROW SPACING EFFECTS ON YIELD AND QUALITY OF IRRIGATED POTATOES[1]
- 1996 -

Carl J. Rosen, Dave Birong, and Glenn Titrud[2]

Abstract: The second year of a three year field study was conducted at the Sand Plain Research Farm in Becker to evaluate 30 inch row spacing at two plant populations (15,840 and 18,216 plants/A) on irrigated Norland and Russet Burbank potato production. For Norland, total yield was significantly greater at 30 inch spacing compared to 36 inch spacing at both plant populations. This yield increase was primarily due to an increase in smaller (<2.25 inch) sized tubers. For Russet Burbank, between row spacing had no effect on total yield, but, yield of 6-12 oz tubers was greater with 36" row spacing compared to 30 inch row spacing.

Traditional spacing between rows for potatoes is 36 inches. However, row spacing for many of the rotation crops such as sweet corn and soybean is 30 inches. Efficiency in farming operations would be improved if all crops grown had the same row spacing since tractors could be used interchangeably. Before a switch to 30 inch row spacing is made, growers need to know how tuber production may be affected. Results from 1995 indicated that total yield of Russet Burbank was significantly greater at 30 inch spacing compared to 36 inch spacing at; however, the yield increase was primarily due to an increase in smaller (<6 oz) sized tubers. Because yield of smaller tubers increased with narrower rows, the potential for increased profitability may be greater for varieties such as Norland where smaller tubers are often preferred. The objective of this study therefore was to determine the effects of 30 inch row spacing on yield and quality of both Russet Burbank and Norland potatoes.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm at Becker on a Hubbard loamy sand following a previous crop of rye. Selected soil chemical properties (0-6") prior to planting were: Soil pH(1:1 - soil:water), 6.4; Bray P1, 30 ppm; and NH_4OAc K, 118 ppm. Nitrate-N in the top two feet prior to planting was 22 lb/A. Two between row spacings were tested using Russet Burbank and Red Norland cultivars. Each cultivar was grown in separate plots. The between row spacings were 30" and 36" at two plant populations - 15,840 and 18,216 plants per acre. These plant populations correspond to 11 and 9.5 inches within row spacing for 36" rows and 13.2 and 11.5 inches within row spacing for the 30" rows. For each cultivar, the four treatments were replicated 4 times in a split plot design with between row spacing as the main plots and within row spacing as the sub plots. Each plot was 6 rows wide and 40 feet in length. Furrows were opened mechanically and a starter fertilizer of (lbs/A) 25 N, 110, P_2O_5, 200 K_2O, 20 Mg, and 33 S was banded 2 to 3 inches to each side below the furrow. Norland "B" size tubers were planted on April 17, 1996 and Russet Burbank "A" size cut tubers were planted on April 22, 1996. Admire was applied directly in furrow for insect control and the rows were then mechanically hilled. For Norland, N as ammonium nitrate was applied at the rate of 100 lb N/A at emergence (May 29), and 50 lb N/A at hilling (June 12). For Russet Burbank, N as ammonium nitrate was applied at the rate of 100 lb N/A at emergence (May 29) and 110 lb N/A at hilling (June 12). Norland vines were killed July 18 and the middle two rows of each plot were harvested July 31. Russet Burbank vines were killed on September 9 and the middle two rows of each plot were harvested September 16. Tubers were weighed and graded according to size.

Results

Norland: Yield and quality as affected by row spacing is presented in Table 1. Use of 30 inch row spacing significantly increased total yield compared to 36 inch spacing. As with the results from 1995 with Russet Burbank, this effect was due to an increase in the yield of smaller sized tubers (less than 2.25 inches). Yield of the largest sized tubers (greater than 3 inches) increased with wider spacing within rows (lower plant populations), but were not affected by between row spacing. Spacing had no effect on vine yield, hollow heart incidence, or growth cracks.

Petiole nitrate-N on June 28 was not significantly affected by spacing or plant population (Table 2). Even though tuber yield and total dry matter production was greater with 30 inch row spacing, there was no difference in N due to row spacing or plant population. The main reason for lack of an effect due to row spacing or plant poulation was due to numerically higher N concentrations in the vines and tubers of the 36" row spacing, which offset the higher yield of the 30" row spacing.

Russet Burbank: Yield and quality as affected by row spacing is presented in Table 3. Use of 30 inch row spacing had no effect on total yield compared to 36 inch spacing. However, yield of the 6-12 oz tubers was greater with the wider 36 inch rows. Misshapen tubers tended to be greater with 30 inch rows. Spacing had no effect on vine growth, hollow heart incidence or specific gravity.

Petiole nitrate-N on June 28 was lower for the 30 inch spacing compared to 36 inch spacing with no effect due to plant population (Table 4). Since plant populations were the same with each row spacing, the amount of N applied per plant was for each row spacing. Reasons for the lower petiole nitrate-N concentrations with the 30 inch row spacing are unclear. Dry matter production and N uptake by vines and tubers were not significantly affected by row spacing or plant population.

As in 1995, the results of this study suggest that 30 inch spacing would not be that useful for potatoes where larger sized tubers are required. However, for Norland or seed potatoes where smaller sized tubers are often desirable, 30 inch row spacing may be advantageous. At least one more year of study is needed before definite conclusions can be made.

[1]Funding for this research was provided by a grant from the Area 2 Potato Research Council.
[2]Extension Soil Scientist and Assistant Scientist, respectively, Dept. of Soil, Water and Climate; Supervisor, Sand Plain Research Farm.

Table 1. Effect of row spacing and plant population on vine yield and yield and quality of Norland tubers - Becker, MN. (Vines killed July 18, 1996).

Between Row Spacing	Within Row Spacing	Plants per Acre	Vine	Fresh weight - Tuber size: <1½"	1½-1⅞"	1⅞-2¼"	2¼-2½"	2½-3"	>3"	Total	Growth Cracks	Hollow Heart
inches	inches		Tons/A	cwt/A							% incidence	
30	11.4	18,340	11.6	12.7	28.8	131.4	102.2	101.6	9.5	386.2	0.0	1.0
30	13.2	15,840	11.1	10.8	33.7	125.5	98.6	105.6	14.9	389.1	0.0	1.0
36	9.5	18,340	13.0	9.0	26.3	106.2	91.1	99.1	10.2	341.9	0.0	0.0
36	11.0	15,840	12.2	7.4	21.7	100.3	89.6	102.6	11.8	333.4	0.0	0.0
Significance			NS	++	*	**	NS	NS	++	**	NS	NS
BLSD (0.05)			--	4.8	6.5	14.0	--	--	5.1	26.4	--	--
Spacing			NS	*	**	**	NS	NS	NS	**	NS	NS
Population			NS	NS	NS	NS	NS	NS	*	NS	NS	NS
Space X Pop			NS	NS	*	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant; **, *, ++ = significant at 1%, 5% and 10%, respectively.

Table 2. Effect of row spacing and plant population on petiole nitrate-N (sampled June 28) and nitrogen content, concentration and dry matter production of Norland potatoes at harvest, Becker, MN.

Between Row Spacing	Within Row Spacing	Plants per Acre	Nitrogen content: Vine	Tuber	Total	Nitrogen concentration: Petiole	Vine	Tuber	Dry matter: Vine	Tuber	Total
inches	inches		lbs/A			ppm NO_3-N	% N		Tons/A		
30	11.4	18,340	57.1	101.8	158.9	12,286	2.42	1.45	1.2	3.5	4.7
30	13.2	15,840	50.2	96.3	146.5	11,391	2.16	1.39	1.2	3.5	4.7
36	9.5	18,340	60.0	88.6	148.7	13,277	2.55	1.50	1.2	3.0	4.2
36	11.0	15,840	58.9	86.3	145.1	14,170	2.57	1.46	1.1	3.0	4.1
Significance			NS	*	NS	NS	NS	NS	NS	*	*
BLSD (0.05)			--	12.49	--	--	--	--	--	0.5	0.6
Spacing			NS	**	NS	NS	NS	NS	NS	**	**
Population			NS	NS	NS	NS	NS	NS	NS	NS	NS
Space X Pop			NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant; **, *, = significant at 1% and 5%, respectively.

Table 3. Effect of row spacing and plant population on vine yield and yield and quality of Russet Burbank tubers. Becker, MN. (Vines killed September 9, 1996).

Between Row Spacing	Within Row Spacing	Plants per Acre	Fresh weight: Knobs	Tuber Size: ≤3 oz	3-6 oz	6-12 oz	≥12 oz	Total	Vine	Specific Gravity	Hollow Heart
inches	inches		cwt/A						Tons/A		%
30	11.4	18,340	18.6	63.2	162.2	206.3	80.4	530.7	9.6	1.0920	15.0
30	13.2	15,840	21.1	56.5	145.1	194.3	84.5	501.5	10.7	1.0905	12.0
36	9.5	18,340	4.9	56.2	172.5	224.2	70.8	528.6	10.0	1.0879	15.0
36	11.0	15,840	10.5	42.6	142.6	233.9	83.3	512.9	10.5	1.0893	15.0
Significance			**	*	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)			6.8	14.2	--	--	--	--	--	--	--
Spacing			**	*	NS	*	NS	NS	NS	NS	NS
Population			++	*	++	NS	NS	NS	NS	NS	NS
Space X Pop			NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant; **, *, ++ = significant at 1%, 5% and 10%, respectively.

Table 4. Effect of row spacing and plant population on petiole nitrate-N (sampled June 28) and nitrogen content, concentration and dry matter production of Russet Burbank potatoes at harvest. Becker, MN.

Between Row Spacing	Within Row Spacing	Plants per Acre	Nitrogen content Vine	Nitrogen content Tuber	Nitrogen content Total	Nitrogen concentration Petiole	Nitrogen concentration Vine	Nitrogen concentration Tuber	Dry matter Vine	Dry matter Tuber	Dry matter Total
inches	inches		------	lbs/A	--------	ppm NO_3-N	--- %	N ---	-----	Tons/A	-----
30	11.4	18,340	35.0	131.7	166.7	21,276	1.49	1.08	1.1	6.1	7.2
30	13.2	15,840	33.9	138.5	172.4	21,358	1.51	1.22	1.1	5.7	6.8
36	9.5	18,340	28.3	138.2	166.5	23,489	1.53	1.18	0.9	5.9	6.8
36	11.0	15,840	32.6	129.5	162.2	23,707	1.47	1.17	1.1	5.6	6.7
Significance			NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)			--	--	--	--	--	--	--	--	--
Spacing			NS	NS	NS	*	NS	NS	NS	NS	NS
Population			NS	NS	NS	NS	NS	NS	NS	NS	NS
Space X Pop			NS	NS	NS	NS	NS	++	NS	NS	NS

NS = nonsignificant; *, ++ = significant at 5% and 10%, respectively.

EFFECT OF NITROGEN RATE AND TIMING ON YIELD OF RED NORLAND POTATO[1]

Carl J. Rosen and Dave Birong[2]

ABSTRACT: The second year of a three year field study was conducted at the Sand Plain Research Farm at Becker to determine the effects of nitrogen rate and timing on yield of Red Norland potatoes. For early harvest Norland, increasing N rate from 125 to 285 lb N/A did not significantly affect total tuber yield; however, timing of N application affected tuber size distribution. Increasing N rate at planting at the 205 lb N/A rate tended to decrease total yield and larger sized (greater than 2.5 inches) tubers. Delaying Norland vine kill by three weeks increased tuber yield by about 100 cwt/A compared to the yield obtained with the early harvest. Increasing N rate from 165 to 245 lb N/A had no effect on total yield, suggesting that under the conditions of this study, 165 lb N/A was sufficient for optimum yield of mid/late season harvested Norland.

Norland is an early maturing red potato variety used primarily for the fresh market. Depending on the market, vines are killed from mid-July to late August. Recent studies with Russet Burbank have shown that timing of nitrogen application can have a dramatic effect on nitrogen use efficiency by the potato crop. Delaying most of the nitrogen until after emergence decreased nitrate concentrations in the soil water below the root zone by over 50%. Few studies, however, have been conducted with Norland potato to determine the effects of N rate and timing on yield at various harvest dates. Nitrogen applied too early in the season may be susceptible to leaching losses than nitrogen applied during the period of maximum uptake. On the other hand, N fertilizer applied early in the season may affect tuber initiation, which in turn can affect tuber number and size. The overall objective of this study was to define optimum nitrogen application times and rates for the Norland variety where the crop is harvested for both an early and mid/late season market.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm in Becker Minnesota on a Hubbard sandy loam. Selected chemical properties in the 0-6" depth were as follows: pH, 6.4; Bray P, 45 ppm; and NH_4OAc K, 127 ppm. An average of 14 lb nitrate-N was available in the top 2 ft. Prior to planting, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. Effects of nitrogen treatments were evaluated at an early and late harvest date. Each harvest date was evaluated in separate strips. At planting, phosphate (11-48-0) and potash fertilizer (0-0-60 and 0-0-22) were banded 3 inches to the side and 2 inches below each tuber to supply 25 lb N/A, 110 lb P_2O_5/A, 200 lb K_2O/A, 20 lb Mg/A, and 34 lb S/A. For early harvest Red Norland, twelve N treatments were tested. Five of the twelve nitrogen treatments were: 125, 165, 205, 245, and 285 lb N/A. All nitrogen was applied in three split applications: 25 lb N/A at planting (banded as described above) and the remainder split equally between emergence and hilling. The remaining seven treatments were designed to evaluate the effect of increased starter N (25 to 85 lb N/A) on yield. Rates of N higher than 25 lb N/A in the starter were supplemented with urea and banded as described above. Various times of application were evaluated at the and 205 lb N/A rates. Specific timing of N application for each treatment for Norland is shown in Table 1. For the late season harvest, six treatments were tested at 165, 205, and 245 lb N/A with either 25 or 65 lb N/A in the starter (Table 4).

Treatments were replicated 4 times in a randomized complete block design. Spacing was 10" in the row and 36" between rows for all varieties. Each plot was 4 rows wide and 20 feet in length. Norland "B" size cut seed potatoes were planted on April 17, 1996 for both the harvest dates. Admire was applied in furrow for Colorado potato beetle control to all plots. Emergence N was applied on May 22 and hilling N was applied on June 11. For early harvest Norland, petioles were collected at two sampling dates (June 24 and July 17). Petioles from the mid-season harvest Norland were collected at five sampling dates starting June 20 at two week intervals. Half of the petioles collected were crushed to express the sap for quick nitrate determination, and the remainder were dried for conventional nitrate determination. Early Norland vines were killed July 17 and tubers were harvested July 31. Late season Norland vines were killed August 8 and tubers were harvested August 20. At each harvest, total yield, graded yield, and internal disorders were recorded. Total dry matter and nitrogen content of vines and tubers were also determined to calculate total nitrogen uptake by the crop.

Results

Early Harvest Norland: Yield of early harvested Norland tuber and vines is presented in Table 1. Increasing nitrogen rate from 120 lb N/A to 280 lb N/A did not significantly affect total tuber yield; however, increasing N rate at planting at the 205 lb N/A rate tended to decrease total yield and larger sized (greater than 2.5 inches) tubers. At the 165 lb N rate, increasing N in the starter had no effect no total yield but did tend to decrease the yield of larger sized tubers and increase the yield of smaller sized (less than 2.5 inches) tubers. Neither N rate nor timing significantly affected vine yield. Growth cracks and hollow heart incidence were not affected by treatment.

Nitrogen uptake tended to increase with increasing N rate (Table 2). Increasing N in the starter tended to decrease N uptake at the 205 lb N rate but had the opposite effect at the 165 lb N/A rate. Total dry matter accumulation was not affected by treatment. Petiole nitrate-N on June 24 increased with increasing N rate and decreased with increasing N in the starter (Table 3). On June 24, the highest yield and quality was associated with sap nitrate-N levels between 1400 and 1600 ppm and dry weight concentrations between 1.7 and 2.3%. By July 17 (one day before harvest), petiole nitrate-N increased with increasing N rate, but was not affected by N in the starter.

[1]Funding for this research was provided by a grant from the Area 2 Potato Research Council.
[2]Extension Soil Scientist and Assistant Scientist, respectively, Dept. of Soil, Water, & Climate.

Late season Harvest Norland: Delaying vine kill by 3 weeks increased yield on average by about 100 cwt/A. With 25 lb N/A in the starter, yield of the largest sized (greater than 3") tubers increased with N rate and yield of the 2.5 to 3" sized tubers decreased (Table 4). With 65 lb N/A in the starter, yield of the largest sized tubers tended decrease with N rate as did yield of tubers in the 2.25 to 2.5" category. Vine yield was not affected by N treatment. Growth cracks and hollow heart incidence were not consistently affected by N treatment.

Even though tuber yield increased at the later harvest date total N uptake was only slightly higher (5 to 10 lb N/A). The main reason for a lack of N uptake is that the crop had basically matured and most of the N had been taken up by mid-July. The N content in the vines at the later harvest was lower, while tuber N content was higher compared to the early harvest. Nitrogen content of vines and tubers at harvest increased with increasing N rate (Table 5). Starter N did not significantly affect N uptake. Dry matter production was not affected by N rate, but higher amounts of N in the starter tended to reduce dry matter production. On all sampling dates, petiole nitrate-N increased with increasing N rate, but was not affected by N in the starter.

Table 1. Effect of nitrogen treatments on early harvest Norland tuber quality and fresh weight of vines and tubers - Becker, MN.

Treatment			Fresh weight								Growth	Hollow
			Vine	<1½"	1½-1⅞"	1⅞-2¼"	2¼-2½"	2½-3"	>3"	Total	Cracks	Heart
	N total	N timing	Tons/A	cwt/A							% incidence	
1.	125	(25,50,50)[1]	4.00	11.5	29.9	144.6	94.3	64.3	12.8	357.4	0.0	1.0
2.	165	(25,70,70)	3.92	11.4	24.6	125.3	82.3	73.5	14.1	331.2	0.0	1.0
3.	205	(25,90,90)	4.75	12.8	30.0	139.8	90.2	77.3	12.8	362.9	0.0	0.0
4.	245	(25,110,110)	4.53	13.1	34.1	136.3	90.9	75.3	12.9	362.6	0.0	0.0
5.	285	(25,130,130)	4.47	13.4	27.9	123.2	81.8	76.1	8.3	330.7	0.0	0.0
6.	165	(45,60,60)	4.38	14.7	50.1	130.4	89.0	52.6	9.3	346.1	0.0	0.0
7.	165	(65,50,50)	4.41	19.5	35.6	149.5	95.5	60.2	8.9	369.2	0.0	1.0
8.	165	(85,40,40)	4.66	10.7	27.1	124.2	103.2	71.5	4.6	341.3	0.0	3.0
9.	205	(45,80,80)	4.59	17.1	28.5	139.1	74.6	68.5	9.1	336.9	0.0	1.0
10.	205	(65,70,70)	3.94	22.7	43.6	125.9	64.8	45.6	8.4	311.0	0.0	1.0
11.	205	(85,60,60)	4.75	20.8	32.7	137.9	79.5	56.8	6.1	333.8	0.0	1.0
12.	165	(25,110,30)	3.79	9.5	22.8	140.2	86.6	72.7	5.1	336.9	0.0	0.0
Significance			NS	**	*	NS	*	NS	NS	NS	NS	NS
BLSD (0.05)			--	5.8	16.4	--	22.7	--	--	--	--	--
Contrasts												
Lin Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lin Rate N (2, 6, 7, 8)			NS	NS	NS	NS	*	NS	*	NS	NS	NS
Quad Rate N (2, 6, 7, 8)			NS	**	**	++	NS	++	NS	NS	NS	NS
Lin Rate N (3, 9, 10, 11)			NS	**	NS	NS	NS	*	++	++	NS	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	NS	NS	*	NS	NS	++	NS	NS
Planting rate (2,12) vs (7,8)			*	*	NS	NS	*	NS	*	NS	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 2. Effect of nitrogen treatments on early harvest Norland nitrogen content, nitrogen concentration, and dry matter production - Becker, MN.

	Treatment		Nitrogen content			N concentration		Dry matter		
	N total	N timing	Vine	Tuber	Total	Vine	Tuber	Vine	Tuber	Total
			-------- lbs/A	-------		----- % N	-----	-------- Tons/A	------	
1.	125	(25,50,50)[1]	16.5	96.1	112.6	2.32	1.64	0.36	2.93	3.29
2.	165	(25,70,70)	19.2	86.1	105.3	2.74	1.50	0.36	2.85	3.21
3.	205	(25,90,90)	29.1	102.5	131.6	3.43	1.71	0.44	3.00	3.44
4.	245	(25,110,110)	33.8	111.0	144.8	3.85	1.81	0.44	3.08	3.52
5.	285	(25,130,130)	32.3	95.2	127.5	3.71	1.77	0.44	2.69	3.13
6.	165	(45,60,60)	22.0	99.4	121.4	2.72	1.72	0.40	2.94	3.34
7.	165	(65,50,50)	19.9	97.4	117.3	2.31	1.61	0.43	3.05	3.48
8.	165	(85,40,40)	22.3	93.0	115.3	2.96	1.66	0.38	2.86	3.24
9.	205	(45,80,80)	26.9	99.7	126.6	3.21	1.83	0.42	2.75	3.17
10.	205	(65,70,70)	24.7	81.5	106.2	3.12	1.56	0.40	2.62	3.02
11.	205	(85,60,60)	26.4	94.7	121.1	2.91	1.73	0.45	2.74	3.19
12.	165	(25,110,30)	13.6	79.8	93.4	2.10	1.32	0.33	3.06	3.39
Significance			**	*	**	**	NS	*	NS	NS
BLSD (0.05)			4.0	18.6	15.2	0.47	--	0.10	--	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			**	NS	**	**	NS	*	NS	NS
Quad Rate N (1, 2, 3, 4, 5)			*	NS	NS	*	NS	NS	NS	NS
Lin Rate N (2, 6, 7, 8)			NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate N (2, 6, 7, 8)			NS	NS	++	++	NS	++	NS	NS
Lin Rate N (3, 9, 10, 11)			NS	++	*	*	NS	NS	NS	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	++	NS	NS	NS	NS	NS
Planting rate (2,12) vs (7,8)			**	*	**	NS	++	*	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3. Effect of nitrogen treatments on early harvest Norland nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap. Becker, MN.

	Treatment		Date: June 24		Date: July 17	
	N total	N timing	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
			------- ppm NO_3-N	-------	-------	-------
1.	125	(25,50,50)[1]	17750	1350	515	218
2.	165	(25,70,70)	17812	1400	2560	413
3.	205	(25,90,90)	21348	1625	6164	898
4.	245	(25,110,110)	23103	1675	11826	1045
5.	285	(25,130,130)	21586	1725	13312	1280
6.	165	(45,60,60)	17392	1475	2264	343
7.	165	(65,50,50)	17033	1425	918	318
8.	165	(85,40,40)	16427	1275	1751	343
9.	205	(45,80,80)	20086	1575	5360	773
10.	205	(65,70,70)	20577	1550	5773	683
11.	205	(85,60,60)	18851	1475	4672	743
12.	165	(25,110,30)	11471	1075	188	168
Significance			**	**	**	**
BLSD (0.05)			2212	100	3134	220
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS
Lin Rate N (2, 6, 7, 8)			NS	*	NS	NS
Quad Rate N (2, 6, 7, 8)			NS	**	NS	NS
Lin Rate N (3, 9, 10, 11)			++	**	NS	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	NS	NS
Planting rate (2,12) vs (7,8)			*	**	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 4. Effect of nitrogen treatments on late harvest Norland tuber quality and fresh weight of vines and tubers - Becker, MN.

Treatment	N total	N timing	Vine	<1½"	1½-1⅞"	1⅞-2¼"	2¼-2½"	2½-3"	>3"	Total	Growth Cracks	Hollow Heart
			Tons/A	cwt/A							% incidence	
1.	165	(25,70,70)[1]	2.02	6.3	13.6	92.5	102.1	156.1	75.7	446.3	3.0	3.0
2.	205	(25,90,90)	2.31	6.2	13.5	92.5	98.3	164.7	76.4	451.6	0.0	2.0
3.	245	(25,110,110)	2.27	5.0	12.4	97.2	105.1	129.1	110.2	459.0	0.0	2.0
4.	165	(65,50,50)	2.27	7.1	19.3	109.2	122.3	152.4	43.6	453.9	1.0	2.0
5.	205	(65,70,70)	2.37	8.5	15.4	95.5	99.0	140.9	86.9	446.2	0.0	8.0
6.	245	(65,90,90)	2.27	10.3	17.0	106.6	100.2	144.2	58.2	436.5	0.0	4.0
Significance			NS	NS	NS	NS	*	NS	**	NS	*	NS
BLSD (0.05)			--	--	--	--	17.1	--	32.2	--	2.1	--
Contrasts												
Lin Rate N (1, 2, 3)			NS	NS	NS	NS	NS	++	*	NS	**	NS
Quad Rate N (1, 2, 3)			NS	NS	NS	NS	NS	++	NS	NS	++	NS
Lin Rate N (4, 5, 6)			NS	++	NS	NS	**	NS	NS	NS	NS	NS
Quad Rate N (4, 5, 6)			NS	NS	NS	NS	++	NS	*	NS	NS	++
Main Effects												
N rate												
165			2.15	6.7	16.4	100.8	112.2	154.2	59.7	450.0	2.0	2.5
205			2.34	7.4	14.5	94.0	98.7	152.8	81.7	449.1	0.0	5.0
245			2.27	7.7	14.7	101.9	102.6	136.6	84.2	447.7	0.0	3.0
Significance			NS	NS	NS	NS	*	NS	++	NS	**	NS
Contrasts												
Lin Rate N (1&4,2&5,3&6)			NS	NS	NS	NS	++	NS	*	NS	**	NS
Quad Rate N (1&4,2&5,3&6)			NS	NS	NS	NS	++	NS	NS	NS	++	NS
N timing												
25 planting			2.20	5.9	13.1	94.1	101.8	149.9	87.5	452.3	1.0	2.3
65 planting			2.30	8.6	17.3	103.8	107.2	145.8	62.9	445.6	0.3	4.7
Significance			NS	*	*	++	NS	NS	**	NS	NS	NS
Interaction												
N rate*N timing			NS	NS	NS	NS	++	NS	*	NS	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 5. Effect of nitrogen treatments on late harvest Norland nitrogen content, nitrogen concentration and dry matter production. Becker, MN.

Treatment	N total	N timing	Nitrogen content Vine	Nitrogen content Tuber	Nitrogen content Total	N concentration Vine	N concentration Tuber	Dry matter Vine	Dry matter Tuber	Dry matter Total
			---- lbs/A ----			---- % N ----		---- Tons/A ----		
1.	165	(25,70,70)[1]	9.9	115.9	125.8	1.86	1.44	0.27	4.02	4.29
2.	205	(25,90,90)	11.2	124.8	136.0	1.88	1.48	0.31	4.21	4.52
3.	245	(25,110,110)	15.2	128.1	143.3	2.37	1.53	0.32	4.19	4.51
4.	165	(65,50,50)	10.2	110.4	120.6	2.05	1.37	0.25	4.05	4.30
5.	205	(65,70,70)	14.8	125.2	140.0	2.31	1.61	0.32	3.90	4.22
6.	245	(65,90,90)	13.9	128.2	142.1	2.20	1.73	0.32	3.71	4.03
Significance			*	NS	++	NS	*	NS	NS	NS
BLSD (0.05)			4.0	--	21.3	--	0.24	--	--	--
Contrasts										
Lin Rate N (1, 2, 3)			**	NS	++	NS	NS	NS	NS	NS
Quad Rate N (1, 2, 3)			NS	NS	NS	NS	NS	NS	NS	NS
Lin Rate N (4, 5, 6)			*	*	*	NS	**	++	NS	NS
Quad Rate N (4, 5, 6)			++	NS	NS	NS	NS	NS	NS	NS
Main Effects										
N rate										
165			10.1	113.2	123.3	1.95	1.41	0.26	4.03	4.29
205			13.0	125.0	138.0	2.10	1.55	0.31	4.05	4.36
245			14.6	128.2	142.8	2.28	1.63	0.32	3.95	4.27
Significance			**	*	*	NS	*	++	NS	NS
Contrasts										
Lin Rate N (1&4,2&5,3&6)			**	*	**	NS	**	*	NS	NS
Quad Rate N (1&4,2&5,3&6)			NS	NS	NS	NS	NS	NS	NS	NS
N timing										
25 planting			12.1	122.9	135.0	2.03	1.48	0.30	4.14	4.44
65 planting			13.0	121.3	134.3	2.19	1.57	0.30	3.89	4.19
Significance			NS	NS	NS	NS	NS	NS	++	++
Interaction										
N rate*N timing			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 6. Effect of nitrogen treatments on late harvest Norland nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date			
			June 24		July 1	
			dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
	N total	N timing	ppm NO_3-N			
1.	165	(25,70,70)[1]	19450	1275	16925	1425
2.	205	(25,90,90)	21646	1375	24114	1825
3.	245	(25,110,110)	21836	1400	25768	1925
4.	165	(65,50,50)	18565	1250	15823	1400
5.	205	(65,70,70)	21616	1350	24391	1725
6.	245	(65,90,90)	24281	1400	25266	1875
Significance			**	**	**	**
BLSD (0.05)			2702	88	2201	139
Contrasts						
Lin Rate N (1, 2, 3)			++	**	**	**
Quad Rate N (1, 2, 3)			NS	NS	*	*
Lin Rate N (4, 5, 6)			**	**	**	**
Quad Rate N (4, 5, 6)			NS	NS	**	NS
Main Effects						
N rate						
165			19008	1263	16374	1413
205			21631	1363	24253	1775
245			23059	1400	25518	1900
Significance			**	**	**	**
Contrasts						
Lin Rate N (1&4,2&5,3&6)			**	**	**	**
Quad Rate N (1&4,2&5,3&6)			NS	NS	**	*
N timing						
25 planting			20978	1350	22269	1725
65 planting			21487	1333	21827	1667
Significance			NS	NS	NS	NS
Interaction						
N rate*N timing			NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 6 (cont.). Effect of nitrogen treatments on late harvest Norland nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			July 15 dry weight Petiole-N	July 15 sap Horiba	August 5 dry weight Petiole-N	August 5 sap Horiba
	N total	N timing	ppm NO_3-N			
1.	165	(25,70,70)[1]	4011	510	573	223
2.	205	(25,90,90)	9139	1070	2032	368
3.	245	(25,110,110)	13259	1425	4583	588
4.	165	(65,50,50)	990	278	611	298
5.	205	(65,70,70)	7734	923	3163	413
6.	245	(65,90,90)	13372	1425	4412	523
Significance			**	**	++	*
BLSD (0.05)			3811	269	3931	238
Contrasts						
Lin Rate N (1, 2, 3)			**	**	*	**
Quad Rate N (1, 2, 3)			NS	NS	NS	NS
Lin Rate N (4, 5, 6)			**	**	*	*
Quad Rate N (4, 5, 6)			NS	NS	NS	NS
Main Effects						
N rate						
165			2501	394	592	260
205			8437	996	2598	390
245			13315	1425	4498	555
Significance			**	**	*	**
Contrasts						
Lin Rate N (1&4,2&5,3&6)			**	**	**	**
Quad Rate N (1&4,2&5,3&6)			NS	NS	NS	NS
N timing						
25 planting			8803	1002	2396	392
65 planting			7365	875	2729	411
Significance			NS	NS	NS	NS
Interaction						
N rate*N timing			NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

EVALUATION OF "MEISTER" CONTROLLED RELEASE FERTILIZER FOR IRRIGATED POTATO PRODUCTION - 1996[1]

Carl J. Rosen and Dave Birong[2]

ABSTRACT: The effect of Meister controlled release nitrogen fertilizer on yield and quality of Irrigated Russet Burbank potatoes was determined in a field study conducted at the Sand Plain Research Farm in Becker. Five urea treatments (125, 165, 205, 245, and 285 lb N/A) split applied at planting, emergence, and hilling were compared to Meister nitrogen fertilizer applied at the same rates, but all applied in a band at planting. Two post-hilling treatments were also evaluated where 165 lb N was split applied as urea followed by 80 lb N/A post-hilling as urea-ammonium nitrate ands 165 lb N/A was banded as Meister followed by 80 lb N/A post-hilling as urea-ammonium nitrate. At equivalent N rates, yields with the controlled release fertilizer were significantly higher than those with the urea fertilizer. On average, hollow heart incidence was lower with the controlled release fertilizer than with urea. Post-hilling nitrogen applications did not significantly affect yield but did tend to reduce hollow heart incidence. Greater N recovery in the tubers was obtained with the Meister fertilizer compared to urea. Petiole nitrate-N was higher with urea treatments early in the season, but was lower toward the end of the season compared to the controlled release nitrogen fertilizer source.

Controlled release fertilizers have been used in crop production to varying degrees for many years. These types of fertilizers can potentially be useful for nitrogen management since high rates of quick release fertilizer such as urea, ammonium sulfate, or ammonium nitrate are susceptible to leaching. Some of the drawbacks of the traditional controlled release fertilizers such as sulfur coated urea are the slow and unpredictable release rates. Some studies with sulfur coated urea have shown significant quantities remaining after the growing season. Meister (Chisso Ashai Co., Tokyo) is the trade name of controlled release nitrogen fertilizers that are made of urea granules coated with polyolefin resin and talc. They have an analysis of 40-0-0. The talc addition is used to control moisture permeability and the rate of dissolution, thus allowing the development of products with varying release rates. The release of N from the polyolefin coated fertilizer is primarily determined by soil temperature with less influence due to soil moisture. Most of the nitrogen taken up by the potato crop occurs between 20 and 60 days after emergence (about 40 to 80 days after planting). It is critical, therefore, to have N available for uptake during this time period. Nitrogen available too early in the season may be subject to losses due to leaching rains and lack of an established root system to take up the N. Fertilizer developed to release N during the period of maximum uptake may be an efficient method of applying N fertilizer to improve yield and minimize nitrate losses. The overall objective of this study was to determine the effects of a Meister controlled release N fertilizer on potato yield, quality, and N use efficiency under irrigated conditions in Minnesota.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard sandy loam following a previous crop of rye. Selected soil chemical properties in the 0-6" depth were as follows: pH, 6.5; organic matter, 2.1%; Bray P1, 51 ppm; and NH_4OAc K, 142 ppm. An average of 11 lb nitrate-N was available in the top 2 ft prior to planting. Russet Burbank was used as the test cultivar. Prior to planting, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. At planting, phosphate (11-48-0) and potash fertilizer (0-0-60 and 0-0-22) were banded 3 inches to the side and 2 inches below each tuber to supply 110 lb P_2O_5/A, 200 lb K_2O/A, 20 lb Mg/A, and 34 lb S/A. Six N treatments and two N sources were evaluated. The N sources were urea (46-0-0) as the quick release fertilizer and Meister controlled release fertilizer. The Meister fertilizer (40-0-0) was a mixture of 70 day release (75%) and a 50 day release (25%) granules. Five of the six N treatments for both N sources were: 125, 165, 205, 245, 285 lb N/A. At planting, 25 lb N/A of this N rate was banded as MAP for all treatments. For urea, the remaining N was applied in two applications split equally between emergence and hilling. For the Meister N source, the total N rates applied were the same as for the urea treatments except that all N was banded at planting, which included the 25 lb N/A as MAP, as well as the controlled release fertilizer. Two additional treatments included the 165 lb N/A rate as described above for both N sources plus two 40 lb N/A post-hilling splits as urea-ammonium nitrate to give a total of 245 lb N/A for each N source.

Treatments were replicated 4 times in a randomized complete block design. Spacing was 10" in the row and 36" between rows. Each plot was 4 rows wide and 20 feet in length. Russet Burbank cut "A" size seed potatoes were planted on April 22, 1996. Admire was applied in furrow for Colorado potato beetle control to all plots. For the urea treatments, emergence N was applied on May 23 and hilling N was applied on June 11. Petioles were sampled at two week intervals starting June 20. Half of the petioles collected were crushed to express the sap for quick nitrate determination, and the remainder were dried for conventional nitrate determination. Vines were killed September 9 and tubers were harvested September 16. At each harvest, total yield, graded yield, tuber specific gravity, and internal disorders were recorded. Total dry matter and nitrogen content of vines and tubers were also determined to calculate total nitrogen uptake by the crop. Irrigation was provided according to the checkbook method. Rainfall and irrigation on a weekly basis is provided in Figure 1.

Results

Yield and quality: Tuber and vine yield as affected by both urea and controlled release fertilizers is presented in Table 1. Increasing rate of N as urea from 120 lb N/A to 280 lb N/A had no effect on total yield, but increased yield of tubers greater than 6 oz. Yield of undersized tubers (< 6 oz) decreased with increasing N rate. Tuber size seemed to be optimized at the 285 lb N/A rate. At equivalent N rates, post-hilling N had no effect on total yield, but tended to increase the yield of tubers in the greater than 12 oz category and knobby tubers. Urea treatments had no effect on specific gravity or hollow heart incidence. Vine yield increased with increasing N rate.

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Increasing the rate of N as controlled release fertilizer had no effect on total yield but as with urea, the yield of tubers larger than 6 oz increased. Similarly, the yield of tubers less than 6 oz decreased with increasing N rate. The optimum N rate for controlled release fertilizer was 205 lb N/A. At equivalent N rates, post-hilling N as urea-ammonium nitrate with banded controlled released fertilizer at planting had no effect on total yield but did increase yield of tubers in the 3-6 oz category. Vine yield increased with increasing N rate. Controlled release N treatments had no effect on specific gravity or hollow heart incidence.

At equivalent N rates, total tuber yields with controlled release fertilizer were higher than those with urea. Compared to urea, the controlled release fertilizer also tended to increase yield in the greater than 12 oz and 3-6 oz categories. Hollow heart incidence also tended to be lower with controlled release fertilizer.

Nitrogen content, nitrogen concentration, and dry matter in vines and tubers: Total dry matter production at harvest was not significantly affected by N treatment or N source (Table 2). Dry matter production of vines at harvest increased with increasing N rate. Dry matter production of tubers was slightly higher with Meister fertilizer compared to urea. Nitrogen concentrations in vines and tubers increased with increasing N rates for both N sources with greater concentrations with Meister fertilizer compared to urea. Nitrogen content of vines increased with increasing N rate, but was not affected by N source. In contrast N content of tubers increased with increasing N rate and was also higher with Meister fertilizer compared to urea. Total N recovered in the vines plus tubers at harvest increased with increasing N rates with higher recovery obtained with the Meister source compared to urea. The N recovered in the Meister treatments was 16 to 50 lb N/A higher that recovered by the urea treatments. These results suggest an improved N use efficiency with the controlled release fertilizer compared to urea. At equivalent N rates, post-hilling N applications had little effect on dry matter production or N content of vines and tubers.

Petiole nitrate-N: Petiole nitrate-N on a sap and dry weight basis is presented in Table 3. Within each N source, petiole nitrate-N increased with increasing N rate at all sampling dates. The effect of N source on petiole nitrate-N depended on sampling date and N rate. Early in the season, petiole nitrate-N was generally higher with urea treatments, with greatest differences between urea and Meister occurring at the lower N rates ($\leq$ 205 lb N/A). By July 25, petiole nitrate-N was lower in all urea treatments compared to the Meister treatments. These results are consistent with the release rates of the fertilizer sources. That is the urea, a quick release source induced high petiole nitrate-N concentrations early in the season followed by a rather fast drop in concentrations by midseason. In contrast, the Meister N source resulted in lower petiole nitrate-N levels early in the season followed by a much slower rate of decline.

The positive yield responses obtained with the Meister fertilizer are encouraging. This new type of controlled release fertilizer may be an option that can be used to minimize leaching of nitrate during irrigated potato production. Before definitive conclusions can be made, further studies are needed to evaluate the effect of this fertilizer on yield and nitrate leaching in subsequent years.

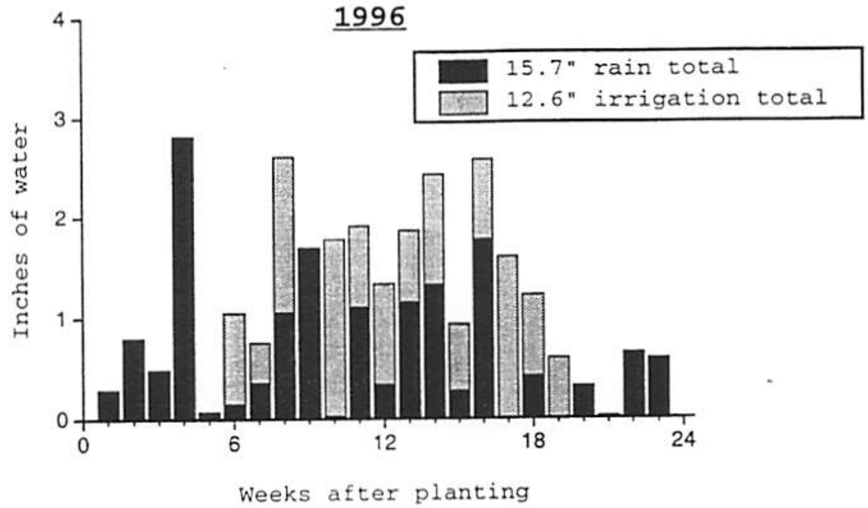

Figure 1. Rainfall and irrigation at Becker, MN during the 1996 growing season.

Table 1. Effect of nitrogen treatments on vine yield, and tuber yield and quality - Becker, MN.

Treatment			Fresh weight							Specific	Hollow
N Source	N Trmt	N timing	Vine	Knobs	≤3 oz	3-6 oz	6-12 oz	≥12 oz	Total	Gravity	Heart-%
			Tons/A	cwt/A							incidence
Urea - Quick Release											
1.	125	(25,50,50)[1]	3.69	15.5	74.5	186.3	209.1	42.3	527.7	1.0875	26.4
2.	165	(25,70,70)	6.31	14.5	82.1	178.1	189.7	52.8	517.2	1.0895	34.8
3.	205	(25,90,90)	6.82	14.5	61.9	157.2	215.0	91.0	539.6	1.0917	25.0
4.	245	(25,110,110)	8.40	8.8	63.8	171.9	215.9	68.1	528.5	1.0908	22.5
5.	285	(25,130,130)	11.81	28.0	61.7	152.1	232.7	93.3	567.8	1.0907	30.8
6.	245	(25,70,70)+80[2]	9.10	24.8	59.0	152.7	200.7	96.7	533.9	1.0901	8.3
Meister - Controlled Release											
7.	125	(125,0,0)[1]	3.01	19.0	88.7	219.5	197.3	50.1	574.6	1.0921	16.7
8.	165	(165,0,0)	6.16	30.6	67.6	187.1	213.6	69.0	567.9	1.0911	15.3
9.	205	(205,0,0)	7.61	16.7	69.8	175.0	231.8	90.9	584.2	1.0919	23.2
10.	245	(245,0,0)	8.44	26.2	65.7	156.6	222.4	105.8	576.7	1.0899	19.4
11.	285	(285,0,0)	9.60	24.0	61.4	149.5	236.5	110.1	581.5	1.0907	15.3
12.	245	(165,0,0)+80[2]	7.95	18.7	69.5	183.7	215.9	86.7	574.5	1.0896	15.5
Significance			**	NS	**	**	NS	**	NS	NS	++
BLSD (0.05)			2.02	--	15.8	35.2	--	35.4	--	--	20.4
Main Effects											
Fert Trmt											
125			3.35	17.3	81.6	202.9	203.2	46.2	551.2	1.0898	21.5
165			6.23	22.5	74.9	182.6	201.6	60.9	542.5	1.0903	25.1
205			7.21	15.6	65.8	166.1	223.4	90.9	561.8	1.0918	24.1
245			8.42	18.8	64.9	163.2	219.6	89.7	556.2	1.0903	20.7
285			10.70	26.0	61.5	150.8	234.6	101.7	574.6	1.0907	23.0
165+80[2]			8.52	21.7	64.3	168.2	208.3	91.7	554.2	1.0898	11.9
Significance			**	NS	**	**	++	**	NS	NS	NS
BLSD (0.05)			1.38	--	10.3	22.9	29.3	22.9	--	--	--
Fert Source											
Urea			7.66	18.1	67.3	166.1	210.3	74.3	536.1	1.0900	24.7
Meister			7.13	22.5	70.5	178.6	219.6	85.5	576.7	1.0909	17.6
Significance			NS	NS	NS	++	NS	++	**	NS	*
Interaction											
Fert Trmt*Fert Source			NS	NS	++	NS	NS	NS	NS	NS	NS
Contrasts											
Lin Rate Urea (1, 2, 3, 4, 5)			**	NS	**	*	*	**	NS	NS	NS
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Urea (4) vs (6)			NS	++	NS	NS	NS	++	NS	NS	NS
Lin Rate Meister (7, 8, 9, 10, 11)			**	NS	**	**	*	**	NS	NS	NS
Quad Rate Meister (7, 8, 9, 10, 11)			++	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			NS	NS	NS	++	NS	NS	NS	NS	NS
Urea (1-6) vs Meister (7-12)			NS	NS	NS	++	NS	++	**	NS	*

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 1. Effect of nitrogen treatments on vine yield, tuber yield, and tuber quality - Becker, MN.

Treatment			Fresh weight							Specific	Hollow
N Source	N Trmt	N timing	Vine	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Gravity	Heart-%
Urea - Quick Release			Tons/A	cwt/A							incidence
1.	125	(25,50,50)[1]	3.69	15.5	74.5	186.3	209.1	42.3	527.7	1.0875	26.4
2.	165	(25,70,70)	6.31	14.5	82.1	178.1	189.7	52.8	517.2	1.0895	34.8
3.	205	(25,90,90)	6.82	14.5	61.9	157.2	215.0	91.0	539.6	1.0917	25.0
4.	245	(25,110,110)	8.40	8.8	63.8	171.9	215.9	68.1	528.5	1.0908	22.5
5.	285	(25,130,130)	11.81	28.0	61.7	152.1	232.7	93.3	567.8	1.0907	30.8
6.	245	(25,70,70)+80[2]	9.10	24.8	59.0	152.7	200.7	96.7	533.9	1.0901	8.3
Meister - Controlled Release											
7.	125	(125,0,0)[1]	3.01	19.0	88.7	219.5	197.3	50.1	574.6	1.0921	16.7
8.	165	(165,0,0)	6.16	30.6	67.6	187.1	213.6	69.0	567.9	1.0911	15.3
9.	205	(205,0,0)	7.61	16.7	69.8	175.0	231.8	90.9	584.2	1.0919	23.2
10.	245	(245,0,0)	8.44	26.2	65.7	156.6	222.4	105.8	576.7	1.0899	19.4
11.	285	(285,0,0)	9.60	24.0	61.4	149.5	236.5	110.1	581.5	1.0907	15.3
12.	245	(165,0,0)+80[2]	7.95	18.7	69.5	183.7	215.9	86.7	574.5	1.0896	15.5
Significance			**	NS	**	**	NS	**	NS	NS	++
BLSD (0.05)			2.02	--	15.8	35.2	--	35.4	--	--	20.4
Main Effects											
Fert Trmt											
125			3.35	17.3	81.6	202.9	203.2	46.2	551.2	1.0898	21.5
165			6.23	22.5	74.9	182.6	201.6	60.9	542.5	1.0903	25.1
205			7.21	15.6	65.8	166.1	223.4	90.9	561.8	1.0918	24.1
245			8.42	18.8	64.9	163.2	219.6	89.7	556.2	1.0903	20.7
285			10.70	26.0	61.5	150.8	234.6	101.7	574.6	1.0907	23.0
165+80[2]			8.52	21.7	64.3	168.2	208.3	91.7	554.2	1.0898	11.9
Significance			**	NS	**	**	++	**	NS	NS	NS
BLSD (0.05)			1.38	--	10.3	22.9	29.3	22.9	--	--	--
Fert Source											
Urea			7.66	18.1	67.3	166.1	210.3	74.3	536.1	1.0900	24.7
Meister			7.13	22.5	70.5	178.6	219.6	85.5	576.7	1.0909	17.6
Significance			NS	NS	NS	++	NS	++	**	NS	*
Interaction											
Fert Trmt*Fert Source			NS	NS	++	NS	NS	NS	NS	NS	NS
Contrasts											
Lin Rate Urea (1, 2, 3, 4, 5)			**	NS	**	*	*	**	NS	NS	NS
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Urea (4) vs (6)			NS	++	NS	NS	NS	++	NS	NS	NS
Lin Rate Meister (7, 8, 9, 10, 11)			**	NS	**	**	*	**	NS	NS	NS
Quad Rate Meister (7, 8, 9, 10, 11)			++	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			NS	NS	NS	++	NS	NS	NS	NS	NS
Urea (1-6) vs Meister (7-12)			NS	NS	NS	++	NS	++	**	NS	*

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 2. Effect of nitrogen treatments on nitrogen content, nitrogen concentration, and dry matter production of vines and tubers - Becker, MN.

Treatment			Nitrogen content			N concentration		Dry matter		
			Vine	Tuber	Total	Vine	Tuber	Vine	Tuber	Total
N Source	N Trmt	N timing	-------	lbs/A	--------	---- % N ----		------	Tons/A	------
1.	125	(25,50,50)[1]	14.1	123.5	137.6	0.92	0.96	0.77	6.42	7.19
2.	165	(25,70,70)	21.4	139.2	160.6	1.18	1.13	0.94	6.15	7.09
3.	205	(25,90,90)	21.3	139.4	160.7	1.34	1.11	0.79	6.33	7.12
4.	245	(25,110,110)	34.1	148.4	182.5	1.49	1.23	1.21	6.45	7.66
5.	285	(25,130,130)	35.5	170.2	205.7	1.51	1.32	1.18	6.49	7.67
6.	245	(25,70,70)+80[2]	40.1	152.6	192.7	1.85	1.19	1.08	6.42	7.50
Meister - Controlled Release										
7.	125	(125,0,0)[1]	15.2	138.3	153.5	1.08	1.03	0.70	6.70	7.40
8.	165	(165,0,0)	23.1	157.9	181.0	1.33	1.25	0.87	6.38	7.25
9.	205	(205,0,0)	28.1	182.3	210.4	1.62	1.35	0.87	6.78	7.65
10.	245	(245,0,0)	41.6	175.9	217.5	1.88	1.28	1.11	6.91	8.02
11.	285	(285,0,0)	43.0	194.2	237.2	2.02	1.47	1.10	6.60	7.70
12.	245	(165,0,0)+80[2]	33.8	172.3	206.1	1.74	1.30	0.97	6.64	7.61
Significance			**	**	**	**	**	*	NS	NS
BLSD (0.05)			10.3	20.0	21.1	0.43	0.17	0.35	--	--
Main Effects										
Fert Trmt										
125			14.6	130.9	145.5	1.00	1.00	0.74	6.56	7.30
165			22.2	148.5	170.7	1.26	1.19	0.90	6.26	7.16
205			24.7	160.8	185.5	1.48	1.23	0.83	6.56	7.39
245			37.8	162.2	200.0	1.68	1.25	1.15	6.71	7.86
285			39.3	182.2	221.5	1.77	1.40	1.14	6.55	7.69
165+80[2]			37.0	162.4	199.4	1.79	1.24	1.02	6.53	7.55
Significance			**	**	**	**	**	**	NS	NS
BLSD (0.05)			7.0	13.9	14.7	0.29	0.11	0.21	--	--
Fert Source										
Urea			27.8	145.5	173.3	1.38	1.16	0.99	6.37	7.36
Meister			30.8	170.1	200.9	1.61	1.28	0.94	6.67	7.61
Significance			NS	**	**	*	**	NS	++	NS
Interactio n										
Fert Trmt*Fert Source			NS	NS	NS	NS	NS	NS	NS	NS
Contrasts										
Lin Rate Urea (1, 2, 3, 4, 5)			**	**	**	**	**	**	NS	NS
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Urea (4) vs (6)			NS	NS	NS	++	NS	NS	NS	NS
Lin Rate Meister (7, 8, 9, 10, 11)			**	**	**	**	**	**	NS	NS
Quad Rate Meister (7, 8, 9, 10, 11)			NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			NS	NS	NS	NS	NS	NS	NS	NS
Urea (1-6) vs Meister (7-12)			NS	**	**	*	**	NS	++	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3. Effect of nitrogen treatments on Russet Burbank nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date					
			June 20		July 1		July 15	
			dry weight	sap	dry weight	sap	dry weight	sap
N Source	N Trmt	N timing	Petiole-N	Horiba	Petiole-N	Horiba	Petiole-N	Horiba
			ppm NO_3-N					
Urea - Quick Release								
1.	125	(25,50,50)[1]	23578	1725	12216	1325	3490	695
2.	165	(25,70,70)	24507	1750	17697	1725	4174	858
3.	205	(25,90,90)	25364	1825	21966	1850	6215	1085
4.	245	(25,110,110)	23631	1750	24661	1925	13008	1525
5.	285	(25,130,130)	25106	1800	26293	1975	15153	1700
6.	245	(25,70,70)+80[2]	24323	1775	23350	1975	17885	1925
Meister - Controlled Release								
7.	125	(125,0,0)[1]	17271	1400	8355	1100	796	413
8.	165	(165,0,0)	19623	1575	12770	1375	4524	862
9.	205	(205,0,0)	20612	1625	14307	1550	6967	1200
10.	245	(245,0,0)	23851	1700	17501	1725	8006	1275
11.	285	(285,0,0)	24204	1775	20965	1850	14708	1725
12.	245	(165,0,0)+80[2]	17902	1500	11614	1225	11794	1500
Significance			**	**	**	**	**	**
BLSD (0.05)			2159	91	1948	95	3707	262
Main Effects								
Fert Trmt								
	125		20425	1563	10286	1213	2143	554
	165		22065	1663	15233	1550	4349	860
	205		22988	1725	18137	1700	6591	1143
	245		23741	1725	21081	1825	10507	1400
	285		24655	1788	23629	1913	14931	1713
	165+80[2]		21113	1638	17482	1600	14840	1713
Significance			**	**	**	**	*	*
BLSD (0.05)			1576	65	1375	67	2570	182
Fert Source								
Urea			24418	1771	21031	1796	9987	1298
Meister			20577	1596	14252	1471	7799	1163
Significance			**	**	**	**	**	**
Interaction								
Fert Trmt*Fert Source			**	**	**	**	++	++
Contrasts								
Lin Rate Urea (1, 2, 3, 4, 5)			NS	NS	**	**	**	**
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	**	**	NS	NS
Post-hilling Urea (4) vs (6)			NS	NS	NS	NS	*	**
Lin Rate Meister (7, 8, 9, 10, 11)			**	**	**	**	**	**
Quad Rate Meister (7, 8, 9, 10, 11)			NS	NS	NS	*	NS	NS
Post-hilling Meister (10) vs (12)			**	**	**	**	++	NS
Urea (1-6) vs Meister (7-12)			**	**	**	**	*	*

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3 cont. Effect of nitrogen treatments on Russet Burbank nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker MN.

Treatment			Date: July 25		Date: August 9	
N Source	N Trmt	N timing	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
			ppm NO_3-N			
Urea - Quick Release						
1.	125	(25,50,50)[1]	614	305	489	158
2.	165	(25,70,70)	1381	498	840	193
3.	205	(25,90,90)	3516	773	2046	235
4.	245	(25,110,110)	6509	1023	3662	405
5.	285	(25,130,130)	9266	1250	5106	660
6.	245	(25,70,70)+80[2]	13606	1575	5747	650
Meister - Controlled Release						
7.	125	(125,0,0)[1]	1229	370	108	188
8.	165	(165,0,0)	2319	683	1653	225
9.	205	(205,0,0)	7235	1090	3279	465
10.	245	(245,0,0)	8614	1295	4889	748
11.	285	(285,0,0)	12372	1625	8504	1023
12.	245	(165,0,0)+80[2]	13923	1650	7656	950
Significance			**	**	**	**
BLSD (0.05)			2683	249	2442	235
Main Effect						
Fert Trmt						
125			922	338	298	173
165			1850	590	1247	209
205			5375	931	2663	350
245			7562	1159	4275	576
285			10819	1438	6805	841
165+80[2]			13765	1613	6701	800
Significance			**	**	*	**
BLSD (0.05)			1872	174	1672	163
Fert Source						
Urea			5816	904	2982	383
Meister			7615	1119	4348	600
Significance			**	**	**	**
Interaction						
Fert Trmt*Fert Source			NS	NS	NS	NS
Contrasts						
Lin Rate Urea (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	++
Post-hilling Urea (4) vs (6)			**	**	++	++
Lin Rate Meister (7, 8, 9, 10, 11)			**	**	**	**
Quad Rate Meister (7, 8, 9, 10, 11)			NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			**	*	*	++
Urea (1-6) vs Meister (7-12)			**	**	*	**

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

CARROT RESPONSE TO NITROGEN FERTILIZER ON A MINERAL SOIL[1]

Carl Rosen, Bill Hutchison, Cindy Tong, and Dave Birong[2]

Abstract: A field study was conducted at Rosemount to refine nitrogen fertilizer recommendations for carrot production on a mineral soil. The study was conducted as part of larger experiment to evaluate the interactions among nitrogen nutrition, aster leafhopper development and incidence, and postharvest quality. Nitrogen fertilizer application had inconsistent effects on yield. At the early harvest (August 23) highest yields were obtained with 60 lb N/A while at the late harvest (September 19), yield was suppressed at 120 lb N/A. Delaying harvest by 3 to 4 weeks nearly doubled total yield and increased dry matter percentage of the root from 11.5% to 13.0%. Nitrogen content of roots and shoots increased with increasing N rate. Petiole nitrate-N expressed on a dry weight or sap basis was useful for assessing N status of carrots during the growing season.

Carrot production in Minnesota has increased substantially in the past five years. Interest in growing carrots has been in response to emerging fresh and processing markets. There has been very little research conducted that defines the nitrogen requirements of carrots grown on mineral soils. Too little fertilizer applied can potentially limit yields, while excessive rates can lead to poor carrot quality and environmental degradation. This study was conducted as part of larger experiment to evaluate the interactions among nitrogen nutrition, aster leafhopper development and incidence, and postharvest quality. Specific objectives of the research reported here were to: 1) Characterize carrot response to nitrogen application in terms of yield, quality, and dry matter production. 2) Evaluate the use of the Cardy nitrate meter for determining nitrate-N in petiole sap for diagnostic purposes.

Procedures

The experiment was conducted at Rosemount during the 1996 growing season on a Waukigen loam soil. Selected chemical properties in the 0-6" depth were as follows: pH, 6.6; Organic matter, 4.5%; Bray P1, 48 ppm; and NH_4OAc K, 209 ppm. An average of 95 lb nitrate-N was available in the top 2 ft. Prior to planting, 450 lbs 0-14-42 were broadcast and incorporated. Four nitrogen rates were tested: 0, 60, 120, and 180 lb N/A. Half the N was broadcast and incorporated as urea one day before planting (May 17). The remainder of the N was sidedressed as ammonium nitrate on June 16. Carrots were planted with a Stanhay Precision Planter on May 18. Each plot consisted of 16 rows 12" apart. The planting depth was 0.75". The variety used was 'Blaze'. Each treatment was replicated four times. The insecticide Baythroid 2E was sprayed five times at 7 to 10 day intervals on half of the plots starting in mid-June. The other half was left unsprayed to determine the effect of N nutrition on aster leafhopper incidence. Carrots were harvested on two occasions: August 23 and September 19. Each treatment was replicated four times in a split plot design with insecticide treatment as the main plot and N treatment as the subplot. The most recently mature petiole was collected from each plot on July 16 (roots 1/4" diameter), July 26, and August 4 (roots ½" diameter). Forty petioles were collected from each plot. Half the petioles were dried for nitrate determination on a dry weight basis. The remainder were crushed and sap nitrate was determined with a Cardy meter. At each harvest, two sections of row were dug by hand. All carrots were counted, tops removed and weighed, the roots were washed and weighed, and then a 50 count subsample was sorted according to size and quality. Subsamples of tops and roots were saved for dry matter and N analysis. An additional subsample was taken for aster yellows incidence, chemical analyses (terpenoid and isocoumarin) related to bitter flavor, and a taste test for bitterness. Only the yield, N uptake, and nitrate petiole analysis will be presented here.

Results

Yield: The effect of N fertilizer and insecticide treatment on yield, dry matter accumulation, and final plant population on August 23 is presented in Table 1. Maximum total yield tended to increase quadratically with N rate up to 60 lb N/A and then decreased. Most of the yield increase was due to an increase in forked carrots. In general, yield of marketable carrots was not affected by N rate, presumably due to the high level (95 lb N/A) of residual nitrate-N before planting. Insecticide treatment did not affect total yield or quality. Dry matter percentage of roots was not affected by N treatment, but slightly increased with insecticide treatment. Dry matter production of roots decreased at the higher N rates while dry matter production of the shoots increased. Insecticide treatment had no effect on dry matter production of roots or shoots. Final plant population was not affected by N or insecticide treatments. The effect of N fertilizer and insecticide treatment on yield, dry matter accumulation, and final plant population on

September 19 is presented in Table 2. Delaying harvest by 3 to 4 weeks nearly doubled carrot yield regardless of treatment. Total yield was not consistently affected by N treatment. Lowest yield occurred at the 120 lb N/A rate while highest yield occurred at the 60 and 180 lb N/A rates. Insecticide treatment tended to decrease the yield of forked carrots. Delaying harvest by 3-4 weeks increased root dry matter by about 1-2%. Dry matter percentage of roots was highest when N was not applied. As in the first harvest, insecticide treatment tended to increase root dry matter percentage. Dry matter production of shoots and roots was not consistently affected by N rate. Insecticide treatment had no effect on dry matter production of roots or shoots. Final plant population was not affected by N or insecticide treatments.

Nitrogen content and concentration: Nitrogen content and concentration of shoots and roots increased with increasing N application on the first harvest date (Table 3). Nitrogen content of the shoots was about twice that of the roots. Total N content of shoots and roots ranged from 60 lb N/A without N fertilizer applied to 100 lb N/A when supplied with 180 lb N/A. On the second harvest date, similar trends were observed: N content and concentration of shoots and roots increased with increasing N rate (Table 4). In contrast to the first harvest date, N content in roots was slightly higher

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than that in shoots on the second harvest date. Total N content of shoots and roots ranged from about 100 lb N/A when grown in control plots to 140 lb N/A in plots supplied with 180 lb N/A. Insecticide treatment had no effect on N content or concentrations of shoots and roots at either harvest.

Petiole nitrate: At all sampling dates, nitrate-N on a dry weight and sap basis increased linearly with increasing N rate. Insecticide treatment had no effect on petiole nitrate on July 16 and tended to lower nitrate concentrations on a dry weight basis on July 26 and on a sap basis on August 4. Reasons for this apparent lowering in nitrate concentrations are not known. The petiole test on either a dry weight or sap basis does appears to be useful for assessing N status of carrots; however, since yield was not consistently affected by N treatment, only generalizations can be made about interpretation of the petiole nitrate concentrations reported. When the root diameter at the top is about 1/4", nitrate-N concentrations on a dry weight basis were between 4000 to 5000 ppm (0.4 to 0.5%) and on a sap basis ranged from 1000 to 1200 ppm. By the time root diameter was about ½", petiole dry weight nitrate-N decreased to 0.04 to 0.15% and sap nitrate-N decreased to 150 to 350 ppm. Further studies where a response to N is obtained are needed to calibrate the petiole nitrate test interpretations.

Table 1. Effect of nitrogen fertility and alfalfa leaf hopper treatments on carrot yield and quality; August 23, 1996.

Treatment					Root Diameter				Dry Matter	Dry Matter			Carrot
#	N	Insecticide	<4"	Forks	<⅞"	⅞ to 1½"	>1½"	Total Yield	Root	Roots	Tops	Total	population
	lb/A		cwt/A						%	Tons/Acre			plants/ft
1.	0	-	13.9	49.2	11.5	91.0	0	165.6	11.3	0.94	1.39	2.33	6.0
2.	0	+	6.9	37.8	26.7	120.4	0	191.8	11.8	1.13	1.24	2.37	6.7
3.	60	-	8.5	90.4	18.7	98.2	0	215.8	11.9	1.28	1.59	2.87	6.4
4.	60	+	8.4	51.8	22.2	111.0	0	193.4	11.7	1.13	1.52	2.65	6.6
5.	120	-	8.7	75.0	22.7	77.9	0	184.3	12.0	1.10	1.61	2.71	6.6
6.	120	+	15.2	44.2	12.7	119.2	0	191.3	11.8	1.14	1.57	2.71	5.7
7.	180	-	14.4	49.8	16.2	87.5	0	167.9	11.1	0.93	1.44	2.37	6.1
8.	180	+	2.6	59.0	19.0	108.6	0	189.2	12.0	1.14	1.66	2.80	6.1
	Significance		+	NS	NS	NS	--	NS	NS	NS	NS	NS	NS
	(BLSD)		12.5	--	--	--	--	--	--	--	--	--	--
Main Effects													
N Rate													
	0		10.4	43.5	19.1	105.7	0	178.7	11.5	1.04	1.31	2.35	6.3
	60		8.4	71.1	20.5	104.6	0	204.6	11.8	1.21	1.55	2.76	6.5
	120		11.9	59.6	17.7	98.6	0	187.8	11.9	1.12	1.59	2.71	6.2
	180		8.5	54.4	17.6	98.0	0	178.5	11.6	1.04	1.55	2.59	6.1
	Significance		NS	NS	NS	NS	--	NS	NS	NS	+	+	NS
	Lin Rate N		NS	NS	NS	NS	--	NS	NS	NS	++	NS	NS
	Quad Rate N		NS	+	NS	NS	--	+	NS	+	+	++	NS
Insecticide													
	-		11.4	66.1	17.3	88.6	0	183.4	11.6	1.06	1.51	2.57	6.3
	+		8.3	48.2	20.2	114.8	0	191.5	11.8	1.14	1.50	2.64	6.3
	Significance		+	NS	NS	NS	--	NS	+	NS	NS	NS	NS
Contrasts													
N rate*Insecticide			++	NS	NS	NS	--	NS	NS	NS	NS	NS	NS

NS = Not significant; ++ and + = significant at the 10% and 20% level, respectively.

Table 2. Effect of nitrogen fertility and alfalfa leaf hopper treatments on carrot yield and quality; September 19, 1996.

#	N	Insecticide	<4"	Forks	<⅞"	⅞ to 1¾"	>1¾"	Total Yield	Dry Matter Root	Roots	Tops	Total	Carrot population
	Treatment				--- Root Diameter ---					--- Dry Matter ---			
	lb/A		cwt/A						%	Tons/Acre			plants/ft
1.	0	-	13.8	151.8	7.6	198.8	21.1	393.1	13.4	2.59	1.82	4.41	5.6
2.	0	+	21.3	79.8	2.3	239.8	61.3	404.5	13.9	2.79	1.90	4.69	4.8
3.	60	-	16.2	172.4	6.2	155.3	62.8	412.9	12.9	2.64	2.07	4.71	4.8
4.	60	+	22.4	114.9	27.6	232.2	5.4	402.5	12.8	2.56	2.02	4.58	5.7
5.	120	-	12.2	143.1	3.1	187.6	6.0	352.0	12.5	2.19	1.88	4.07	5.0
6.	120	+	14.5	152.7	4.2	180.9	27.1	379.4	13.6	2.58	1.80	4.38	4.1
7.	180	-	9.2	169.1	11.4	182.1	64.6	436.4	12.9	2.81	2.27	5.08	4.8
8.	180	+	11.8	103.7	2.9	200.6	62.2	381.2	13.5	2.58	1.78	4.36	5.4
	Significance		NS	+	+	NS	*	NS	NS	+	NS	+	NS
	(BLSD)		--	98.1	26.2	--	56.3	--	--	0.55	--	0.96	--
Main Effects													
N Rate													
	0		17.5	115.8	4.9	219.3	41.2	398.7	13.7	2.69	1.86	4.55	5.2
	60		19.3	143.6	16.9	193.7	34.1	407.6	12.8	2.60	2.05	4.65	5.2
	120		13.4	147.9	3.6	184.3	16.6	365.8	13.0	2.39	1.84	4.23	4.6
	180		10.5	136.4	7.1	191.4	63.4	408.8	13.2	2.69	2.02	4.71	5.1
	Significance		NS	NS	NS	NS	++	+	NS	+	NS	+	NS
	Lin Rate N		+	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Quad Rate N		NS	NS	NS	NS	*	NS	+	++	NS	NS	NS
Insecticide													
	-		12.8	159.1	7.1	180.9	38.7	398.6	12.9	2.56	2.01	4.57	5.1
	+		17.5	112.8	9.2	213.4	39.0	391.9	13.4	2.63	1.88	4.51	5.0
	Significance		NS	++	NS	+	NS	NS	+	NS	NS	NS	NS
Contrasts													
N rate*Insecticide			NS	NS	+	NS	*	NS	NS	+	NS	+	+

NS = Not significant; *, ++ and + = significant at the 5%, 10% and 20% level, respectively.

Table 3. Effect of nitrogen fertility and alfalfa leaf hopper treatments on carrot nitrogen content and concentration; August 23, 1996.

#	N	Insecticide	Nitrogen content: Top	Root	Total	Nitrogen concentration: Top	Root
	lb/A		lbs/A			% N	
1.	0	-	44.4	18.2	62.7	1.61	1.03
2.	0	+	36.9	23.6	60.5	1.49	1.05
3.	60	-	56.5	34.1	90.6	1.81	1.34
4.	60	+	48.7	28.5	77.3	1.61	1.28
5.	120	-	54.6	32.0	86.6	1.75	1.46
6.	120	+	63.8	33.1	97.0	2.05	1.46
7.	180	-	65.4	29.7	95.0	2.29	1.60
8.	180	+	62.6	35.6	98.3	1.84	1.57
	Significance		*	**	**	**	**
	(BLSD)		18.0	9.8	20.6	0.31	0.17
Main Effects							
N Rate							
	0		40.7	20.9	61.6	1.55	1.04
	60		52.6	31.3	83.9	1.71	1.31
	120		59.2	32.6	91.8	1.90	1.46
	180		64.0	32.6	96.7	2.07	1.59
	Significance		**	**	**	**	**
	Lin Rate N		**	**	**	**	**
	Quad Rate N		NS	*	+	NS	++
Insecticide							
	-		55.2	28.5	83.7	1.87	1.36
	+		53.0	30.2	83.2	1.75	1.34
	Significance		NS	NS	NS	NS	NS
Contrasts							
N rate*Insecticide			NS	+	NS	**	NS

NS = Not significant; **, *, ++ and + = significant at the 1%, 5%, 10% and 20% level, respectively.

Table 4. Effect of nitrogen fertility and alfalfa leaf hopper treatments on carrot nitrogen content and concentration; September 19, 1996.

#	N	Insecticide	Nitrogen content Top	Root	Total	Nitrogen concentration Top	Root
	lb/A		--------- lbs/A ---------			----- % N -------	
1.	0	-	40.8	51.2	92.0	1.13	0.98
2.	0	+	47.0	58.0	105.0	1.22	1.04
3.	60	-	59.0	61.6	120.6	1.42	1.17
4.	60	+	56.2	61.7	117.9	1.37	1.21
5.	120	-	66.7	60.5	127.2	1.78	1.38
6.	120	+	49.1	64.2	113.3	1.41	1.25
7.	180	-	72.8	76.2	149.0	1.61	1.36
8.	180	+	63.9	71.1	135.0	1.78	1.40
	Significance		++	*	**	*	**
	(BLSD)		28.2	14.6	27.6	0.53	0.26
Main Effects							
N Rate							
	0		43.9	54.6	98.5	1.17	1.01
	60		57.6	61.7	119.3	1.40	1.19
	120		57.9	62.4	120.3	1.60	1.32
	180		68.3	73.7	142.0	1.70	1.38
	Significance		*	**	**	**	**
	Lin Rate N		**	**	**	**	**
	Quad Rate N		NS	NS	NS	NS	NS
Insecticide							
	-		59.8	62.4	122.2	1.49	1.22
	+		54.0	63.8	117.8	1.45	1.22
Significance			NS	NS	NS	NS	NS
Contrasts							
N rate*Insecticide			NS	NS	NS	NS	NS

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

Table 5. Effect of nitrogen fertility and alfalfa leaf hopper treatments on carrot petioles (dry weight basis) and nitrate concentration in petiole sap.

#	N	Insecticide	July 16 dry weight Petiole-N	July 16 sap Horiba	July 26 dry weight Petiole-N	July 26 sap Horiba	August 4 dry weight Petiole-N	August 4 sap Horiba
	lb/A		ppm NO_3-N					
1.	0	-	4523	950	2431	500	448	171
2.	0	+	3716	1015	1774	455	306	123
3.	60	-	4645	1035	2923	535	480	185
4.	60	+	4514	1023	2584	708	510	190
5.	120	-	4563	1123	3259	663	1288	358
6.	120	+	4964	1035	2555	548	1240	308
7.	180	-	5202	1295	3661	683	1442	395
8.	180	+	5315	1173	3073	835	1708	290
	Significance		NS	NS	+	**	**	**
	(BLSD)		--	--	1825	186	704	111
Main Effects								
N Rate								
	0		4120	983	2103	478	377	147
	60		4580	1029	2753	621	495	188
	120		4764	1079	2907	605	1264	333
	180		5259	1234	3367	759	1575	343
	Significance		NS	+	++	**	**	**
	Lin Rate N		*	*	*	**	**	**
	Quad Rate N		NS	NS	NS	NS	NS	NS
Insecticide								
	-		4733	1101	3068	595	914	277
	+		4627	1061	2497	636	941	228
Significance			NS	NS	+	NS	NS	*
Contrasts								
N rate*Insecticide			NS	NS	NS	++	NS	NS

NS = Not significant; **, *, ++ and + = significant at the 1%, 5%, 10% and 20% level, respectively.

TILLAGE COMPARISON AT ROSEMOUNT, 1996[1]

L. M. Wallach, D.R. Linden, K.L. Walters, R.H. Dowdy, R.R. Allmaras, C.E. Clapp, and J. Rowe[2]

Abstract

A long term tillage system study was initiated at Rosemount in 1991. Four tillage systems including conventional, conservation, ridge, and minimized tillages are used with continuous corn and corn/soybean rotations. Nitrogen inputs remained constant across all treatments planted to corn with no nitrogen applied to treatments in soybeans. The objective of the study is to determine the long term effects of various cropping systems on herbicide movement, earthworm activity, grain yield, nutrient availability, nutrient uptake, root distribution, and soil quality. Preliminary results are available for many of the objectives. Grain yield, corn emergence, surface residue, earthworm activity, and aggregate stability are presented in this report.

Site: An 18 acre site at the Rosemount Agricultural Experiment Station was chosen for study. The dominant soil type is a Waukegon Silt Loam (Typic Hapludoll) which has 20 to 32 inches of silt loam overlying calcareous sand and gravel with a slope of less than 2%. The site was grid sampled prior to plot layout.

Experimental Design

The site was separated into 36 plots of 0.4 acres each. A continuous corn (CC), corn/soybean (CS) [soybean 1996], and soybean/corn (SC) [corn 1996] rotations were planted into four tillage systems in a randomized complete block design with three replications. The four tillage systems are described as:

Conventional (T1): Plots are moldboard plowed following corn and chisel plowed following soybeans. Disk and/or field cultivate to prepare seedbed. One or two cultivations after planting as needed.

Conservation (T2): Plots are chisel plowed following corn with no fall tillage following soybeans. Disk and/or field cultivate to prepare seedbed for soybeans. Corn is no-till seeded into soybean stubble. One or two cultivations after planting as needed.

Ridge-till (T3): No tillage following corn or soybean. Planting is done in ridges formed by previous cultivation. Two cultivations following planting to control weeds and re-establish ridges.

Minimized Tillage (T4): Generally, no primary or secondary tillage is prescheduled. Tillage will be performed only when soil or weed conditions require attention. Cultivation performed only when determined necessary.

Experimental Procedure

All CC and CS conventional tillage plots were moldboard plowed on April 30. Also, SC conventional tillage plots and CC and CS conservation tillage plots were chisel plowed on the same day. All of the conventional and conservation plots were field cultivated prior to planting. Corn (Pioneer 3751) was planted in the CC and SC plots across all tillage systems on May 21. The seeds were planted at a population of 28,000 seeds/acre. Lorsban insecticide was banded over the row on all continuous corn plots at a rate of 8 oz./1000 feet of row. Corn emergence was counted from two 20' sections of row in each plot periodically for the first four weeks of growth. Corn stands were observed and recorded during the season and the final plant population was recorded on October 1. Soybeans were planted on May 30 and May 31 at a rate of 60 lbs/acre to a depth of 2" in all CS plots. The Hodgson variety was used which contains 2900 seeds/lb. Dual II was broadcast on June 4 to all plots at a rate of 2.25 pints/acre to control pre-emergent broad-leaved weeds. Also on June 4, Round-up Ultra was broadcast on all no-till soybean plots at a rate of 1 ½ quart/acre. On June 4, all plots planted to corn were broadcast sprayed with 1.5 pint/acre of Buctril and 11 oz/acre 2,4-D. On July 2 all plots planted to soybeans in 1996 were broadcast sprayed with 1.5 pint/acre of Basagran and .25 oz/acre of Pinnacle. Also on July 2, all plots planted to corn were cultivated with the 6 row Hinnicker Sweep, all ridge-till corn plots were re-ridged, and all corn plots received 105 lbs/acre of nitrogen fertilizer (as 28% solution). Between July 12 and July 17 all continuous corn ridge-till plots were hand-weeded. Fusilade was broadcast on all plots planted to soybeans at a rate of 12 oz/acre on July 22. All plots were harvested on October 22. Tillages were not performed in the fall as laid out in the experimental procedure due to the soil freezing earlier than expected. The LSD comparison of means procedure at 5% was used to analyze all of the data in this paper.

Results and Discussion

Crop Results - Grain yields and moisture percentages from all tillages and rotations are given in figures 1-3 and table 1. Corn emergence data is given in figure 4, and surface residue percentages are located in figure 5.

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The yield was measured in grain weight from the middle 12 rows in the corn plots and the middle 8 rows in the soybean plots.
Continuous Corn (CC): Conventional and conservation tillages yielded the highest, minimized tillage was in the middle, and ridge tillage yielded the lowest (fig. 1). The continuous corn yields averaged over five years rank the tillage systems differently than that r 1996 yields. The five year average places conventional highest followed by conservation, ridge, and minimized tillage.
Corn Following Soybeans (SC): The 1996 corn yields in the soybean/corn rotation were greatest under conventional tillage, conservation and ridge tillages were in the middle, and minimized tillage yielded the lowest (fig. 2). The five year average for the soybean/corn rotation also ranked conventional first, followed by conservation, ridge, and minimized tillages.

Soybeans Following Corn (CS): The 1996 soybean yields in the corn/soybean rotation were all similar (fig 3). The five year average soybean yield ranked conventional first, followed by ridge, conservation, and minimized tillage.

Residue: Residue cover at planting is shown in figure 5. Conservation, ridge, and minimized tillage provide enough corn and soybean residues on the surface to meet the erosion control requirements, which stipulates that at least 30% of the surface must be covered at planting. It must be noted that in the conservation tillage plots, corn is no-tilled into the previous years soybean stubble leaving the soybean stubble on the surface. Ridge tillage plots provided sufficient residue to meet conservation compliance under the continuous corn and the soybean/corn rotation. The conventional tillage system provided enough residue to meet conservation requirements in the plots cropped to corn in 1996 following soybeans only. The other conventional tillage plots did not provide enough surface residue to qualify for the conservation requirements. It might be expected that the SC plots in conventional tillage would contain at least 30% residue cover over the winter since they are chisel plowed in the fall, but the fall chisel plowed soybean plots (soybean in 1995, corn in 1996) only had 12.6% residue cover at planting. This is consistent with the previous years residue data, where the fall chisel plowed soybeans only left 13.3% surface residue. Although, in the past two years, these fall tillage operations have been performed in the spring. Greater residue percentages would have been on the surface of these plots over the winter than the percentages that were recorded before planting.

Emergence: Corn seedling emergence was first recorded on June 5, 15 days after planting (fig. 4). Most plots had between 88-99% emergence at this time, except minimum (both CC and SC) and ridge (only CC) tillage plots which showed 23-59% emergence. Emergence had increased across all plots by the 20th day after planting, but the percentages remained variable between the cropping systems. This variability is presumably due to the spring soil moistures and temperatures. Figure 4 shows 3 different corn emergence trends. Conventional (CC and SC), conservation (CC and SC), and ridge (SC) plots sprouted corn quickly with 88-99% emergence 15 days after planting. The second trend is within the ridge (CC) plots and the minimized (SC) plots where they had only attained 55-59% emergence after 15 days. The last and slowest trend was seen in the minimized (CC) plot where only 23% emergence was seen after 15 days. The corn emergence trend in 1996 is fairly similar to the trend seen previously, except that, in general, the emergence numbers were somewhat higher in 1996 than in 1995. Corn seedling emergence exceeded 90% for all cropping systems 28 days after planting. In the conservation tillage plots under the continuous corn rotation there are emergence levels that go above 100%. This is thought to be the case due to corn cobs that have remained in the soil from previous years. These corn cobs sprout plants that could have led us to count more than what should have emerged based on the number of seeds planted.

Earthworm Results: Earthworms were sampled from all plots to determine differences in populations between tillages and rotations. Mustard flour extraction had to be used to measure the populations of *Lumbricus terrestris* in the spring and excavation and hand-sorting were used for *Aporrectodea tuberculata* in the spring and fall. The population data can be found in table 2. Also, earthworm surface castings were measured in the fall.

L. terrestris POPULATIONS: Twenty nightcrawlers (*L. terrestris*) were inoculated at the same location in each plot during the spring of 1995. An estimate of nightcrawler survival was obtained during the spring of 1996. This was done using the mustard flour extraction method described by Hogger, 1993, at each site of inoculation. Ridge tillage had the highest number of nightcrawlers extracted, conservation and minimized tillages were in the middle, and conventional tillage extracted the lowest number of nightcrawlers. *L. terrestris* prefers stable soil conditions so as to keep their burrows intact. This occurs under the ridge and minimized tillage systems. They most likely favor the ridge tillage system for its warmer soil temperatures over the minimized tillage system, as well as the added surface biomass from the weed pressures that have been observed under ridge tillage. Conservation tillage appears to be a slightly more favorable environment for the nightcrawler as compared with conventional tillage. Conservation tillage leaves more residue at or close to the surface and leads to less destruction of burrows. The CS (soybean in 1996) plots had a higher number of nightcrawlers extracted than either of the other two rotations. More data will be collected in the future.

A. tuberculata POPULATIONS: The earthworm *A. tuberculata* was measured in the field by taking a 1 foot in diameter and 1 foot deep sample of surface soil from each plot once in the spring (between June 10-12) and once in the fall (between October 4-9) (fig. 6). The samples were brought back to the lab and hand-sorted for earthworm numbers. This is the natural earthworm population distribution in the experimental plots. When comparing crop rotations, the CS (soybean 1996) rotation had the greatest number of *A. tuberculata* for both samplings. When comparing tillage, conventional and ridge tillage had the highest numbers. Figure 6 shows the CS rotation under conventional tillage in the spring as having 3 worms, but increasing greatly by the fall to 18 worms. It should be noted that the spring sampling took place a little over a month past the tillage operations, which is why the numbers are low. The CS rotation in the fall had increased to 18 worms in the absence of any tillage for months. *A. tuberculata* are subsurface feeders so the conventional tillage system leaves them a lot of decomposing residue at a depth they would prefer. They also are not as attached to their burrow system and are not prone to relocate if the system becomes destroyed. Conventional tillage soil is also very loose, so *A. tuberculata* can easily maneuver through the soil. The ridge tillage system maintains higher soil temperatures with the elevated ridges. There also may be more biomass available to them from the observed weed pressure in the ridge tillage system.

Surface Castings: Earthworm castings were measured in every plot during the fall of 1996. The casts were measured by length in millimeters across their longest axis. All of the casts within one square foot were measured. The castings were classified as either *A. tuberculata* or *L. terrestris*, since these are the only two species present and their castings are fairly distinguishable from each other. The castings were placed into 5 size categories: 0-5 mm, 6-10 mm, 11-15 mm, 16-25 mm, and 26+ mm. The *L. terrestris* had one extra category for middens. Middens are the surface of their vertical burrows and are a mixture of castings and residue. Length and width of middens were measured, but for the analysis only the number of midden per plot was used. Significant differences were found in almost every size class for tillage and/or rotation.
Rotation: Castings of *A. tuberculata* and *L. terrestris* were statistically more numerous in the CS (soybean in 1996) rotation than the CC (continuous corn) or the SC (corn in 1996) rotation, which were statistically similar. This was true of all size classes except the 0-5 mm for both species of earthworm. In the 0-5 mm size class the rotations in general appeared similar in relation to number of earthworm castings. It was expected that the CS rotation would contain more earthworms since soybeans contain more protein than corn and earthworms are attracted to this high protein food source.
Tillage (A. tuberculata): The castings of *A. tuberculata* were the most numerous overall in the ridge tillage plots and the least numerous overall in the conventional tillage plots (figs. 7,8, and 9). In the 0-5 mm, 6-10 mm, and 11-15 mm size classes, castings were highest under ridge tillage. In the 16-25 mm size class, castings were similar across all tillages. In the 26+ mm size class, castings were the highest under ridge and minimized tillages. The high number under ridge tillage is consistent with the sampled earthworm numbers, but the conventional tillage had considerably less surface castings than would have been suggested by the earthworm numbers in those plots. This is due to the nature of the residue under conventional tillage. There is almost no surface residue under conventional tillage, all of the residue is at the plow layer. Earthworms would have no reason to surface in order to eat and cast. Also, during the cast sampling there was almost no precipitation and the soils were very dry. Had it been spring or during a period of greater precipitation, the surface castings may have been greater for this tillage. The ridge tillage (as well as the minimized tillage) would promote more surface castings even during times of less precipitation since the residues remain at the surface. The surface residues also provide cool places and shelter from any hungry earthworm predators.
Tillage (L. terrestris): The castings of *L. terrestris* were the most numerous overall in the ridge tillage plots and the least numerous overall in the minimized tillage plots (figs 10,11, and 12). In the 0-5 mm and the 6-10 mm size classes, all casting amounts are similar. This is due to the fact that *L. terrestris* castings by nature are a larger sized cast. In the 11-15 mm size class, castings are highest under ridge tillage. In the 16-25 mm size class, castings are the highest under ridge and conservation tillages. In the 26+ mm size class, castings are the highest under ridge tillage. The middens showed no differences between tillages, but were more numerous under the CS (soybean 1996) rotation. A lot less *L. terrestris* castings were found than *A. tuberculata* so not many differences were detected between the tillages. The minimized tillage may have shown up as less significant in some size classes because it was more difficult to measure castings under that tillage system since there was so much residue on the surface, grass growing in the sample areas which had to be cut away before counting, and a more hummocky surface where residues and castings would fall down into holes that were filled with residue which were difficult to recover castings from.

1995 Aggregate stability results: Samples were taken from all experimental plots on three different dates in 1995: May 24 (S1), June 15-16 (S2), and June 28-29 (S3). Two depths were sampled from all the plots on each date: 0-7.5 cm (top sample) and 7.5-30 cm (bottom sample). 50 grams of air-dried soil from each plot, depth, and date underwent the wet aggregate submersion method (modified Yoder, 1936). Five sieves (4 mm, 2 mm, 1 mm, 500 micrometer, and 250 micrometer) were nested on top of each other, with the largest sieve at the top and the smallest sieve on the bottom. The samples were then placed into the top sieve and lowered into room temperature deionized water to soak for 10 minutes. The sieves were attached to a vertical shaker and after soaking, they were shook for 10 minutes. Then the samples were recovered from each sieve size. Each sieve fraction was measured in dry weight and was expressed as a percentage of the total 50 gram sample. The percent aggregates greater than 1 mm were added together and reported here since this fraction of aggregates is the most sensitive to tillage differences. The aggregate stability data can be found in table 3.

Aggregate Stability (% aggregates greater than 1 mm): In the top samples, the greatest aggregate stability was under minimized tillage (fig. 13). The next greatest aggregate stability was under ridge and conservation tillage, which were similar. The weakest aggregate stability was under conventional tillage. In the bottom samples, the weakest aggregate stability was also under conventional tillage (fig. 14). The other three tillages had greater aggregate structure and were similar, except for the sample from ridge tillage on the June 28-29 sample date. Aggregates don't have much time to form into large conglomerations under more intensive tillage practices since the soil is greatly disturbed annually. Under the minimized and ridge tillage systems larger aggregates have a chance to form since tillage operations are minimal. There weren't differences between rotations.

Conclusion

The data collected and analyzed from this experiment in the past two years have been more in depth and show more complexities within the different systems. Even though the yields in the conservation tillages have not surpassed those of the conventional tillage, other measurable qualities, such as the earthworms and aggregates, are greater under these alternative tillage methods. As the soils are built up under these less intensive tillage practices from the increased residues and biological activity, the yields may increase. After the production methods are in practice for even longer periods of time new trends may emerge. More biological, physical, and chemical data will be collected in future years to monitor the trends.

Table 1 Grain yields for the tillage study at Rosemount, 1996.

Treatment		Grain Yield			
Tillage	Rotation	1996 bu/ac	1996 mt/ha	92-96 avg. bu/ac*	92-96 avg. mt/ha*
Conventional (T1)	Cont.Corn	153.01	8.11	140.782	7.464
	Corn/Soy	39.51	2.31	40.702	2.342
	Soy/Corn	154.73	8.2	154.486	8.19
Conservation (T2)	Cont.Corn	135.41	7.18	128.642	6.82
	Corn/Soy	37.98	2.22	39.956	2.3
	Soy/Corn	142.04	7.53	141.608	7.506
Ridge-Till (T3)	Cont.Corn	50.76	2.69	114.452	6.066
	Corn/Soy	40.29	2.36	39.818	2.292
	Soy/Corn	112.65	5.97	142.27	7.54
Minimum-Till (T4)	Cont.Corn	95.52	5.06	110.184	5.84
	Corn/Soy	38.66	2.26	39.732	2.288
	Soy/Corn	106.91	5.67	130.302	7.052

*For 1992-1996 grain averages, the CS column is the average of all soybean yields within a particular tillage and the SC column is the average of all corn yields within a particular tillage for all plots in the corn/soybean rotation.

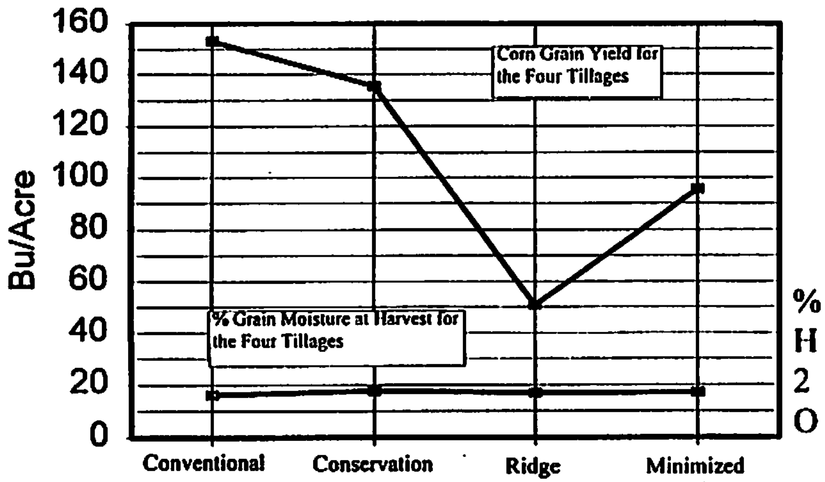
Table 2 A. tuberculata and L. terrestris Populations per square foot for the Tillage Study at Rosemount, 1996

Treatment			A. tuberculata populations		L. terrestris Mustard Flour Extraction
Tillage	Rotation		Spring 1996	Fall 1996	Spring 1996
Conventional (T1)	Cont.Corn	CC	2	5	0
	Corn/Soy	CS	3	18	0
	Soy/Corn	SC	4	6	0
Conservation (T2)	Cont.Corn	CC	1	3	0
	Corn/Soy	CS	5	11	1
	Soy/Corn	SC	3	2	0
Ridge-Till (T3)	Cont.Corn	CC	0	5	3
	Corn/Soy	CS	15	9	1
	Soy/Corn	SC	6	8	2
Minimum-Till (T4)	Cont.Corn	CC	3	6	0
	Corn/Soy	CS	4	2	2
	Soy/Corn	SC	5	5	0

Grain Yield Summary

Continuous Corn

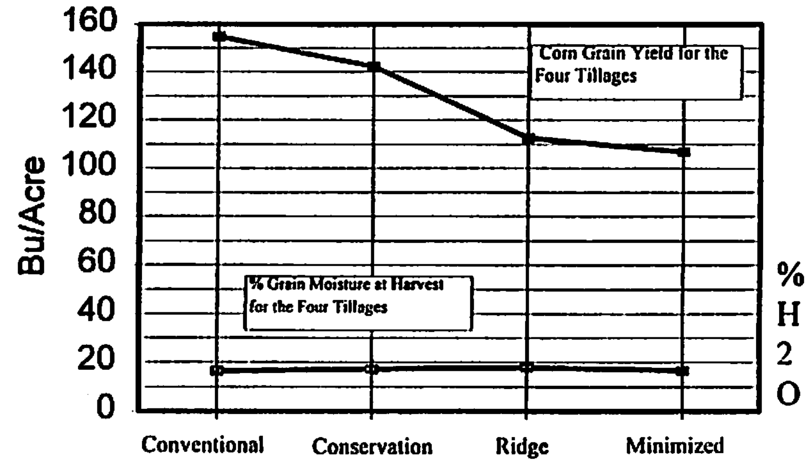
Fig. 1



Grain Yield Summary

Corn in '96 Following Soybeans

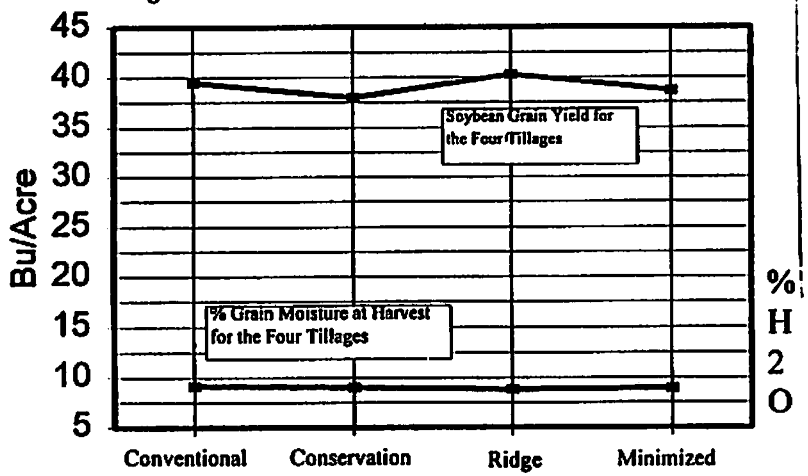
Fig. 2



Grain Yield Summary

Soybean in '96 Following Corn

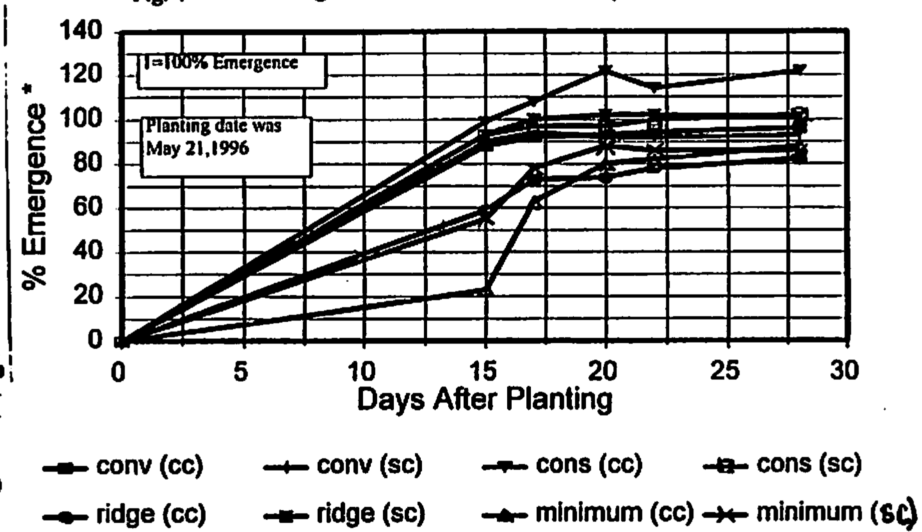
Fig. 3



1996 Corn Emergence

Tillage and Rotation Comparison

Fig. 4

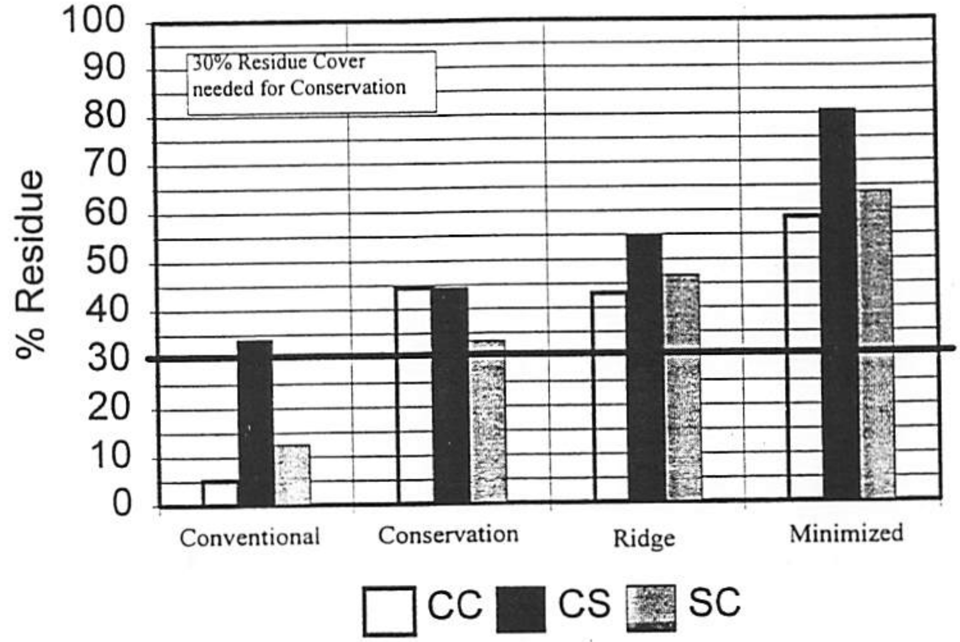


* Percent emergence is based on 28,000 seeds planted per acre

Residue Cover Comparison

Tillage and Rotation Effects

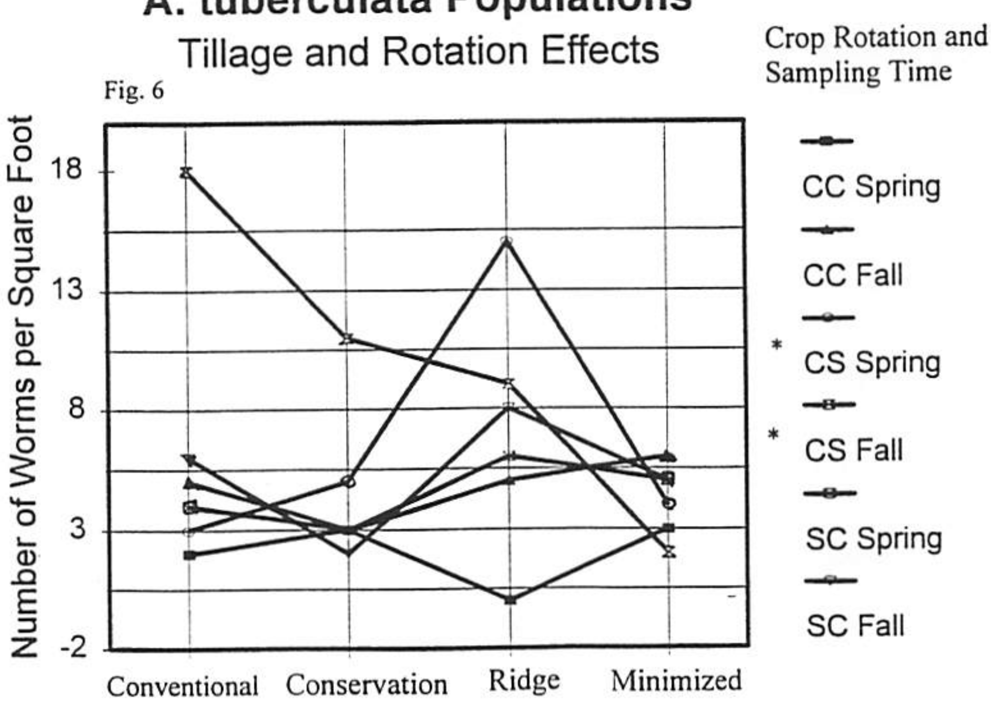
Fig.5



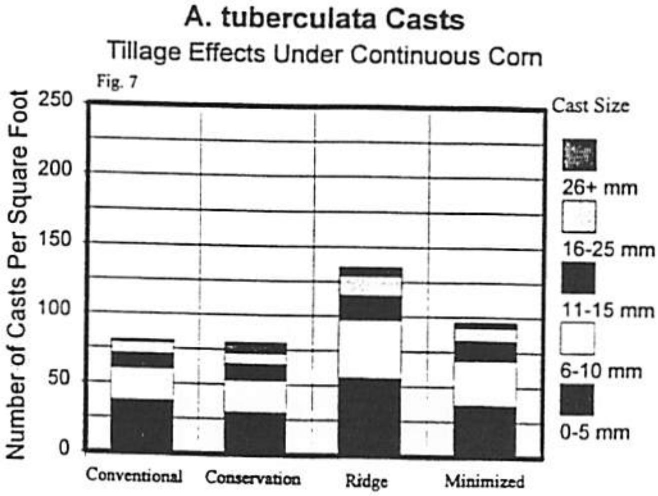
A. tuberculata Populations

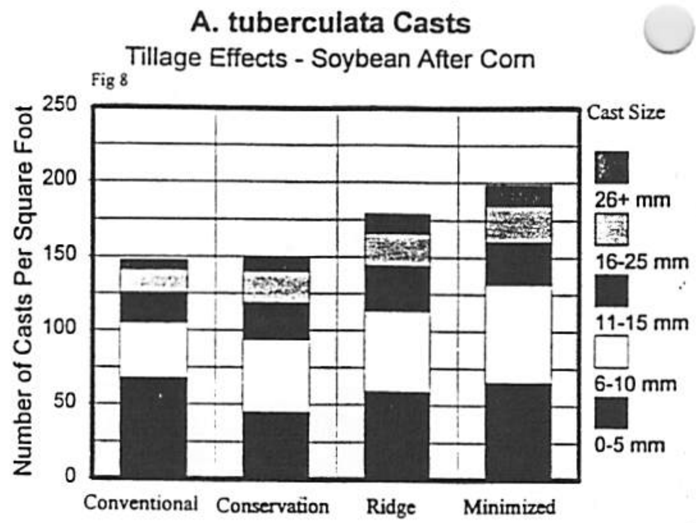
Tillage and Rotation Effects

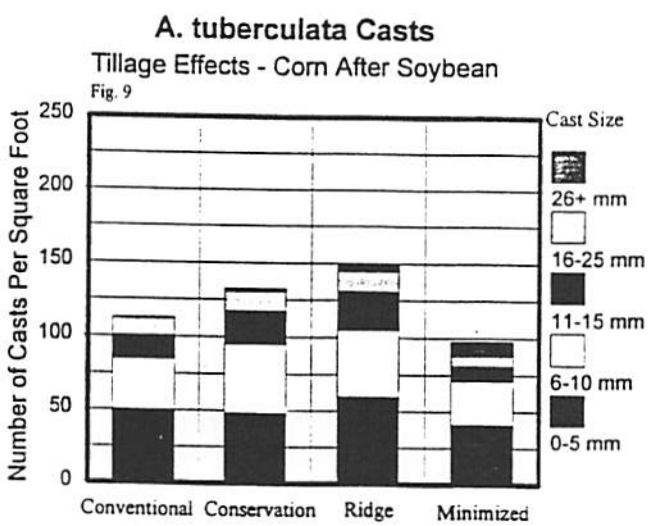
Fig. 6

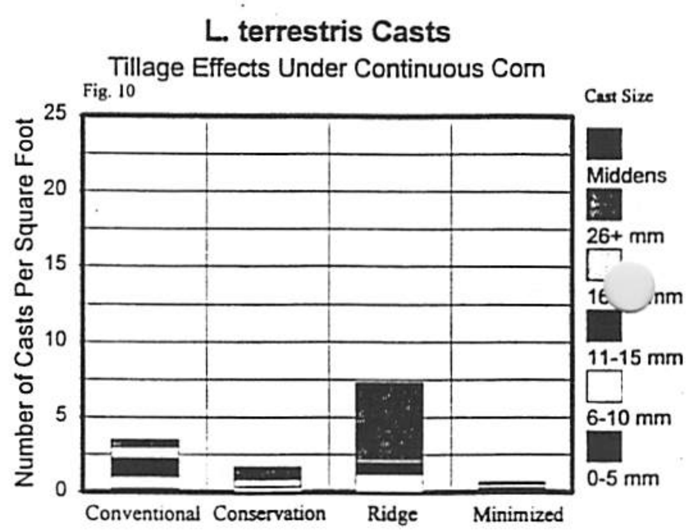


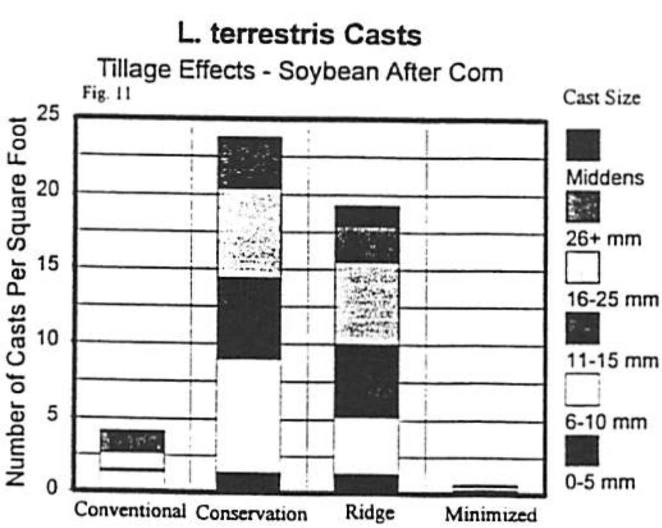
* This rotation has significantly more worms


A. tuberculata Casts
Tillage Effects Under Continuous Corn
Fig. 7
Number of Casts Per Square Foot
250
200
150
100
50
0
Conventional
Conservation
Ridge
Minimized
Cast Size
26+ mm
16-25 mm
11-15 mm
6-10 mm
0-5 mm


A. tuberculata Casts
Tillage Effects - Soybean After Corn
Fig 8
Number of Casts Per Square Foot
250
200
150
100
50
0
Conventional
Conservation
Ridge
Minimized
Cast Size
26+ mm
16-25 mm
11-15 mm
6-10 mm
0-5 mm


A. tuberculata Casts
Tillage Effects - Corn After Soybean
Fig. 9
Number of Casts Per Square Foot
250
200
150
100
50
0
Conventional
Conservation
Ridge
Minimized
Cast Size
26+ mm
16-25 mm
11-15 mm
6-10 mm
0-5 mm


L. terrestris Casts
Tillage Effects Under Continuous Corn
Fig. 10
Number of Casts Per Square Foot
25
20
15
10
5
0
Conventional
Conservation
Ridge
Minimized
Cast Size
Middens
26+ mm
11-15 mm
6-10 mm
0-5 mm


L. terrestris Casts
Tillage Effects - Soybean After Corn
Fig. 11
Number of Casts Per Square Foot
25
20
15
10
5
0
Conventional
Conservation
Ridge
Minimized
Cast Size
Middens
26+ mm
16-25 mm
11-15 mm
6-10 mm
0-5 mm

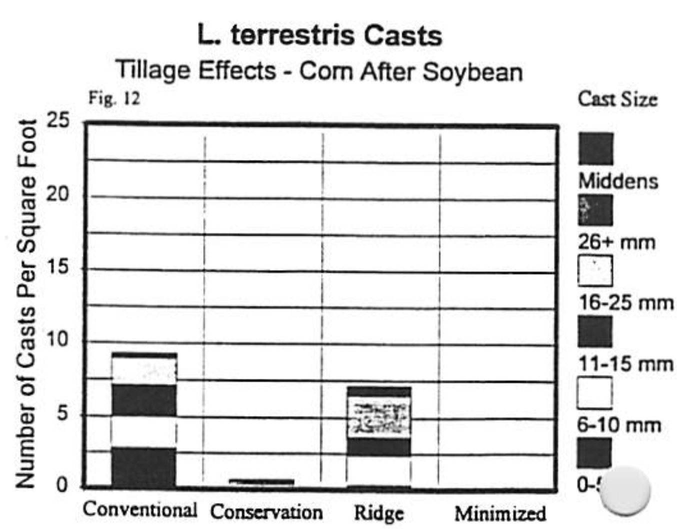

L. terrestris Casts
Tillage Effects - Corn After Soybean
Fig. 12
Number of Casts Per Square Foot
25
20
15
10
5
0
Conventional
Conservation
Ridge
Minimized
Cast Size
Middens
26+ mm
16-25 mm
11-15 mm
6-10 mm

Table 3 Aggregate Stability for the Tillage Study at Rosemount, 1995

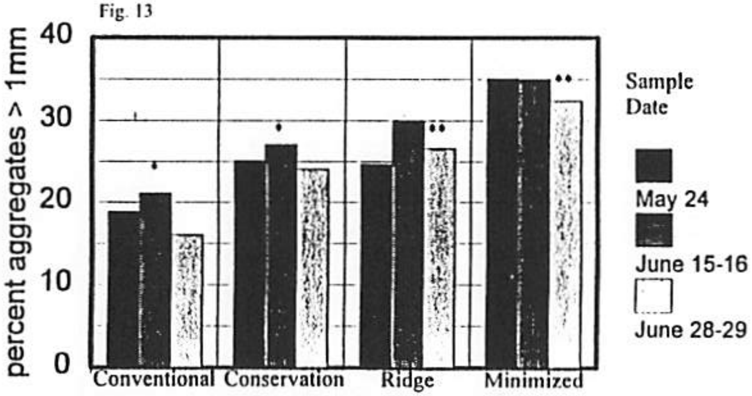
Treatment			% Aggregates > 1mm					
Tillage	Rotation		s1*		s2*		s3*	
			top**	bottom***	top	bottom	top	bottom
Conventional (T1)	Cont.Corn	CC	14.507	23.49	20.82	19.87	16.863	21.63
	Soy/Corn	SC	22.873	28.453	21.613	19.533	14.493	22.317
	Corn/Soy	CS	19.127	23.483	20.973	21.003	16.83	17.033
Conservation (T2)	Cont.Corn	CC	20.433	29.537	21.127	29.29	23.063	29.033
	Soy/Corn	SC	26.463	31.46	31.803	31.11	24.38	26.893
	Corn/Soy	CS	28.49	32.887	28.383	35.213	24.833	29.673
Ridge-Till (T3)	Cont.Corn	CC	21.757	34.877	24.067	29.507	26.08	22.15
	Soy/Corn	SC	25.6	32.16	32.73	34.3	23.543	22.477
	Corn/Soy	CS	26.8	33.66	33.017	29.117	30.28	30.337
Minimum-Till (T4)	Cont.Corn	CC	41.503	35.94	30.977	29.447	31.527	26.31
	Soy/Corn	SC	35.493	29.04	39.647	29.983	32.503	32.927
	Corn/Soy	CS	28.143	26.593	33.983	28.727	33.193	28.763

* s1 is May 24 sample date, s2 is June 15-16 sample date, s3 is June 28-29 sample date
** top sample is 0-7.5cm depth
***bottom sample is 7.5-30cm depth

Aggregate Stability

by Tillage for 0-7.5cm Samples

Fig. 13

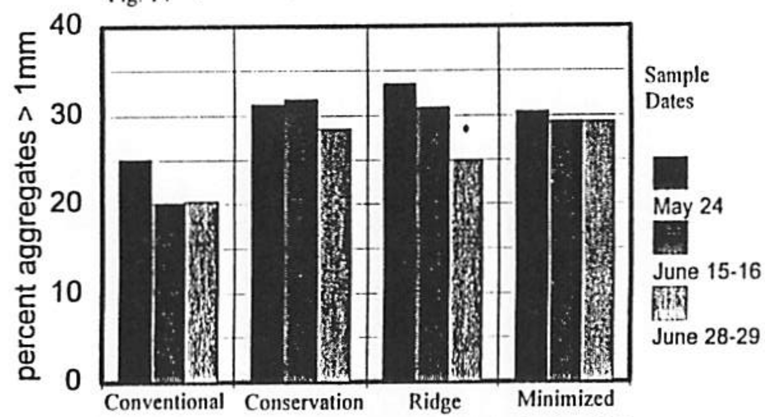


* Conventional tillage had the least aggregates of this size for all sample dates, but on the June 15-16 sample date this conservation tillage sample was similarly as low.

** Minimized tillage had the greatest aggregates of this size for all sample dates, but on the June 28-29 sample date this ridge tillage sample was similarly as high.

Aggregate Stability

Fig. 14 by Tillage for 7.5-30cm samples



* Conventional tillage had the least aggregates of this size for all sample dates, but on the June 28-29 sample date this ridge tillage sample was similarly as low. All other samples were similarly higher in percent aggregates.

NITRATE LOSSES THROUGH SUBSURFACE TILE DRAINS FOLLOWING CRP, ALFALFA, CONTINUOUS CORN AND CORN/SOYBEAN ROTATIONS

L.D. Klossner, D.R. Huggins, G.W. Randall, and M.P. Russelle[1]

ABSTRACT

Nitrate losses in tile drainage water have negative implications for both production and enivironmental aspects of agriculture. In 1988, four crop systems: continuous corn, corn-soybean, alfalfa and Conservation Reserve Program (CRP, 50% alfalfa, 50% smooth brome) were established at the Southwest Experiment Station in Lamberton to determine cropping system effects on biomass yields, N uptake, residual soil NO_3^- and NO_3^- and pesticide losses through tile drains. In 1994, the CRP and alfalfa treatments were converted to corn to assess whether converting land from CRP to annual crops could significantly affect water quality. In 1995, the previous CRP and alfalfa treatments were again planted to corn. In 1996, the previous CRP and alfalfa treatments were planted to soybeans. No significant yield differences were observed in the continuous corn and soybean-Corn rotations. Soybean yields were significantly less in the cn-SB rotation as compared to the alf-c-c-SB and crp-c-c-SB rotations. Crop rotation significantly effected tile flow in 1996, tile flows ranged from a high of 7.02 acre-in in continuous corn to a low of 5.23 acre-in in alf-c-c-SB. Tile flows peaked in June. Continous corn nitrate concentrations were significantly higher than the other crop rotations, 10.56 ppm, while concentrations of 7.36 were observed in alf-c-c-SB. Nitrate concentrations were highest in May and July. Nitrate losses were highest in June. Continuous corn had the highest losses, 11.26 lb/A, and alf-c-c-SB the lowest, 6.08 lb/A. Nitrate losses were less in 1996 as compared to 1995.

INTRODUCTION

The nitrogen-pesticide movement study was initiated in 1988 to determine the effect of four cropping systems (continuous corn, corn-soybean, alfalfa and CRP) on above ground biomass yield and NO_3-N loss in tile drainage water. The study is located on fifteen drainage plots originally established at the Southwest Experiment Station, Lamberton in 1972. From 1973 to1979 nitrogen rates of 18 to 400 lb N/A were applied to corn. From 1980 to 1985, continuous corn without N and in 1986 and 1987 continuous corn with only 50 lb N/A was grown to reduce the effects of previous N-rate applications. In 1993, phase 2 of the nitrogen-pesticide movement study was initiated to access nitrate losses through tile drains following conversion of CRP and alfalfa to corn and soybeans.

METHODS AND MATERIALS

In the spring of 1988 four cropping systems were assigned to fifteen drainage plots (45'x50') in a randomized, comp[illegible] block design with three replications. The plots are isolated by plastic to a depth of 6'. The four cropping systems included: continu[illegible] corn, corn-soybean sequence, continuous alfalfa, and continuous CRP (Conservation Reserve Program). In the fall of 1993, phase 2 of the study was initiated to evaluate the following cropping systems: continuous corn, alfalfa-Corn, crp-Corn, corn-Soybean and soybean-Corn. Starter fertilizer was applied to the continuous corn, alfalfa-Corn, crp-Corn and soybean-Corn plots. These same crops were continued in 1995. In 1996, the alfalfa-Corn, and crp-Corn rotations were cropped to soybeans (alfalfa-c-c-SB, crp-c-c-SB). Complete plot management details are listed in Table 1. Rates of applied N for corn were determined from soil samples taken in April, a yield goal of 140 bu/A, credits for the previous crop, and University of Minnesota recommendations. Where:
$N\ rate = (Yg \times 1.2) - STN_{(0\text{-}24in)} - N_{PC}$.

RESULTS

No significant yield differences were observed between continuous corn and soybean-Corn rotations in 1996. Yields, in 1996, were greater in the continuous corn rotation as compared to 1995, but lower in the soybean-Corn rotation.

Significant differences were observed in 1996 soybean yields. Yields were significantly less in the corn-SB rotation as compared to the alf-c-c-SB and crp-c-c-SB rotations. Soybean yields, in the corn-SB rotation, were similar to 1995 soybean yields.

Crop rotation significantly effected tile flows in 1996. Tile flows ranged from 7.02 acre-in in continuous corn to 5.23 acre-in in alf-c-c-SB. Tile flows were less in 1996 than 1995, but greater than 1994. The alfalfa rotation has had the greatest effect on tile flow, having the lowest tile flow in 1994-1996. Tiles flows peaked in June and decreased throughout the year.

Continuous corn nitrate concentrations were significantly higher, on average, than the other crop rotations. Average concentrations ranged from a high of 10.56 ppm in continuous corn to a low of 7.36 ppm in alf-c-c-SB. Nitrate concentrations were highest in May and July, with the peak in July due to nitrate leaching after sidedress applications in late June.

Nitrate losses were highest in June, and then decreased throughout the year. Continuous corn had the highest nitrate losses with 11.26 lb/A, with the lowest occuring in the alf-c-c-SB rotation, 6.08 lb/A. Nitrate losses decreased in 1996 as compared to 1995.

[1] L.D. Klossner, and D.R. Huggins are Assistant Scientist, and Assistant Professor at the Southwest Experiment Station, Lamberton, MN. G.W. Randall is Professor at the Southern Experiment Station, Waseca, MN. M.P. Russelle is Soil Scientist at the USDA-ARS-US Dairy Forage Research Center, St. Paul, MN.

Table 1. Nitrate-Pesticide Movement Plot Management for 1996

Cropping System - Continuous Corn

Item	Type	Rate	Date
Seed	Pioneer 3531	30,000/A	5/16/96
Fertilizer	Starter	15-30-20 lb/A (N-P_2O_5-K_2O)	5/16/96
	Urea	100 lb N/A	6/24/96
Herbicide	Lasso	4 lb/A (ai)	5/13/96
Insecticide	Lorsban	1 lb/A	5/16/96
Primary Tillage	Moldboard Plow	1 pass	Fall 95
Secondary Tillage	Spring Cultivation	2 pass	5/13/96
	Row Cultivation	1 pass	6/24/96

Cropping System - sb-CN

Item	Type	Rate	Date
Seed	Pioneer 3531	30,000/A	5/16/96
Fertilizer	Starter	15-30-20 lb/A (N-P_2O_5-K_2O)	5/16/96
	Urea	60 lb N/A	6/24/96
Herbicide	Lasso	4 lb/A (ai)	5/13/96
Primary Tillage	None		
Secondary Tillage	Spring Cultivation	2 pass	5/13/96
	Row Cultivation	1 pass	6/24/96

Cropping System - cn-SB, alf-c-c-SB, crp-c-c-SB

Item	Type	Rate	Date
Seed	Parker	150,000/ A	5/20/96
Row Width	30"		
Herbicide	Lasso	4 lb/A (ai)	5/13/96
Primary Tillage	Moldboard Plow	1 pass	Fall 95
Secondary Tillage	Spring Cultivation	2 pass	5/13/96
	Row Cultivation	1 pass	6/24/96

Table 2. Analysis of Variance - 1996 Yields

Crop	Source	DF	SS	MS	F	P
Corn	Rep	2	248.90	124.45	1.37	0.3080
	Rot	1	0.43	0.43	0.00	0.9471
Soybeans	Rep	2	73.14	36.57	3.09	0.0798
	Rot	2	202.33	101.17	8.55	0.0043

Table 3. 1996 cropping system yields

Year	Cont-C	alf-c-c-SB	cn-SB	crp-c-c-SB	sb-CN	$LSD_{0.05}$
	Yield (bu/A)					
1996	124.03	44.83	37.88	44.99	123.65	4.29*†

Year	Cont-C	alf-CN	cn-SB	crp-CN	sb-CN	$LSD_{0.05}$
	Yield (bu/A)					
1995	107.80	109.99	37.79	133.92	133.02	11.88*‡
1994	164.32	170.40	44.78	177.10	172.19	7.99*‡

* Significant difference
† Yield LSD does not include corn yield
‡ Yield LSD does not include soybean yield

Table 4. Analysis of Variance - Tile Drainage Discharge

	Source	DF	SS	MS	F	P
Tile Flow	Rep	2	1.58	0.79	7.47	0.0015
	Rot	4	1.30	0.33	3.07	0.0248
	Month	4	303.27	75.82	716.18	0.0001
	Rot*Month	16	2.13	0.13	1.26	0.2609
Nitrate Conc.	Rep	2	36.93	18.46	4.91	0.0114
	Rot	4	105.80	26.45	7.04	0.0002
	Month	5	553.05	138.26	36.80	0.0001
	Rot*Month	16	88.38	5.52	1.47	0.1509
Nitrate Loss	Rep	2	2.24	1.21	3.07	0.0556
	Rot	4	8.78	2.19	6.01	0.0005
	Month	5	430.02	107.50	284.40	0.0001
	Rot*Month	16	12.24	0.76	2.09	0.0249

Table 5. Tile Flow as influenced by cropping system

Month	C-C	alf-c-c-SB	cn-SB	crp-c-c-SB	sb-CN	$LSD_{0.05}$
	Tile Flow (Acre-in)					
May	0.51	0.28	0.50	0.36	0.52	0.11*
June	5.70	4.54	5.80	5.25	5.09	1.33
July	0.26	0.14	0.16	0.13	0.15	0.15
November	0.33	0.18	0.33	0.17	0.35	0.15*
December	0.22	0.09	0.11	0.07	0.22	0.14*
Total (96)	7.02	5.23	6.90	5.98	6.33	0.24*
Total(95)	7.76	6.92	7.85	8.35	9.13	0.71
Total (94)	5.00	4.03	5.52	4.55	5.25	0.21*

* Significant treatment differences

Table 6. Flow weighted NO_3-N concentration via the tile lines as influenced by cropping system

Month	C-C	alf-c-C-SB	cn-SB	crp-c-c-SB	sb-CN	$LSD_{0.05}$
	Flow weighted NO_3-N Conc. (ppm)					
May	14.78	11.60	9.99	12.93	9.54	3.08*
June	5.80	4.58	4.53	6.42	6.00	1.21*
July	12.31	9.91	10.18	13.52	11.60	3.27*
November	9.65	6.92	7.99	7.54	6.50	2.55*
December	10.26	3.80	4.63	4.10	6.13	3.97*
Avg (96)	10.56	7.36	7.46	8.90	7.95	1.42*
Avg(95)	12.26	7.35	8.28	6.52	9.62	1.97*
Avg(94)	11.45	3.10	8.85	1.00	9.79	2.89*

* Significant treatment differences

Table 7. NO_3-N loss via the tile lines as influenced by cropping system

Month	C-C	alf-c-c-SB	cn-SB	crp-c-c-SB	sb-CN	$LSD_{0.05}$
	NO_3-N loss (lb/A)					
May	1.72	0.72	1.07	1.04	1.11	0.60*
June	7.50	4.70	5.85	7.62	6.90	2.47*
July	0.73	0.30	0.36	0.40	0.40	0.39*
November	0.77	0.26	0.54	0.29	0.51	0.44*
December	0.54	0.10	0.18	0.09	0.33	0.44*
Total (96)	11.26	6.08	8.00	9.44	9.25	0.44*
Total(95)	19.83	12.55	15.06	15.36	22.26	3.44*
Total(94)	13.34	2.88	11.63	1.08	11.53	0.68*

* Significant treatment differences

NITROGEN FERTILITY MANAGEMENT OF CORN

L.D. Klossner, D.R. Huggins and G.L. Malzer[1]

ABSTRACT

The N-Fertility study at the Southwest Experiment Station in Lamberton has two rotations (continuous corn and corn/soybean) five nitrogen rates (0, 40, 80, 120, 160 lb N/A), three nitrogen timings (fall, spring, sidedress) and two nitrogen forms (anhydrous ammonia, urea). The current study is a modification of the continuous corn study initiated in 1960 on tiled Normania loam. The study was modified in 1994 to include additional N rates, a corn/soybean rotation, and anhydrous ammonia. The first year of results that included corn yields both in continuous corn and corn/soybean rotations was in 1995. Soil moisture levels were above the 30-year average during the fall of 1995 and spring of 1996. Corn yields were greater for continuous corn with urea nitrogen applications (116 bu/A) than continuous corn with anhydrous ammonia nitrogen applications (100 bu/A). Sidedress anhydrous ammonia applications increased yields with all nitrogen rates, except 80 lb N/A. Sidedress urea applications increased yields at all nitrogen rates. Yields were greatest at nitrogen rates of 160 lb N/A.

METHODS AND MATERIALS

The N-Fertility Management study is a modification of the continuous corn study, which was initiated in 1960 at the Southwest Experiment Station on tiled Normania loam. The study is a randomized complete block, split plot design with four replications. Main plots (20'x57.5') consist of crop rotation (continuous corn and corn/soybean). Subplot (20'x28.75') treatments during corn years are timing (fall, spring, sidedress), form (urea, anhydrous ammonia), and N-rate (0,40,80,120,160 lb/A). Soil moisture measurements are made on the first and the fifteenth of each month starting in May and continuing through November. Soil moisture samples are taken to a depth of 5 feet and split up into 6 inch increments for the first 2 feet and 1 foot increments for the last 3 feet. Additional management data are shown in Table 2.

RESULTS AND DISCUSSION

Soil moisture data from the Nitrogen Fertility project is shown is Table 1 and Figure 1. Table 3 shows the analysis of variance data where N rate, timing, form, and interactions were statistically significant. Soil moisture was above normal compared to the 30-year average during the fall of 1995, and the spring of 1996. These high soil moisture conditions favored sidedress-applied N as compared to fall applied N (Table 4). Yields were greatest at nitrogen rates of 160 lb N/A with both anhydrous ammonia and urea nitrogen treatments (Table 4).

Table 1. Available Soil Moisture (0-5 ft.)

Sample Date	1995 Total Available Soil Moisture	30 Year AverageNfm97bb.wpd
	inches	
9/1/95	5.13	3.91
9/15/95	4.90	4.30
10/1/95	5.98	4.27
10/15/95	5.44	4.43

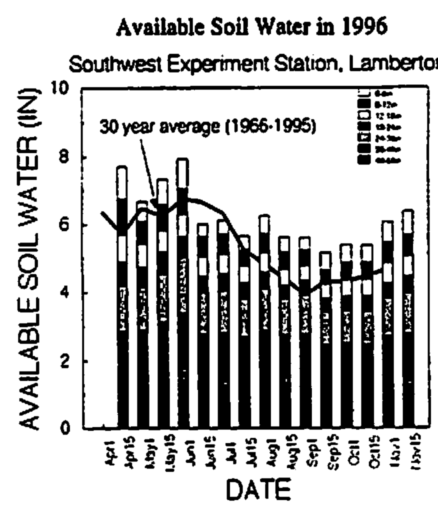


Figure 1. Available Soil Water sampled during the 1996 growing season at the Southwest Experiment Station.

[1] L.D. Klossner, and D.R. Huggins, are Assistant Scientist, Assistant Professor, at the Southwest Experiment Station, Lamberton, MN 56152. G.L. Malzer is Professor the Department of Soil, Water and Climate, University of Minnesota, St. Paul, MN.

Table 2. N-Fertility Plot Management for 1996 - Continuous Corn

Item	Type	Rate	Date
Primary Tillage	Moldboard Plow (Corn)	1 pass	Fall 95
Secondary Tillage	Field Cultivator	1 pass	4/27/96
	Row Cultivation	1 pass	
Seed	Pioneer 3531	30,000/A	4/30/96
Fertilizer	Starter	0-30-30 lb/A (N-P_2O_5-K_2O)	4/30/96
N Treatment	Fall	40, 80, 120, 160 lb/A	Fall 95*
	Spring	40, 80, 120, 160 lb/A	4/30/96
	Sidedress	40, 80, 120, 160 lb/A	6/13/96
Herbicides	Dual II	2.44 lbs/A (ai)	4/30/96
Insecticides	Force	1.5 lb/A	4/30/96

* Fall fertilizer treatments applied prior to fall tillage

Table 3. Analysis of Variance - Continuous Corn

Source	DF	SS	MS	F	P
Rep	3	12897.35	4299.12	18.67	0.0001
N	3	146139.86	48713.29	211.51	0.0001
Time	2	11930.15	5965.07	25.90	0.0001
Form	1	13113.38	13113.38	56.94	0.0001
N*Time	6	1821.44	303.57	1.32	0.2518
N*Form	3	8660.20	2886.73	12.53	0.0001
Time*Form	2	4659.46	2284.73	9.92	0.0001
N*Time*Form	6	4365.90	727.65	3.16	0.0058

Table 4. Corn Yields in 1996 - Continuous Corn

	Anhydrous Ammonia				Urea*			
N-Rate (lb/A)	Fall	Spring	Sidedress	$LSD_{0.05}$	Fall	Spring	Sidedress	$LSD_{0.05}$
	bu/A							
40	60.99	67.67	75.65	8.71*	68.05	72.29	89.14	9.66*
80	87.52	63.20	85.58	17.29*	95.76	109.51	124.85	16.78*
120	112.01	92.18	113.86	16.61*	109.78	138.69	152.51	19.98*
160	135.30	148.93	155.60	18.25*	133.30	148.65	154.28	14.63*
$LSD_{0.05}$	20.39*	13.11*	11.42*		17.67*	16.70*	12.97*	
Check	51.03							

* Significant treatment differences

TILLAGE MANAGEMENT IN CORN-SOYBEAN ROTATIONS AT THE SOUTHWEST EXPERIMENT STATION

L.D. Klossner, and D.R. Huggins[1]

ABSTRACT

Tillage practices that improve environmental quality while remaining economically profitable is a major objective of agricultural research. Five tillage system: paraplow, ridge tillage, conventional tillage, reduced tillage, and spring tillage were established in corn and soybean crop rotations in 1986. In 1989, the paraplow treatment was converted to no-tillage and in 1994, the tillage systems were further divided into five separate row management systems. Row management effected corn yield data in no-till, ridge-till, and reduced-till plots. Conventional tillage yields were greater in every row management system. Row management had variable effects on soybean yields. Narrow rows and the use of row cleaners had a positive effect on soybean yields in the ridge-till and conventional til systems. When row management treatments are compared, there is no significant difference in yield except in row management 1 where conventional tillage yields are significantly higher. Long-term corn and soybean yield data (1986-1996) has shown conventional tillage to be the greatest yielding tillage system.

INTRODUCTION

This study was initiated in 1986, on a Normania clay loam, to evaluate and monitor five different tillage systems in a corn-soybean rotation for their effects on crop growth, development, yield, soil hydraulic and structural properties, and other soil quality properties.

EXPERIMENTAL DESIGN AND TREATMENTS

Experimental Design: Randomized, complete-block, split plot experiment with four replications. Main plots (50'x155') were tillage treatments of no-tillage, ridge tillage, conventional tillage, reduced tillage, and spring tillage (See Table 1 and 2).

Five subplots (10'x155') consisted of vanous row management (RM) treatments and differ for corn and soybean crops.

<u>Subplots within corn</u> - detailed corn plot management data is shown in Table 1.

1. Row cleaners (Yetter rolling fingers mounted on J.D. 7200 Conservation Planter)
2. Without row cleaners
3. Row cleaners and starter fertilizer (11-33-11)
4. Without row cleaners and with starter fertilizer (11-33-11)
5. Anhydrous pre-plant indexed on the row (120 lb N/A), with row cleaners and starter fertilizer (11-33-11)

<u>Subplots within soybeans</u> - detailed soil plot management data is shown in Table 2.

1. Row cleaners, 30" rows
2. Without row cleaners, 30" rows
3. With N fertilizer (60 lb N/A) no row cleaner, 30" rows
4. With N fertilizer(60 lb N/A), 7.5" rows
5. Without N fertilizer, 7.5" rows

RESULTS AND DISCUSSION

Row management effected corn yields in no-till, ridge-till and reduced-till plots, but was not significant in the conventional and spring-till plots (Table 4). In the no-till, RM5 (A.A. ppi, with row cleaners, and starter fertilizer) was significantly greater than all other row management systems. In the ridge-till, RM5 was significantly less than all row management systems, except RM2 (without row cleaners). In the reduced-till, RM4 (without row cleaners, and with starter fertilizer) was significantly less than both RM1 (with row cleaners) and RM5. When row management systems are compared with tillage, conventional tillage yields were greater in every row management system.

Soybean yields were effected by row management in the ridge-till, conventional till and spring-till plots (Table 6). In the ridge-till, RM2 (30" rows, without row cleaners) yields were significantly lower than all other RM systems. In the conventional till, RM3 (30" rows, with N, without row cleaners) was significantly less than all RM systems, except RM2. In the spring-till, RM4 (7.5" rows, with N) was significantly greater than RM2. When row management treatments are compared to each tillage system there is no significant difference in yield except in RM1 (30" rows, with row cleaners) where conventional tillage yields are significantly higher than all other tillage systems.

Long-term corn data (1986-1996) has shown that conventional tillage has been the greatest yielding tillage system 8 out of 11 years, and has averaged 7 bu/A or more than any other tillage system (Table 8). Long-term soybean yield data (1986-1996) has also shown conventional tillage as the greatest yielding system 7 out of 11 years.

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Table 1. 1996 Corn Plot Management

Tillage System	Sub Trt*	Planter	Row Cult	Fertilizer	Seed and Starter Fert.	Spring Tillage	Weed Control (ai)
		Corn Sub-Treatments Within Tillage Systems					
No-Tillage	1	JD 4-row	None	Trts 1 and 2	All subtreatments	None	Bladex 2 lb/A
				135 lb N/A	Pioneer 3531	-	Harness 2 ½ pt/A
no fall tillage	2	JD 4-row	None	6/25/96	30,000/A		Roundup 2 qt/A
				Trts 3 and 4	Trts 1 and 2 none		5/18/96
	3	JD 4-row	None	120 lb N/A	Trts 3, 4 and 5		Stinger 2/3 pt/A
				6/25/96	11-33-11 lb/A		Buctril Atrazine 1
	4	JD 4-row	None	Trt 5 120 lb N/A	(N-P_2O_5-K_2O)		½ pt/A 6/8/96
				A.A. ppi 5/16/96	5/17/96		
	5	JD 4-row	None				
Ridge-Tillage	1	JD 4-row	6/28/96	Trts 1 and 2	All subtreatments	None	Bladex 2 lb/A
				135 lb N/A	Pioneer 3531		Harness 2 ½ pt/A
no fall tillage	2	JD 4-row	6/28/96	6/25/96	30,000/A		Roundup 2 qt/A
	3	JD 4-row	6/28/96	Trts 3 and 4	Trts 1 and 2 none		5/18/96
	4	JD 4-row	6/28/96	120 lb N/A	Trts 3, 4 and 5		
				6/25/96	11-33-11 lb/A		
	5	JD 4-row	6/28/96	Trt 5 120 lb N/A	(N-P_2O_5-K_2O)		
				A.A. ppi 5/16/96	5/17/96		
Conventional	1	JD 4-row	6/26/96	Trts 1 and 2	All subtreatments	Disc	Bladex 2 lb/A
				135 lb N/A	Pioneer 3531		Harness 2 ½ pt/A
chisel plow	2	JD 4-row	6/26/96	6/25/96	30,000/A	5/7/96	Roundup 2 qt/A
Fall 1995	3	JD 4-row	6/26/96	Trts 3 and 4	Trts 1 and 2 none		5/18/96
	4	JD 4-row	6/26/96	120 lb N/A	Trts 3, 4 and 5		
				6/25/96	11-33-11 lb/A		
	5	JD 4-row	6/26/96	Trt 5 120 lb N/A	(N-P_2O_5-K_2O)		
				A.A. ppi 5/16/96	5/17/96		
Reduced	1	JD 4-row	6/26/96	Trts 1 and 2	All subtreatments	Disc	Bladex 2 lb/A
				135 lb N/A	Pioneer 3531		Harness 2 ½ pt/A
no fall tillage	2	JD 4-row	6/26/96	6/25/96	30,000/A	5/7/96	Roundup 2 qt/A
	3	JD 4-row	6/26/96	Trts 3 and 4	Trts 1 and 2 none		5/18/96
	4	JD 4-row	6/26/96	120 lb N/A	Trts 3, 4 and 5		
				6/25/96	11-33-11 lb/A		
	5	JD 4-row	6/26/96	Trt 5 120 lb N/A	(N-P_2O_5-K_2O)		
				A.A. ppi 5/16/96	5/17/96		
Spring Tillage (96)	1	JD 4-row	6/26/96	Trts 1 and 2	All subtreatments	Disc	Bladex 2 lb/A
				135 lb N/A	Pioneer 3531		Harness 2 ½ pt/A
Flex Tillage (97)	2	JD 4-row	6/26/96	6/25/96	30,000/A	5/7/96	Roundup 2 qt/A
no fall tillage	3	JD 4-row	6/26/96	Trts 3 and 4	Trts 1 and 2 none		5/18/96
	4	JD 4-row	6/26/96	120 lb N/A	Trts 3, 4 and 5		
				6/25/96	11-33-11 lb/A		
	5	JD 4-row	6/26/96	Trt 5 120 lb N/A	(N-P_2O_5-K_2O)		
				A.A. ppi 5/16/96	5/17/96		

Corn Subtreatments Within Tillage Systems
1=with row cleaners
2=without row cleaners
3=with row cleaners + starter
4=without row cleaners + starter fertilizer
5=Anhydrous pre-plant indexed on the row, w/row cleaners + starter fertilizer

Table 2. 1996 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	Roundup 1 lb/A 5/23/96
no fall tillage	2	JD 4-row	None				Dual II 2 ½ pts/A
	3	JD 4-row	None	Trts 3 and 4	Trt 4 and 5		5/31/96
	4	JD 752	None	60 lb N/A	Parker 200,000/A		Poast Plus1 ½
	5	JD 752	None	(NH_4NO_3) broadcast 5/30/96	planted 5/30/96		pts/A 7/9/96
Ridge-Tillage	1	JD 4-row	6/28/96		Trt 1, 2, and 3 Parker 150,000/A	None	Roundup 1 lb/A 5/23/96
no fall tillage	2	JD 4-row	6/28/96				Dual II 2 ½ pts/A
	3	JD 4-row	6/28/96	Trts 3 and 4	Trt 4 and 5		5/31/96
	4	JD 752	6/28/96	60 lb N/A	Parker 200,000/A		Poast Plus1 ½
	5	JD 752	6/28/96	(NH_4NO_3) broadcast 5/30/96	planted 5/30/96		pts/A 7/9/96
Conventional	1	JD 4-row	6/26/96		Trt 1, 2, and 3	Disc	Dual II 2 ½ pts/A
Primary Tillage	2	JD 4-row	6/26/96		Parker 150,000/A	5/29/96	5/31/96 Poast Plus 1½
Moldboard plow	3	JD 4-row	6/26/96	Trts 3 and 4	Trt 4 and 5		pts/A
Fall 95	4	JD 752	None	60 lb N/A	Parker 200,000/A		7/9/96
	5	JD 752	None	(NH_4NO_3) broadcast 5/30/96	planted 5/30/96		
Reduced	1	JD 4-row	6/26/96		Trt 1, 2, and 3	Disc	Dual II 2 ½ pts/A
Primary Tillage	2	JD 4-row	6/26/96		Parker 150,000/A	5/29/96	5/31/96 Poast Plus 1½
Chisel plow	3	JD 4-row	6/26/96	Trts 3 and 4	Trt 4 and 5		pts/A
Fall 95	4	JD 752	None	60 lb N/A	Parker 200,000/A		7/9/96
	5	JD 752	None	(NH_4NO_3) broadcast 5/30/96	planted 5/30/96		
Spring Tillage (96)	1	JD 4-row	6/26/96		Trt 1, 2, and 3	Disc	Dual II 2 ½ pts/A
Flex Tillage (97)	2	JD 4-row	6/26/96		Parker 150,000/A	5/29/96	5/31/96 Poast Plus 1½
no fall tillage	3	JD 4-row	6/26/96	Trts 3 and 4	Trt 4 and 5		pts/A
	4	JD 752	None	60 lb N/A	Parker 200,000/A		7/9/96
	5	JD 752	None	(NH_4NO_3) broadcast 5/30/96	planted 5/30/96		

*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 - 1996	Source	DF	SS	MS	F	P
	Rep	3	893.55	297.85	3.82	0.0112
	Till	4	8381.92	2095.48	26.89	0.0001
	Rep*Till	12	8839.73	736.64	9.45	0.0001
	RowMgt	4	419.62	104.90	1.35	0.2552
	Till*RowMgt	16	3861.15	241.32	3.10	0.0001
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	8381.92	2095.48	2.84	0.0717

Table 4. Corn Yields in 1996

Tillage System	Row Management 1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	111.5	112.5	118.2	115.9	126.8	8.4*
Ridge-Tillage	124.6	117.5	119.0	128.4	105.7	13.3*
Conventional	133.3	133.6	137.0	136.4	132.4	7.5
Reduced	125.4	123.2	124.5	118.2	125.4	7.0*
Spring	131.7	125.6	132.2	130.0	127.0	7.2
$LSD_{0.05}$	18.1*	17.3*	13.4*	13.6*	20.8*	

*Significant treatment differences

Table 5. Analysis of Variance

Soybeans - 1996	Source	DF	SS	MS	F	P
	Rep	3	119.73	39.91	3.29	0.0223
	Till	4	123.11	30.78	2.54	0.0422
	Rep*Till	12	635.67	52.97	4.36	0.0001
	RowMgt	4	313.20	78.30	6.45	0.0001
	Till*RowMgt	14	147.01	9.19	0.76	0.7315
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	123.11	30.78	0.58	0.6822

Table 6. Soybean Yields in 1996

Tillage System	Row Management					
	1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	40.2	40.4	42.4	43.9	43.5	3.7
Ridge-Tillage	41.8	40.6	41.4	44.7	44.0	3.6*
Conventional	44.4	43.0	40.4	45.1	43.4	3.1*
Reduced	41.2	41.6	42.6	44.2	41.6	3.0
Spring	39.9	38.9	40.4	43.9	41.1	4.2*
$LSD_{0.05}$	2.2*	4.3	4.6	6.9	5.7	

*Significant treatment differences

Table 7. 1986-1996 Corn Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Avg
	bu/A											
Notill	142.0	132.4	73.7	122.2	114.5	133.4	134.2	71.9	146.7	117.4	117.1	118.7
Ridge	145.4	125.4	82.2	132.6	118.4	128.9	145.3	72.0	162.2	120.4	119.0	122.9
Conv.	141.5	136.4	76.7	139.0	137.2	132.2	153.6	76.6	166.3	134.4	134.5	129.9
Reduced	139.8	124.8	70.1	128.1	120.5	133.6	130.7	75.1	162.7	126.2	123.3	121.4
Spr. till	132.4	119.8	65.4	131.8	122.8	132.6	136.6	73.4	164.5	127.0	129.3	121.4
$LSD_{0.05}$	11.7*	6.7*	6.7*	6.9*	6.0*	6.2	10.2*	4.3*	6.9*	8.7*	13.2*	3.7*

* Significant treatment differences

Table 8. 1986-1996 Soybean Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Avg
	bu/A											
Notill	47.4	39.3	26.9	40.9	44.7	40.3	35.9	19.8	41.7	40.5	42.1	38.1
Ridge	47.2	38.7	26.7	49.2	48.7	41.3	35.3	31.5	42.6	38.9	42.5	40.2
Conv.	47.9	38.8	32.7	48.8	51.8	48.0	37.3	38.9	47.1	42.4	43.2	43.4
Reduced	46.7	39.5	26.3	45.8	51.6	46.2	37.7	34.5	43.1	40.3	42.2	41.3
Spr. till	48.9	37.0	26.2	47.1	45.4	44.4	36.5	33.1	41.6	43.3	40.8	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*	3.5	1.7*

* Significant treatment differences

VARIABLE INPUT CROP MANAGEMENT SYSTEMS AT THE SOUTHWEST EXPERIMENT STATION: 1996 MANAGEMENT HISTORY AND YIELDS

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

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 on the Elwell Agroecology Farm and the Southwest Experiment Station at Lamberton. Inputs and management factors for 1989-1995 production seasons have been presented in earlier writeups. This presentation covers the inputs and yields for the 1996 growing season.

INTRODUCTION

In 1988 the University of Minnesota gained access to a research site called the 'Koch Farm'. This site was renamed the 'Elwell Agroecology Farm' (EAF) in 1996. The EAF was a minimum input farm for at least 35 years prior to 1988. The Variable Input Crop Management Study (VICM) was begun in 1989. The overall objective of this study 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. 1996 was the eighth 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 EAF 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 Inputs (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 added nutrients 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 1996 for VICM I and VICM II respectively. Details of plot management are given in Tables 5 and 6 for VICM I and VICM II respectively.

RESULTS

Crop yields for 1996 for VICM I and II are summarized in Tables 3 and 4 respectively. For corn, the highest yielding treatments were the HPI and LPI for both rotations in both VICM I and II, with the exception of the 2-year rotation in VICM I. For soybean, HPI and LPI were the highest yielding treatments in both rotations in both VICM I and II, with ORG statistically not different for the 4-year rotation in VICM I. For oats, yield groupings varied for the two experiments. In VICM I - HPI, LPI, and ORG were not significantly different, thought HPI had the highest yield. In VICM II, the highest oat yields were obtained under ORG management, which was significantly different than either HPI or LPI. This pattern follows a trend observed in several previous years. Alfalfa showed little difference between management treatments except for the MIN treatment being generally lower yielding.

Comparison of corn and soybean yield for the two rotation lengths analyzed over all management treatments (Table 5) found that the 4-year rotation yielded significantly higher than the two year rotation - continuing a pattern observed in previous years. This pattern was observed in three of four years (1993-1996) for each of VICM I and II corn, and for all four years in this period for VICM II soybean. We believe that one factor contributing to the difference is decreased weed pressure following oats and alfalfa in the 4-year rotation (data not shown).

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Table 1. 1996 management for each treatment - Variable Input Crop Management System I (VICM I).

Mgt Level	Fall Tillage	Spring Tillage	Seed (rate:plants/ac)	Fertilizer	Herbicide (amount of material ac⁻¹)	Rotary Hoe	Row Cult.
CS-Rotation: CORN							
MIN	Chisel Fall 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	None	None	5/18,5/19,5/29,5/30,6/3	6/10
LPI	none	Field Cult. 4/29, 5/1	P3769 (31,000) 5/1	90-30-15 Band 5/1	Surpass (2.5 pts) 5/7 - 10" band Exceed (0.88oz) 6/20 - 10" band	5/18,5/21, 5/29,5/29	6/11
HPI	Chisel Fall 1995	Field Cult. 4/29, 5/1	P3769 (31,000) 5/2	110-55-50 broadcast 4/30	Doubleplay(6pts) Bladex (2.2lbs) all broadcast 5/1	none	6/13
ORG	Chisel Fall 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	137-64-83 injected hog manure 4/24	none	5/18,5/21, 5/29,5/30,6/3	6/10
CS-Rotation: SOYBEAN							
MIN	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	none	none	6/3	6/27, 7/19
LPI	Chisel Fall 1995	Field Cult. 5/22, 5/22	Parker (158,000) 5/24	0-20-0 10" band 5/24	Select (8oz) 6/25 Pursuit(4oz)&Pinnacle(1/4oz) 6/26 10" band	none	6/27, 7/19
HPI	Moldboard Fall 1995	Field Cult. 5/22,5/22,5/22	Parker (158,000) 5/24	0-35-0	Treflan (1.5pts) 5/22	none	6/27
ORG	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	54-25-33 injected hog manure 4/24	none	6/3	6/27
CSOA-Rotation: CORN							
MIN	Moldboard Fall 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	None	None	5/18,5/21, 5/29,5/30,6/3	6/10
LPI	Moldboard Fall 1995	Field Cult. 4/29, 5/1	P3769 (31,000) 5/1	15-30-30 Band 5/1	Surpass (2.5 pts) 5/7, Exceed (0.88oz) 6/20 10" band	5/18,5/21 5/29,5/29	6/11
HPI	Moldboard Fall 1995	Field Cult. 4/29, 5/1	P3769 (31,000) 5/18	30-55-50 broadcast 4/30	Doubleplay (6pts) 5/1 Bladex (2.2lbs) 5/1	none	6/13
ORG	Moldboard Fall 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	193-47-234 beef man. 11/95	none	5/18,5/21 5/29,5/30,6/3	6/10
CSOA-Rotation: SOYBEAN							
MIN	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	none	none	6/3	6/27, 7/19
LPI	Chisel Fall 1995	Field Cult. 5/22, 5/22	Parker (158,000) 5/24	0-20-0 band 5/24	Select (8oz) 6/25, Pursuit(4oz)&Pinnacle(1/4oz)6/26 10" band	none	6/27, 7/19
HPI	Moldboard Fall 1995	Field Cult. 5/22, 5/22, 5/22	Parker (158,000) 5/24	0-35-0 broadcast 5/20	Sonolan (2 pts) 5/22	none	6/27
ORG	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	none	none	6/3	6/27
CSOA-Rotation: OAT							
MIN	Chisel Fall 1995	Field Cult.4/25 Drag&Pack 4/25	Dane (85lb/ac) 4/25	none	none	none	none
LPI	none	Field Cult. 4/24 Drag&Pack 4/25	Dane (85lb/ac) 4/25	50-50-25 4/24	Buctril (1pt) 5/29	none	none
HPI	Chisel Fall 1995	Field Cult. 4/24 Drag&Pack 4/25	Dane (85lb/ac) 4/25	50-50-25 4/24	Buctril (1pt) 5/29	none	none
ORG	Chisel Fall 1995	Field Cult. 4/25 Drag&Pack 4/25	Dane (85lb/ac) 4/25	64-16-78 beef man. 11/95	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5265(15 lb/ac) w/ prev year oats	none	none	none	none
LPI	none	none	P5265(15 lb/ac) w/ prev year oats	0-80-30 8/1	none	none	none
HPI	none	none	P5265(15 lb/ac) w/ prev year oats	0-50-30 8/1	none	none	none
ORG	none	none	P5265(15 lb/ac) w/ prev year oats	none	none	none	none

Table 2. 1996 management for each treatment - 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 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	None	None	5/18,5/21, 5/29,5/30,6/3	6/4
LPI	none	Field Cult. 4/29, 5/1	P3769 (31,000) 5/1	90-30-15 band 5/1	Surpass (2.5 pts) 5/7 - 10" band Exceed (0.88oz) 6/20 - 10" band	5/29,5/29	6/4
HPI	Chisel Fall 1995	Field Cult. 4/29, 5/1	P3769 (31,000) 5/2	110-55-50 broadcast 4/30	Doubleplay(6pts), Bladex(2.2lbs) broadcast 5/1	none	6/4
ORG	Chisel Fall 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	64-16-78 injected hog manure 4/24	none	5/18,5/21, 5/29,5/30,6/3	6/4
CS-Rotation: SOYBEAN							
MIN	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	none	none	6/3	7/9
LPI	Chisel Fall 1995	Field Cult. 5/22, 5/22	Parker (158,000) 5/24	0-20-0 band 5/24	Pursuit (4oz), Pinnacle(1/4oz) 10" band 6/20	none	7/9
HPI	Moldboard Fall 1995	Field Cult. 5/22, 5/22, 5/22	Parker (158,000) 5/24	0-35-0 broadcast 5/20	Treflan (1.5pts) broadcast 5/22	none	7/9
ORG	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	none	none	6/3	7/9
CSOA-Rotation: CORN							
MIN	Moldboard Fall 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	None	None	5/18,5/21, 5/29,5/30,6/3	6/4
LPI	Moldboard Fall 1995	Field Cult. 4/29	P3769 (31,000) 5/1	15-30-30 Band 5/1	Surpass (2.5pts) 5/7 Exceed (0.88oz) 6/20 all 10" band	5/29,5/29	6/4
HPI	Moldboard Fall 1995	Field Cult. 4/29, 5/1	P3769 (31,000) 5/2	30-55-50 broadcast 4/30	Doubleplay (6pts), Bladex (2.2lb) both broadcast 5/1	none	6/4
ORG	Moldboard Fall 1995	Field Cult. 4/29, 5/16	P3769 (30,000) 5/17	64-16-78 beef man.11/95	none	5/18,5/21, 5/29,5/30,6/3	6/4
CSOA-Rotation: SOYBEAN							
MIN	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	none	none	6/3	7/9
LPI	Chisel Fall 1995	Field Cult. 5/22, 5/22	Parker (158,000) 5/24	0-20-0 band 5/24	Pursuit (4oz), Pinnacle (1/4oz) 10" band 6/20	none	7/9
HPI	Moldboard Fall 1995	Field Cult. 5/22,5/22,5/22	Parker (158,000) 5/24	0-35-0 broadcast 5/20	Sonolan (2pts) broadcast 5/22	none	7/9
ORG	Moldboard Fall 1995	Field Cult. 5/22, 5/29	Parker (158,000) 5/30	none	none	6/3	7/9
CSOA-Rotation: OAT							
MIN	Chisel Fall 1995	Field Cult. 4/25 Drag&Pack 4/25	Dane (85lb/ac) 4/25	none	none	none	none
LPI	none	Field Cult. 4/24 Drag&Pack 4/25	Dane (85lb/ac) 4/25	55-20-20 broadcast 4/24	Buctril (1pt) 5/29 broadcast	none	none
HPI	Chisel Fall 1995	Field Cult. 4/24 Drag&Pack 4/25	Dane (85lb/ac) 4/25	55-20-20 broadcast 4/24	Buctril (1pt) 5/29 broadcast	none	none
ORG	Chisel Fall 1995	Field Cult. 4/25 Drag&Pack 4/25	Dane (85lb/ac) 4/25	64-16-78 beef man. 11/95	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5265(15 lb/ac) w/ prev year oats	none	none	none	none
LPI	none	none	P5265(15 lb/ac) w/ prev year oats	0-50-45 8/1	none	none	none
HPI	none	none	P5265(15 lb/ac) w/ prev year oats	0-50-45 8/1	none	none	none
ORG	none	none	P5265(15 lb/ac) w/ prev year oats	none	none	none	none

Table 3. 1996 Yields - Variable Input Crop Management Systems (VICM I). LSD values are Fisher's Protected LSD (management effect significant at $p<0.05$), and refer to the least significant difference ($\alpha = 0.05$) between management systems within a given crop and rotation. (That is, values within the same row.)

Rotation	Crop	Management Level: MIN	LPI	HPI	ORG	$LSD_{0.05}$
		bu/A				
CSOA	Corn	76.8c	148ab	157a	134b	20.4
CS	Corn	58.6c	137b	161a	120b	18.9
SOAC	Soybeans	37.9b	50.2a	49.7a	46.7a	6.36
SC	Soybeans	34.4b	45.0a	49.0a	33.1b	6.14
ACSO	Alfalfa*	3.03b	5.02a	5.38a	4.95a	1.01
OACS	Oats	35.5b	72.8a	66.4a	65.8a	9.80

*Alfalfa yields are (T/A)

Table 4. 1996 Yields - Variable Input Crop Management Systems II (VICM II). LSD values are Fisher's Protected LSD (management effect significant at $p<0.05$), and refer to the least significant difference ($\alpha = 0.05$) between management systems within a given crop and rotation. (That is, values within the same row.)

Rotation	Crop	Management Level: MIN	LPI	HPI	ORG	$LSD_{0.05}$
		bu/A				
CSOA	Corn	117b	151a	146a	115b	20.8
CS	Corn	55.0c	141a	148a	94.0b	21.0
SOAC	Soybeans	36.4b	51.4a	52.2a	42.0b	6.20
SC	Soybeans	28.2b	41.9a	46.8a	23.6b	10.4
ACSO	Alfalfa*	4.34b	4.64ab	4.87ab	5.31a	0.693**
OACS	Oats	58.7b	58.1b	57.3b	68.1a	7.90

* Alfalfa yields are (T/A)
** Management was significant at $p< 0.065$ for alfalfa.

Table 5. 1996 corn and soybean yields calculated for each rotation length (2-year corn-soybean, and 4-year corn-soybean-oat/alfalfa-alfalfa) over all four management systems, allowing comparison of the effect of rotation length on crop yield (values in the same row).

Experiment	Crop	Rotation Length: 2-year	4-year	$LSD_{0.05}$
		bu ac^{-1}		
VICM 1				
	Corn	119b	129a	8.8*
	Soybean	40.4b	46.2a	3.6**
VICM II				
	Corn	110b	132a	9.3
	Soybean	35.1b	45.5a	8.6

* Rotation length effect significant at $p<0.182$ ** Rotation length effect significant at $p<0.052$

PLANTING DATE EFFECTS ON CORN AND SOYBEAN YIELD AT LAMBERTON - 1996

C.A. Perillo, P.M. Porter, S.R. Quiring[1]

Each year we conduct a planting date study to evaluate probable yield loss due to delayed planting. This allows us to interpret possible planting date effects in other studies conducted in the region, as well as provide information to local farmers with respect to planting date effects. Generally, the earliest planting date is earlier than most farm fields in the region and the latest is well past the last date for normal planting. Results from 1993-95 were reported last year. This report is for 1996 only. In 1996, four corn hybrids (all 105-day relative maturity) were planted on four dates ranging from April 19 to May 22. One soybean variety was planted on seven dates ranging from April 24 to June 23. Planting dates did not affect corn yield or kernel moisture content except for the last date (May 22), which had significantly lower yield and higher moisture content at harvest. In soybean, planting date did not decrease yield until June 11. 1996 had a cool, slow spring, and therefore, the lack of planting date effects (other than extremely late planting) are not surprising.

Methods and Materials

CORN: Four 105-day relative maturity corn hybrids were planted on four dates at approximately 10 day intervals (April 19, April 29, May 13, May 22) in a randomized complete block design with planting date as the main plot and hybrid as the subplot, and four replicates of each treatment. Hybrids were Ciba 4127 (C4127), DeKalb 512 (DK512), Pioneer 3547 (P3547), and Pioneer (P3559). Anhydrous ammonia (150 lb N ac^{-1}) and K_2O (200 lb K ac^{-1}) were applied in Fall 1995. Row spacing was 30 inches.

SOYBEAN: Seven planting dates were tested for one soybean variety (Sturdy), in a randomized complete block design with four replicates. The seven dates were: April 24, May 1, May 13, May 20, May 31, June 11, and June 23. Row spacing was 30 inches.

Results and Discussion

CORN: Analysis of Variance (ANOVA) found that for yield, planting date was significant at $p<0.01$. Hybrid significance level was 0.057, and the planting date X hybrid interaction was significant at $p<0.075$. Both planting date and hybrid were significant effects for kernel moisture at $p<0.01$. (The interaction was not significant). Yield and moisture results for planting date and hybrid are given in Tables 1 and 2, respectively. Values for each treatment are given in Table 3. In general, late planting dates only decreased yield after May 13. The lack of yield decline with later planting dates is in part due to the relatively low accumulation of growing degree days in this period (relative to most years), resulting in no corn emergence prior to May 16. Hybrid differences were minor.

SOYBEAN: Analysis of Variance found that yield was significantly ($p<0.001$) affected by planting date. Results are given in Table 4. Yield declines due to planting date did not begin until the late May and June plantings.

Conclusions

In 1996, delayed planting did not significantly decrease yields compared to the earliest planting dates - at least within the time period that most planting in the region was done. Planting delays past mid-May (for corn) or very late May (for soybean) did cause yield decreases relative to the earliest planting date. Moisture content at harvest was highest in the latest planted crop.

Table 1. Corn yield and moisture content as affected by planting date (analyzed over four 105-day hybrids) at Lamberton, 1996.

Planting Date	April 19	April 29	May 13	May 22	$LSD_{\alpha=0.05}$
Yield (bu ac^{-1})	177a	173a	171a	153b	10.8
Moisture (%)	21.5b	21.6b	22.4b	24.7a	1.40

Table 2. Corn yield and moisture content as affected by hybrid (all 105-day RM, analyzed over four planting dates) at Lamberton, 1996.

	C4127	DK512	P3547	P3559	$LSD_{\alpha=0.05}$
Yield (bu ac^{-1})	169ab	168ab	162b	175a	8.9
Moisture (%)	20.7c	22.4b	24.7a	22.4b	1.0

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Table 3. Effects of planting date and hybrid on corn yield and moisture at Lamberton, 1996.

	Hybrid	C4127	DK512	P3547	P3559	$LSD_{\alpha=0.05}$
Planted April 19						
	Yield (bu ac^{-1})	173ab	182a	166b	187a	13.9
	Moisture (%)	19.9b	20.8b	24.4a	20.8b	2.0
Planted April 29						
	Yield (bu ac^{-1})	166bc	184a	164c	179ab	14.4
	Moisture (%)	20.0b	20.5b	24.4a	21.5b	2.1
Planted May 13						
	Yield (bu ac^{-1})	179a	165a	161a	177a	31.3
	Moisture (%)	20.4b	23.0a	24.0a	22.2ab	2.3
Planted May 22						
	Yield (bu ac^{-1})	158a	139a	158a	156a	14.0
	Moisture (%)	22.4b	25.3a	26.2a	25.0a	2.4

Table 4. Soybean (var. Sturdy) yield for seven planting dates at Lamberton, 1996 ($LSD_{\alpha=0.05}$ = 2.16 bu ac^{-1}).

Planting Date	April 24	May 1	May 13	May 20	May 31	June 11	June 23
Yield (bu ac^{-1})	47.7a	46.6ab	47.1ab	45.7ab	45.5b	36.8c	26.1d

IMPORTANCE OF THE CORN-SOYBEAN ROTATION ON NET RETURNS — 1980's

P.M. Porter, J.G. Lauer, E.S. Oplinger, T.R. Hoverstad, and R.K. Crookston[1]

Abstract

Annual rotation of corn and soybean results in greater net returns than continuous production of either crop. While the magnitude of the rotation effect on yield averaged slightly over 10%, the increase in net returns by annual rotation of corn and soybean over continuous production of either crop averaged 122% and 45%, respectively. Producers should be aware of the impact crop rotation has on their net returns, and respond accordingly when considering their planting options. Planting more acreage to one crop one year because of favorable market prices may have seem attractive that year, but consideration must be given to the loss of net returns if this practice results in continuous production of one crop on the same piece of land for two or more years.

Introduction

With the introduction of synthetic fertilizers, herbicides, and insecticides in the 1960's, researchers questioned the necessity of crop rotation to overcome the negative yield impact observed with continuous corn production. The belief that proper agronomic management practices in continuous corn production could overcome the yield advantage from crop rotation has, however, been discredited. It has also been documented that the yield benefit of crop rotation is not limited to corn. Soybean grown in rotation with corn yield more than continuous soybean. The magnitude of the rotation effect on yield is dependent on numerous agronomic and environmental factors, but averages about 10% for both corn and soybean. The economic consequences of the yield advantage for corn and soybean grown in rotation have not been well documented. The objective of this study was to access the impact lack of crop rotation in a corn-soybean cropping system has on profitability.

Experimental Procedure

Research yield data from corn and soybean cropping systems research trials located in Lamberton and Waseca MN, and Arlington WI were combined with producer cost of production data from southwestern and southeastern Minnesota and southern Wisconsin to calculate net returns. Net return per acre for continuous corn, continuous soybean, and corn and soybean in a corn-soybean rotation were calculated each year at each location utilizing research trial yields, producer price received, and producer cost of production. The producer price received and cost of production values associated with the Lamberton, Waseca, and Arlington research trial yields were obtained from the Southwestern and Southeastern Minnesota Farm Business Management Associations and the Wisconsin "Profits through Efficient Production Systems" program, respectively.

At Lamberton and southwest Minnesota, net returns were calculated from 1985 through 1995 (11 years). At Waseca and southeast Minnesota, research yield data for 1991 and 1993 were unavailable at Waseca; thus economic results were calculated from 1985 through 1995 excluding the years 1991 and 1993 (9 years). At Arlington and southern Wisconsin, economic results were calculated from 1987 through 1993 (7 years), the years producer economic data were available. Net returns for these cropping systems were also determined for each of the three locations over years and for all 27 year X location environments.

Results and Discussion

Compared with continuous corn, corn yield increased by 13, 10, and 18% when rotated annually with soybean over an 11 year period at Lamberton, a 9 year period at Waseca, and a 7 year period at Arlington, respectively (Table 1). Over the same time frames, however, the net return per acre increased by 452, 55, and 145% at Lamberton, Waseca, and Arlington, respectively. Averaged across all 27 environments, the increase in corn yield due to rotation was 13% while the increase in net return due to rotation was 122%.

Compared with continuous soybean, soybean yield increased by 16, 12, and 5.4% when rotated annually with corn over an 11 year period at Lamberton, a 9 year period at Waseca, and a 7 year period at Arlington, respectively (Table 1). Over the same time frames, however, the net return per acre increased by 97, 55, and 13% at Lamberton, Waseca, and Arlington, respectively. Averaged across all 27 environments, the increase in corn yield due to rotation was 11% while the increase in net return due to rotation was 45%.

The corn and soybean yield and economic data from Lamberton and southwestern Minnesota for each year are presented in Table 2. Number of producers from which the economic data were obtained is also included.

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Conclusions

The economic benefit of the corn-soybean rotation compared with continuous corn or continuous soybean was sizeable in relation to the yield benefit of rotation. Averaged across 27 year by location environments, corn in the corn-soybean rotation resulted in 13% greater yields than continuous corn while the net returns were 122% greater. Averaged across the same 27 environments, soybean in the corn-soybean rotation resulted in 11% greater yields than continuous soybean while the net returns were 45% greater. The magnitude of the economic benefit was very dependent on the year analyzed: for example, depressed corn yields in 1988 and 1993 resulted in sizeable net losses for continuous corn.

Table 1. Yield and net return for continuous corn, continuous soybean, and corn and soybean in a corn-soybean rotation from southwest (Lamberton) MN, southeast (Waseca) MN, and southern (Arlington) WI, as well as across all locations.

	Lamberton (11 years data)		Waseca (9 years data)		Arlington (7 years data)		All locations (27 years)	
	Yield	Net return	Yield	Net return	Yield	Net return	Yield	Net return
	bu/ac	$/ac	bu/ac	$/ac	bu/ac	$/ac	bu/ac	$/ac
Continuous corn	115	7.44	137	55.38	127	35.63	126	30.73
Corn in rotation	131	41.04	150	86.06	150	87.38	142	68.09
Continuous soybean	35.3	33.04	35.4	33.56	51.8	116.63	39.5	54.88
Soybean in rotation	40.9	65.08	39.7	57.26	54.6	131.42	43.8	79.67
Corn-soybean rotation	--	53.06	--	71.67	--	109.40	--	73.87

Table 2. Corn and soybean yield and economic data from Lamberton and southwestern Minnesota.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	'85-'95
Producer yield (bu/acre)												
Corn (C)	124	136	138	89	141	131	128	127	61	145	119.7	122
Soybean (S)	34.7	38.5	43.6	31.6	43.1	45.5	40.5	38.8	21.0	47.1	43.6	38.9
Producer price received ($/bu)												
Corn	2.35	2.03	1.53	2.08	2.30	2.30	2.26	2.20	2.11	2.24	2.30	2.16
Soybean	5.38	5.01	4.89	6.80	6.77	5.69	5.41	5.39	5.84	5.94	5.56	5.70
Producer cost of production ($/acre)												
Corn	263	247	243	229	221	242	235	239	239	238	258	241
Soybean	187	170	169	152	151	162	162	161	169	167	178	166
Producer net return ($/acre)												
Corn	29	28	-32	-44	102	58	55	40	-110	88	17	21.05
Soybean	0	23	44	63	141	97	57	48	-47	113	65	54.90
Research yield (bu/acre)												
C yield in C/S	134	170	128	86	164	145	118	140	75	145	132	131
C yield in cont. C	121	140	128	84	143	134	111	122	58	111	118	115
S yield in S/C	42.8	43.0	46.5	33.2	36.9	48.5	47.7	30.5	40.6	37.0	43.0	40.9
S yield in cont. S	38.2	37.4	41.4	27.8	27.8	40.2	44.4	24.4	28.4	37.7	41.0	35.3
Net return using research yield and producer cost of production ($/acre)												
If continuous corn	20	37	-48	-55	108	66	15	29	-117	12	14	7.44
If continuous soybean	19	17	34	37	37	67	78	-30	-3	57	50	33.04
If rotated 50% corn (½ acre)	26	48	-24	-26	78	46	16	35	-40	44	23	20.52
and 50% soybean (½ acre)	22	23	29	37	49	57	48	2	34	27	31	32.54
Total	47	71	6	11	128	103	64	36	-6	70	53	53.06
Producer information												
Number of farms	180	182	178	202	203	200	207	201	202	202	216	198
Farms with corn	127	128	125	138	142	148	152	149	121	147	154	139
Farms with soybean	126	122	121	129	136	139	150	150	146	142	147	137

CORN AND SOYBEAN YIELD STABILITY ACROSS SPACE AND TIME

P.M. Porter*, C.A. Perillo, S.R. Quiring, and R.K. Crookston[1]

Abstract

Yields of continuous corn and soybean were monitored from the same four plots of each crop over a 10-year period (1986-1995) at Lamberton MN to evaluate the amount of spatial and temporal variability over time. The four plots of each crop were in the exact same location during that time period. Each of the four plots for both corn and soybean produced both the highest and lowest yield at least one time during the 10-year period. A yield range in any one year between the four plots of more than 25% of the four-plot average occurred in 40% of the growing seasons. However, when averaged over 10-years, the yields between the four plots were not significantly different. Year-to-year yield variability for both corn and soybean was approximately three times greater than plot-to-plot variability. These results should caution producers from changing management practices based on small yield differences (~<20% of the average) observed during one growing season.

Introduction

With the advent of affordable global positioning systems, combine-mounted yield monitors, computers, and computer mapping programs, more producers are expected to generate yield maps in order to better understand the yield variability they are observing in their fields. With a better understanding of how the yield varies across the landscape will come a better understanding of why the yield variability exists. Through proper interpretation of yield, soil fertility, and topographical maps it is assumed that yields will be increased and/or profits will be maximized utilizing site-specific production practices such as variable rate applications of seed, cultivar, fertilizers, and pesticides. For this article, yield data over a 10-year period (1986-1995) from four continuous corn plots and four continuous soybean plots were evaluated to determine the amount of spatial and temporal variability over that time frame.

Experimental Procedure

The study, originally designed to evaluate corn/soybean cropping sequences, was established in 1981 (Crookston et. al., Agron. J. 83:108-113). Only data from four continuous corn plots and four continuous soybean plots are discussed in this article. Each plot was 12 rows wide (on 30" row widths) and 30 ft long; harvest was from 26 ft of four of the rows. All plots were located within a two acre area on a uniform Webster clay loam soil.

An analysis of variance was conducted using yield data from the four plots over the 10-year period of each crop. Plot average was the average yield of four plots each year. Plot range was the maximum minus minimum yield of the four plots each year. Plot standard deviation was the standard deviation of the four plot yields each year. Ten-year average yield was the average yield from 1986 through 1995 of each plot. Ten-year range was the maximum minus minimum yield from 1986 through 1995 of each plot. Ten-year standard deviation was the standard deviation of yield from 1986 through 1995 of each plot. Plot yields, ranges, and standard deviations were averaged over the 10-year period, and the 10-year yields, ranges, and standard deviations were averaged across the four plots. The average plot standard deviation and the average 10-year standard deviation were measures of plot (spatial) and seasonal (temporal) variability, respectively.

Results and Discussion

Over the 10-year period, year had a highly significant effect on both corn and soybean yields at each test site (Tables 1 and 2). Yields were below normal in 1988 and 1993 because of generally hot, dry conditions and cool, wet conditions, respectively. Over the 10-year period, there was no difference in yield between the four corn plots or between the four soybean plots (Table 1). The fact that plot location did not influence either the corn or soybean yields over the 10-year period was not surprising. The study was conducted at a site where the soil was considered to be uniform with little to no visible topographical differences.

Each of the four plots produced the greatest corn yield compared to the other three plots at least one season during the 10-year period (Table 1). Likewise, each of the four plots produced the lowest corn yield compared to the other three plots within at least one season during the 10-year period. Over the 10-year period, the range in corn yield among the four plots (plot range) expressed as a percentage of the plot average averaged 20%. The range in corn yield expressed as a percentage of the plot average was as low as 4% in 1989 and as high as 49% in 1988. The range in corn yield expressed as a percentage of the plot average was greater than 10% in 9 of 10 growing seasons, and greater than 25% in 4 of 10 growing seasons. The plot range was large compared to the plot average in seasons with poor growing conditions. Plot yield variability for corn was greatest in 1988, when yields were depressed due to hot, dry growing conditions. In 1993, a year with poor growing conditions for corn due to cool, wet conditions, plot yield variability was also relatively large. The range in corn yield for each of the four plots across the 10-year period (10-year range) expressed as a percentage of the 10-year average was greater than 60% for all plots. Over the 10-year period, seasonal variability in corn yield was 2.8 times that of plot variability (27.9 vs. 9.9 bu/acre).

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Each of the four plots produced the greatest soybean yield compared to the other three plots at least one season during the 10-year period (Table 2). Likewise, each of the four plots produced the lowest soybean yield compared to the other three plots within at least one season during the 10-year period. Over the 10-year period, the range in soybean yield among the four plots (plot range) expressed as a percentage of the plot average averaged 17%. The range in soybean yield expressed as a percentage of the plot average was as low as 6% in 1991 and as high as 28% in 1988. The range in soybean yield expressed as a percentage of the plot average was greater than 10% in 9 of 10 growing seasons, and greater than 25% in 4 of 10 growing seasons studied. As with corn, the plot range was large compared to the plot average in 1988, when yields were depressed due to hot, dry growing conditions. The range in soybean yield for each of the four plots across the 10-year period (10-year range) expressed as a percentage of the 10-year average was greater than 50% for all plots. Over the 10-year period, seasonal variability in soybean yield was 2.8 times that of plot variability (7.6 vs. 2.8 bu/acre).

Conclusions

These results suggest the importance of taking great care when interpreting yield maps. For both corn and soybean, a yield range between the highest and lowest yielding plot of more than 25% of the four-plot average occurred in 4 out of 10 of the growing seasons, but when averaged over 10-years, there was no significant yield difference between the four corn plots or between the four soybean plots.

Year-to-year yield variability was approximately three times greater for both corn and soybean than plot-to-plot yield variability. The 10-year time frame this study encompassed included two relative harsh growing seasons (1988 which was hot and dry, and 1993 which was cool and wet). These growing seasons should not be considered anomalies, as harsh climatic conditions resulting in poor crop production do occur regularly.

Basing yield predictions on individual year data would result in quite different and perhaps erroneous conclusions than if yield predictions were based on longer-term (10 year) averages. Emphasizing yield map variability observed in relatively uniform fields during poor growing seasons (when the plot range was very large compared to the four-plot average) is especially risky, and may lead to erroneous conclusions. These results underscore the necessity of in-season field observations to aid yield map interpretation, especially when relatively large yield variations occur during poor growing seasons.

Table 1. Continuous corn yields from four plots over a 10-year period from 1986 through 1995 at Lamberton.

Plot	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	10-yr avg.	10-yr range	10-yr std. dev.	Avg. across years	
	bu/acre														
Lamberton															
1	138	120	63	141	125	117	127	63	110	125	113	78	27.8		
2	155	129	91	146	137	112	138	43	98	116	117	112	33.0		
3	139	128	104	144	140	112	101	69	108	127	117	75	23.2		
4	128	134	78	141	134	102	121	57	129	105	113	85	27.5		
Plot avg.		140	128	84	143	134	111	122	58	111	118				115
Plot range	27*	14*	41**	6	15*	16*	36**	26**	31**	22*				23.2*	
Plot std. dev.	11.2	5.9	17.4	2.6	6.3	6.6	15.2	11.0	12.8	9.9				9.9	
								Avg. across plots:			115	87	27.9		

*,** Range in corn yield exceeded 10 and 25% of the plot average, respectively.

Table 2. Continuous soybean yields from four plots over a 10-year period from 1986 through 1995 at Lamberton.

Plot	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	10-yr avg.	10-yr range	10-yr std. dev.	Avg. across years	
	bu/acre														
Lamberton															
1	35.9	44.6	26.3	30.2	41.2	44.1	25.2	33.1	33.1	38.8	35.3	19.4	6.9		
2	34.6	42.3	24.4	26.1	40.6	40.8	24.7	26.0	41.9	43.8	34.5	19.4	8.3		
3	38.8	38.9	28.5	26.2	38.6	46.9	20.4	28.4	42.8	40.9	35.0	26.5	8.5		
4	40.3	39.9	32.1	28.5	40.3	45.8	27.1	26.0	33.1	40.4	35.4	19.8	6.8		
Plot avg.		37.4	41.4	27.8	27.8	40.2	44.4	24.4	28.4	37.7	41.0				35.0
Plot range	5.7*	5.7*	7.7**	4.1*	2.6	6.1*	6.8**	7.1**	9.7**	4.9*				6.0*	
Plot std. dev.	2.6	2.6	3.3	2.0	1.1	2.6	2.9	3.3	5.4	2.1				2.8	
								Avg. across plots:			35.0	21.2	7.6		

*,** Range in soybean yield exceeded 10 and 25% of the plot average, respectively.

ORGANIC CROP ROTATION STUDY AT LAMBERTON -- 1996

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

Abstract

The 1996 growing season marked the eighth year of the ongoing Organic Rotation Study at Lamberton. The purpose of the experiment is to evaluate both the effect of manure application (versus no added fertility) and the effect of cropping sequence on crop yield — emphasizing corn yield but also evaluating yield of soybean, oat, and alfalfa. Manure application in the organically managed study employing no herbicides or synthetic fertilizer increased corn yields for all rotation lengths (continuous, 2-, 3-, and 4 year rotations). Corn yields in the manured and non-manured treatments averaged over all rotation lengths were 155 and 69 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-, 3-, and 4-year rotations. Soybean yields in the manured and non-manured treatments averaged 37.7 and 33.5 bushels acre^{-1},respectively. 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.

Introduction

This on-going study evaluates various crop rotations managed organically under both high and low fertility levels. The crop rotations include i) continuous corn, ii) a 2-year corn-soybean rotation, iii) a 3-year corn-soybean-oat rotation, and iv) a 4-year corn-soybean-oat-alfalfa rotation. The site of the study (Elwell Agroecology Farm on 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 1996 yield results are reported here. Previous results were presented in earlier editions 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 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 but the alfalfa plots. All weed species were identified and counted in each sample. In corn and soybean two samples 4-ft long and 5-ft wide were collected for grassy weeds, and one sample 145 ft by 5 ft was collected for broadleaf weeds. In oats and alfalfa three 1-ft squares per plot were collected for both grassy and broadleaf weeds.

Results and Discussion

In 1996, corn yields were increased with the addition of manure: manured and non-manured treatments averaged 154 and 69 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 3-year rotations, which in turn yielded less than corn in the 4-yr rotation.

Soybean yields were significantly impacted (P=0.06) by manure application, with the manured treatments yielding 37.8 bushels acre^{-1} and the unfertilized treatments yielding 33.5 bushels acre^{-1}. These results are the opposite of what was observed in 1994 and 1995, where the manured treatments yielded less than the unfertilized treatments. Better weed control was obtained in 1996 compared with the previous years, and may have contributed to these results. Soybean yields were not significantly impacted (P=0.13) by rotation length, however, there was a trend toward greater yields in the 4-year rotation compared with the 2-year rotation.

Oat yields were unaffected by rotation length but increased with manure application (75.2 vs 45.5 bushels acre^{-1} for the fertilized and unfertilized treatments, respectively). The manured alfalfa treatments yielded more than the unfertilized treatments (5.33 vs. 3.02 tons acre^{-1}, respectively.

[1] P.M. Porter (assist. prof. - Dept. Agronomy and Plant Genetics), C.A. Perillo (assist. scientist), D.R. Huggins (assist. prof. - Dept. Soil, Water, and Climate), and S.R. Quiring (senior plot tech.), located at the Southwest Experiment Station, Lamberton, MN.

Table 1. 1996 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	5/29	6/13	
	5/18 (twice)	33000 seeds acre^{-1}	5/30	6/27	354-240-282
		5/18	6/03		on 5/18
Corn-soybean	Field cultivator	Pioneer P3769	5/29	6/13	
	5/18 (twice)	33000 seeds acre^{-1}	5/30	6/27	354-240-282
		5/18	6/03		on 5/18
Corn-soybean-oats	Field cultivator	Pioneer P3769	5/29	6/13	
	5/18 (twice)	33000 seeds acre^{-1}	5/30	6/27	354-240-282
		5/18	6/03		on 5/18
Corn-soybean-oats-alfalfa	Field cultivator	Pioneer P3769	5/29	6/13	
	5/18 (twice)	33000 seeds acre^{-1}	5/30	6/27	69-47-55
	5/18	5/18	6/03		on 5/18
Corn-soybean	Field cultivator	Parker	6/03	6/27	
	5/22	150,000 seeds acre^{-1}	6/11		0-0-0‡
	5/29	5/30			
Corn-soybean-oats	Field cultivator	Parker	6/03	6/27	
	5/22	150000 seeds acre^{-1}	6/11		17-12-14
	5/29	5/30			on 5/21
Corn-soybean-oats-alfalfa	Field cultivator	Parker	6/03	6/27	
	5/22	150,000 seeds acre^{-1}	6/11		38-26-30
	5/29	5/30			on 5/21
Corn-soybean-oats	Field cultivator 4/26	Dane	none	none	
	harrow / packer 4/27	85 lbs acre^{-1}			63-43-51
		4/26			on 4/26
Corn-soybean-oats-alfalfa	Field cultivator 4/26	Dane and Pioneer P5262	none	none	
	harrow / packer 4/27	85 and 12lbs acre^{-1}			63-43-51
		4/26 and 4/26			on 4/26
Corn-soybean-oats-alfalfa	none	Planted previous year	none	none	73-50-59
					on 8/02

† Hybrid or variety is listed, followed by seeding rate in seeds acre^{-1} and planting date.
‡ 354-240-282 was inadvertently applied to one plot (not included in yield results).

Table 2. Rotation length and fertility effects on corn, soybean, oats and alfalfa yields in an organically-managed study at Lamberton, 1996.

Rotation	With manure	Without manure
Corn yield	— bushels acre^{-1} —	
Continuous corn	164.4	47.6 c
Corn-soybean	148.1	65.3 b
Corn-soybean-oats	158.5	70.4 b
Corn-soybean-oats-alfalfa	147.3	91.9 a
Mean	154.6	68.8
CV (%)	10.7	
Pr> F	(Fert 0.01, Rot 0.14, FXR 0.01)	
$LSD_{(0.05)}$	16.4	16.4
Soybean yield	— bushels acre^{-1} —	
Soybean-corn	34.3	32.8
Soybean-oats-corn	37.3	32.3
Soybean-oats-alfalfa-corn	41.9	35.4
Mean	37.8	33.5
CV (%)	13.7	
Pr> F	(Fert 0.06, Rot 0.13, FXR 0.59)	
$LSD_{(0.05)}$	NS	NS

Rotation	With manure	Without manure
Oat yield	— bushels acre^{-1} —	
Oats-corn-soybean	77.2	49.3
Oats-alfalfa-corn-soybean	73.2	41.6
Mean	75.2	45.5
CV (%)	14.4	
Pr> F	(Fert 0.01, Rot 0.23, FXR 0.68)	
$LSD_{(0.05)}$	NS	NS
Alfalfa yield	— ton acre^{-1} —	
Alfalfa-corn-soybean-oats	5.33 a	3.02 b
With vs. without manure		
CV (%)	14.4	
Pr>F	0.01	
$LSD_{(0.05)}$	1.36	

ANHYDROUS AMMONIA - KNIFE SPACING STUDY[1]

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

Abstract

This is the last year of a 3 year study initiated in Morris, MN in 1994 and repeated in 1995 and 1996 to study the effects of nitrogen application on grain yield at 2 anhydrous ammonia applicator knife spacings. 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 and in 1996 there was an increase in grain yield up to 108 lb N/A but there was no difference in grain yield due to knife spacing in any of the years.

Objectives

Anhydrous ammonia is the dominant source of inorganic nitrogen used in corn production. Normally anhydrous ammonia is injected into the soil through knives that run 6 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 experiment was established on Nutley clay soils in 1994 and 1996 and on a Nutley clay/Flom loam complex in 1995. Each year the experimental design was a randomized complete block with 4 replications. The experimental sites were seeded to oats the year before the study, had no nitrogen applied, and were fall chisel plowed. Soil tests taken the fall before the study year indicated high P and K levels, (data not shown). Nitrate-N soil tests, 0-2 foot, taken the fall before the study year showed concentrations of 18 lb/A in 1994, 22 lb/A in 1995, and 28 lb/A in 1996. The 1994-96 individual plots were 6 rows (15ft) wide and 45 feet long. The experimental site was field cultivated for seedbed preparation each year and seeded to Ciba Geigy 4172 corn in 1994 and 1995 and DeKalb 442 corn in 1996 at 30,100 seeds per acre. A 6-row J.D. Maxemerge planter was used for seeding. Grass control was achieved with pre-emergence applications of Alachlor @ 3.0 lb/A a.i. or Metolachlor @ 3.0 lb/A a.i. Broadleaf weeds were controlled with post-emergence applications of Bentazon @ 0.75 lb/A a.i. or Halosulfuron-methyl @ 0.047 lb/A a.i. Each year the study was row cultivated prior to nitrogen application. Anhydrous ammonia was sidedress applied on June 8, 1994, June 21, 1995, and June 26, 1996. Corn was in the V5 stage, 4-5 collars visible at the time of nitrogen applications. 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. Soil conditions were dry at ammonia sidedress application in 1994 with rain 1 week after application, wet soil conditions were prevalent in 1995 with frequent rains before and after ammonia application, and in 1996 soil conditions were dry before ammonia application with rain 1 1/2 weeks after application. Growing season rainfall was 17.51 inches, 20.70 inches, and 11.69 inches for 1994, 1995, and 1996, respectively, compared to an average of 15.71 inches. The study was harvested with a plot combine each fall. Grain yield, grain moisture, date of tasseling, and date of silking were recorded.

Results

There were significant differences in grain yield due to nitrogen rate (Table 1) in all years. Grain yield was maximized at 72 lb/N in 1994 and 1995, and at 108 lb/N in 1996. Grain moisture at harvest was variable but generally the highest at the 0 lb/N treatment, (data not shown). Tasseling and silking were the latest for the 0 lb/N treatment in all years of the study (data not shown). There were no significant effects on grain yield, grain moisture, tasseling, or silking due to knife spacing in any year. The knife spacing x nitrogen rate interaction was not significant in 1994, but was significant in 1995 and 1996. Examination of the 1995 and 1996 data indicates that most of the effects from the knife spacing by nitrogen rate interactions were attributed to nitrogen rate. Three years of results show no differences in grain yield between 30- and 60-inch anhydrous ammonia knife applicator spacings at sidedress.

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

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

Table 1. Effect of applicator knife spacing on corn grain yield, Morris 1994, 1995, and 1996.

Nitrogen Rate	Knife Spacing	1994 Grain Yield	1995 Grain Yield	1996 Grain yield	1994-96 Average Grain yield
-lb/A-	-inches-	-bu/A-	-bu/A-	-bu/A-	-bu/A-
0	30	80.5	103.6	82.5	88.9
36	30	106.9	115.7	101.1	107.9
72	30	150.3	162.6	131.7	148.2
108	30	142.7	162.8	147.1	150.9
144	30	159.3	163.2	155.0	159.2
0	60	80.5	89.5	91.9	87.3
36	60	113.5	139.0	126.0	126.2
72	60	148.9	155.7	147.8	150.8
108	60	153.3	158.7	146.5	152.8
144	60	159.8	162.4	144.7	155.6
Nitrogen Rate					
Sig. Level (%)		99	99	99	
BLSD (.05)		20.5 bu	7.6 bu	9.4 bu	
Knife Spacing					
Sig. Level (%)		34	12	84	
N Rate x Knife Spacing					
Sig. Level (%)		2	99	98	
C.V. (%)		16.7	5.8	7.9	

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

WEATHER DATA - 1996

Month	Period	Precipitation 1996	Precipitation Normal[1]	Avg. Air Temp. 1996	Avg. Air Temp. Normal[1]	Growing Degree Units 1996	Growing Degree Units Normal[1]
		---- inches ----		----- °F -----			
January	1 - 31	3.26	0.98	7.4	10.2		
February	1 - 28	0.14	0.97	16.3	16.1		
March	1 - 31	3.29	2.28	24.1	29.1		
April	1 - 30	1.11	2.97	41.2	43.1		
May	1 - 10	1.56		48.0		32.0	
	11 - 20	1.08		57.1		95.0	
	21 - 31	0.78		56.6		86.5	
	Total	3.42	3.65	53.9	57.7	213.5	327
June	1 - 10	1.10		60.8		110.5	
	11 - 20	3.77		71.7		208.5	
	21 - 30	0.58		74.7		232.5	
	Total	5.45	4.11	69.1	67.1	551.5	515
July	1 - 10	0.65		69.8		199.0	
	11 - 20	0.33		70.5		201.5	
	21 - 31	0.82		66.0		176.5	
	Total	1.80	4.21	68.7	71.3	577.0	646
August	1 - 10	2.64		70.6		204.0	
	11 - 20	1.00		67.1		170.5	
	21 - 31	3.45		68.0		197.5	
	Total	7.09	4.20	68.5	68.4	572.0	567
September	1 - 30	1.81	3.56	60.0	59.9	229.0	316
October	1 - 31	2.90	2.45	49.2	47.9	-	31
November	1 - 30	4.16	1.72	24.3	32.3		
December	1 - 31	1.93	1.35	12.2	16.2		
Year	Jan-Dec	36.36	32.45	41.3	43.4	2143.0[2]	2402
Growing Season	May-Sep	19.57	19.73	64.0	64.9	2143.0	2371

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

Notes:
1) Highest 24-hour precipitation on August 26 - - - 2.75"
2) Growing degree units 10% below normal for season.
3) Highest temperature on June 29 - - - 96F.
4) Last spring frost - - - May 13.
5) First fall frost - - - September 14.

NUTRIENT LOSSES TO TILE LINES AS INFLUENCED BY SOURCE OF N

Waseca, 1996

T.K. Iragavarapu, G.W. Randall, and M.A. Schmitt†

ABSTRACT: A study was started in 1994 to compare the effects of liquid dairy manure and urea applied at similar N rates on N and P movement in the soil and into tile lines and corn production. Corn yields and N uptake were significantly greater for the urea treatment compared to the dairy manure treatment. Nitrogen source had no effect on tile flow, NO_3-N concentration and loss in tile water, and NO_3-N content in the 0-5' profile in the fall. Out of the 36 tile water samples analyzed, ortho-phosphate was detected in 20 samples (55%) while total P was detected in 35 samples (97%). Average total P concentrations (0.03 mg/L) were identical between manure and urea. Ammonium-N was detected in three of the four samples analyzed from each of the treatments and the NH_4-N concentration did not differ between the two N sources. Coliform bacteria was not detected in any of the six water samples analyzed from the dairy manure treatment. Nitrate-N concentrations in porous suction cup samplers tended to be greater in the urea fertilized plots compared to the dairy manure applied plots at the 4 ft depth whereas at the 6 ft depth, there was no clear trend. Nitrate-N concentrations were low (< 6 mg/L) at the 8 ft depth and were similar between the two treatments. Water was found in only 12 of the 40 possible piezometers at the 4 ft depth whereas at the 6 and 8 ft depths 28 and 26, respectively, of the piezometers had water. All the samples analyzed from the 4 ft. depth had detectable amounts of NO_3-N while 78 and 27% of the water samples from the 6 and 8 ft depths, respectively, had detectable amounts of NO_3-N. Soil test P and K values were greater for the dairy manure applied plots compared to the urea treated plots.

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

EXPERIMENTAL PROCEDURES

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

In the fall of 1993, the same 8 plots used in the previous study were converted to dairy manure and urea treatments. Liquid dairy manure was broadcast-applied on November 10, 1995 at a rate of 9000 gal/acre and the plots were moldboard plowed immediately. On April 26, 1996, urea was broadcast-applied by hand to 4 plots at a rate of 135 lb N/A before field cultivation. The nitrogen rate was selected to match the amount of N "available" from the manure based on calculations from the manure analysis (Table 1). "Available" N was calculated based on the assumption that 90% of the ammonium-N (66 lb) and 25% of the organic N (86 x 0.25 = 22 lb) plus 15% of the total N of the manure that was applied in the fall of 1994 (257 x 0.15 = 39 lb) and 5% of the total N of the manure applied in the fall of 1993 (203 x 0.05 = 10 lb) was available for a total of 135 lb N/A.

Corn (P3556) was planted on May 2 at a population of 32000 plants/A. Starter fertilizer was not used because of the high soil tests. Force was applied at 1 lb ai/A to control rootworms. Weeds were controlled with a preemergence application of Harness (2.75 lb ai/A) and Bladex (3 lb ai/A) applied May 13. Weed and insect control were excellent.

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

Silage yields were taken at physiological maturity. Grain yields were taken by combine from 2-45' rows. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on

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a M-W-F basis thereafter for NO_3 analysis. Ammonium-N, total-P, and ortho-P were determined on samples taken on selected days when all tile lines were running in April, May, October, and November. Tile water samples were collected for fecal coliform bacteria analysis in May and June. Water samples collected on a twice-monthly basis from PSC samplers and piezometers were also analyzed for NO_3. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-5' profile was determined from two cores/plot taken in 1-foot increments on November 14, 1996.

RESULTS

Corn grain yield, grain N removal, silage yield, and N uptake were significantly ($P \leq 0.05$) greater in plots that were fertilized with urea compared to those plots that received liquid dairy manure (Table 2). The 19 bu/A yield "advantage" for the urea treatment suggests that sufficient N was not provided by the dairy manure treatment. Visual observations during the season indicated color (dark green) and growth/height advantage for the urea treatment. This is evident from the significantly lower chlorophyll content in leaves of the corn plants in the dairy manure treatment than in the urea treatment during the R2 growth stage of corn. We believe that cooler and drier than normal weather conditions in April, May, and July resulted in slower mineralization of organic N in the manure. This resulted in insufficient N available for plant uptake at the rapid growth stage of corn. Perhaps the assumption that 90% of the ammonium-N and 25% of the organic N in the manure applied in Nov. 95 plus 15% of the total N of manure applied in Nov.1994 and 5% of the total N of the manure applied in Nov. 1993 was available to the 1996 crop was an overestimate of N availability from dairy manure under these conditions.

Table 1. Nutrient analyses and application rate of liquid dairy manure applied in November, 1995.

Dry matter	Total N	NH_4-N	Organic N	Total P_2O_5	Total K_2O
%	lb/1000 gal				
5.1	17.8	8.2	9.6	8.0	22.8
	lb/acre				
	160	74	86	72	205

Table 2. Influence of nitrogen source on corn production and N utilization at Waseca in 1996.

Nitrogen source	Final Population	Chlorophyll reading	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal	Grain H_2O
	$x10^3$	SPAD units	T DM/A	lb N/A	bu/A	%	lb N/A	%
Urea	27.8	52.9	6.16	106.3	135.0	1.10	70.0	23.2
Dairy Manure	27.0	40.9	4.93	79.6	116.1	0.98	53.7	23.6
Check[1/]	-	24.5	2.15	30.2	38.7	0.94	17.2	20.0
LSD (0.05)	NS	6.9	0.55	10.7	16.7	NS	16.1	NS
CV (%)	1.8	4.2	2.8	3.3	3.8	4.1	7.4	4.3

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

Below normal precipitation was recorded in April, May, July, and September months. As a result, little or no tile flow occurred during these months. June rainfall was 1.2" above normal. Although rainfall was 2.9" above normal in August tile flow did not occur because of high ET losses. Tile flow, flow-weighted NO_3-N concentration, and nitrate-N losses did not differ between the two nitrogen sources.

Table 3. Influence of nitrogen source on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1996.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in.	mg/L	lb/A
		Urea	
April	-	-	-
May	-	-	-
June	3.34	11.8	8.8
July	0.02	11.2	0.0
August	-	-	-
September	-	-	-
October	-	-	-
November	0.96	6.7	1.5
Dec	0.26	6.0	0.4
Total	4.58	Avg = 8.9	10.7
		Dairy manure	
April	-	-	-
May	-	-	-
June	3.83	11.9	10.4
July	0.03	9.0	0.1
August	-	-	-
September	-	-	-
October	-	-	-
November	1.01	6.3	1.5
December	0.40	5.5	0.6
Total	5.27	Avg = 8.2	12.6

Residual NO_3-N in the 0-5 ft. soil profile at the end of the 1996 growing season was slightly greater in plots that received dairy manure compared to those that received urea (Table 4). This was especially true in the 0 to 1 ft. soil layer where nitrates in the dairy manure treatment were twice as high as in the urea treatment. This suggests that some late-season availability of N from the manure when the crop uptake of N has ceased may have occurred resulting in greater amounts of NO_3-N accumulated in the top 2 ft. of the dairy manured plots than those treated with urea.

Table 4. Influence of nitrogen source on residual NO_3-N in the soil profile in November, 1996.

Profile Depth	Nitrogen Source: Urea	Nitrogen Source: Dairy manure
ft	NO_3-N (lb/A)	
0-1	16.1 (2.2)†	32.8 (5.0)
1-2	9.7 (1.4)	14.1 (3.3)
2-3	8.5 (1.3)	5.6 (1.2)
3-4	13.1 (0.9)	9.3 (0.6)
4-5	18.9 (2.1)	16.9 (2.3)
Total (0-5')	66.3	78.7

† Numbers in parentheses represent the standard error around the mean.

Soil samples were collected from the plow layer (0-8") in June 1996 to measure the influence of dairy manure vs. urea on soil fertility. Soil pH was similar between the two treatments while soil test P was 14 ppm greater and soil test K was 104 ppm greater in the dairy manure treatment compared to the urea treated plots (Table 5). The same four plots that received dairy manure in the fall of 1995 received dairy manure a rate of 8,000 gal /acre in Nov. 1993, and 10,000 gal/acre in Nov. 1994. In all three years, the amounts of P_2O_5 and K_2O added through the manure were in excess of crop removal of these nutrients. This indicates that repeated application of dairy manure at rates based on N requirement of corn crop can result in a build up of soil test P and K.

Table 5. Influence of nitrogen source on soil pH, soil test P and K in the 0-8" soil profile in June, 1996.

	Nitrogen source	
	Urea	Dairy manure
pH	5.9	6.0
Phosphorus-Bray P_1 (ppm)	26 (3)†	40 (2)
Potassium (ppm)	150 (13)	254 (14)

† Numbers in the parentheses represent the standard error around the mean.

The detection limit for ortho-P in tile water samples was lowered from 0.04 mg/L in 1995 to 0.01mg/L in 1996. As a result, ortho-P was detected in 61% of the water samples from the plots that received dairy manure and in 50% of the water samples from the urea treated plots in 1996 (Table 6). Total phosphorus was detected in all 18 samples analyzed from the urea treatment and in 17 samples from the manured plots. However, average concentrations of ortho-P (0.01-0.02 mg/L) and total P (0.03 mg/L) were very low for both the urea and dairy manure treatments. Coliform bacteria (E.Coli) was not detected in any of the 6 samples analyzed from the manure applied plots. Ammonium-N was detected in three of the four samples analyzed from each of the dairy manure and urea treatments. Ammonium-N concentrations were similar between the dairy manure and urea treatments.

Table 6. Ortho-phosphorus, total phosphorus, coliform bacteria, and ammonium-N detects in tile water samples in 1996.

	Ortho-P		Total P		*E.Coli* Bacteria		NH_4-N	
	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
Number of samples analyzed	18	18	18	18	6	0	4	4
Number of detects[1/]	11	9	17	18	0	-	3	3
% of samples with detects	61	50	94	100	0	-	75	75
Concentration range of detects (mg/L)	0.01-0.03	0.01-0.02	0.02-0.09	0.02-0.08	-	-	0.02	0.02-0.03
Average concentration among detects (mg/L)	0.02	0.01	0.03	0.03	-	-	0.02	0.02

[1/] Detection level is 0.01 mg/L for ortho-P, 0.02 mg/L for total P, and 0.02 mg/L for NH_3-N.

Nitrate-N concentrations in the PSC samplers at the 4-ft depth were consistently greater in plots that received urea compared to those that received dairy manure at all five sampling dates (Fig 1). There was no clear trend at the 6 ft depth. At the 8 ft depth the nitrate-N concentrations were similar between the two treatments at all sampling dates except July 9. Nitrate-N concentrations increased from June 4 to June 19 in both treatments at the 4-ft depth. This increase was also seen at the 6-ft depth, but was most dramatic with urea.. Concentrations of NO_3-N at the 8-ft depth were low (< 6 mg/L) for both treatments. Water samples were collected five times from the piezometers in 1996. Nitrate-N detects in the piezometer water samples are given in Table 7. Across the five sampling dates between June 4 and August 28, water was found in only 12 of a possible 40 piezometers at the 4 ft. depth whereas at the 6 and 8 ft depths 28 and 26, respectively, of the piezometers had water. Average nitrate-N concentrations in the 4 ft depth piezometers were less than those in the 4 ft depth PSC samplers at all sampling dates. In general, more detects were found in the urea treated plots compared to the dairy manure plots. Variation around the mean nitrate-N concentration was greater for the piezometer samples compared to the tile lines or the PSC samplers.

Table 7. Nitrate-N detects in piezometer water samples in 1996.

		6-4		6-19		7-9		7-23		8-28	
	Depth	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
	ft.										
	4	0	1	4	3	0	0	0	0	1	3
# of samples	6	4	4	1	4	4	4	1	2	2	2
analyzed	8	3	4	3	3	2	4	2	1	2	2
	4	-	1	4	3	-	-	-	-	1	3
	6	2	4	1	4	2	4	0	2	1	2
# of detects[1/]	8	2	0	2	1	1	0	0	0	1	0
	4	-	100	100	100	-	-	-	-	100	100
% of samples	6	50	100	100	100	50	100	0	100	50	100
with detects	8	67	0	67	33	50	0	0	0	50	0
	4	-	6.0	1.7-23.0	8.4-20.9	-	-	-	-	0.9	1.2-2.2
Conc. range	6	0.5-7.2	0.8-23.6	2.8	0.9-60.7	0.5-2.6	0.6-30.2	-	0.6-2.0	2.6	1.9-4.6
of data (mg/L)	8	3.1-5.9	-	4.4-17.7	2.0	14.7	-	-	-	1.0	-
	4	-	6.0	14.7	15.4	-	-	-	-	0.9	1.8
Avg. conc. among	6	3.8	8.4	2.8	18.9	1.5	8.1	-	1.3	2.6	3.2
detects (mg/L)	8	4.5	-	11.0	2.0	14.7	-	-	-	1.0	-

[1/] detection limit is 0.5 mg/L.

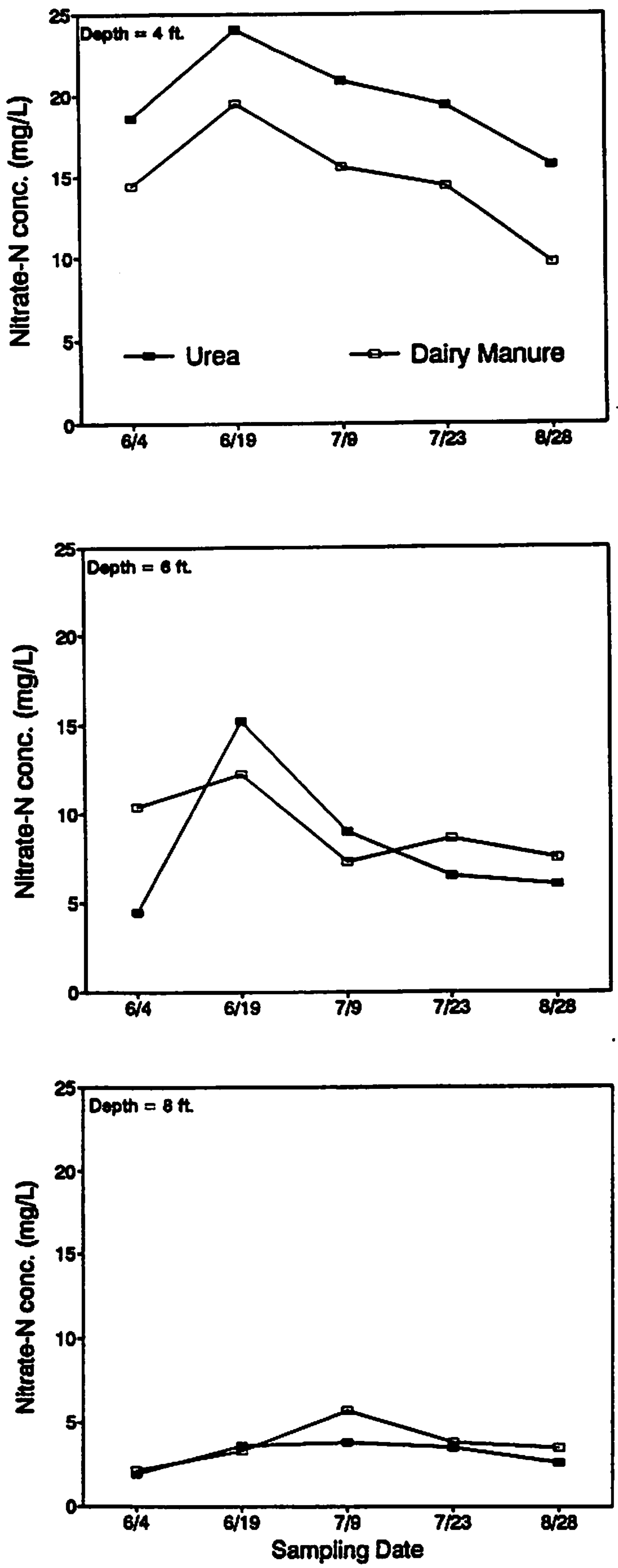

Fig 1. Nitrate-N concentrations in porous suction cup samplers in 1996

NITRATE LOSSES TO TILE DRAINAGE AS AFFECTED BY NITROGEN FERTILIZATION OF CORN IN A CORN-SOYBEAN ROTATION[1]
Waseca, 1996

G. W. Randall and J. A. Vetsch[2]

ABSTRACT: A study was conducted in 1996 to determine the influence of time of N application, N source, and nitrification inhibitor on the yield and uptake of N by corn and the loss of NO_3 to tile drainage. These third-year results showed significant grain and silage yield increases over the control from all N treatments. Highest yields and N uptake were obtained with the spring preplant AA with N-Serve treatment and the spring preplant urea treatment. Yields and N uptake were not different among the fall and spring AA without N-Serve, fall AA with N-Serve, and sidedress AA treatments. Highest NO_3-N concentrations in the grain and stover were found with the spring urea treatment. Flow-weighted NO_3-N concentrations in the drainage water from the corn plots were highest with the fall AA without N-Serve and spring AA with N-Serve treatments. In soybeans, NO_3-N concentrations in the water were not greatly different among the N treatments, which had been applied for the 1995 corn crop. Nitrate-N losses in the drainage water from corn were 5 lb/A lower when N-Serve was used in the fall and 2 lb/A lower when used in the spring. Nitrated-N losses under soybeans ranged from only 5.0 to 6.4 lb NO_3-N/A, indicating little carryover from the 1995 crop. Highest NO_3-N concentrations averaging 18.3 mg/L were found in the fallow plots. Residual soil NO_3-N in November was slightly higher in the urea treatment than in any of the five AA treatments.

Nitrogen (N) losses to tile drainage water have been directly linked to N additions, crop grown, and soil organic matter level. Research has been conducted on NO_3 losses to tile drainage in Minnesota since 1972. This research has focused primarily on the effects of rate and time of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of time of N application and the use of a nitrification inhibitor on NO_3 movement and accumulation in the soil, NO_3 losses via tile drainage, and yield an N uptake by corn grown in a rotation with soybean.

EXPERIMENTAL PROCEDURES

Thirty-six individual tile line plots were installed on a poorly drained Webster clay loam soil at the Southern Experiment Station in 1976. Each 20 x 30' plot is completely surrounded by plastic sheeting to a depth of 6' to prevent lateral flow and contains a tile line (4' deep) 5 feet from one end. All tiles drain to collection pits where flow rates can be measured and water samples collected for analyses. After completing a research project in 1983 using this tile facility, the plots were cropped to corn with a blanket N rate in 1984 and 1985 to establish uniformity.

Beginning in 1986 corn was planted on one-half of the experimental site while soybean was planted on the other half. Thirty two plots (16 with corn and 16 with soybean) with the most uniform drainage were selected from the 36 for the primary study. The experimental design consists of a 4 x 4 Latin square where the rows and columns were based on the previous (1977-83) tile flow rates from each plot. The four primary N treatments (see Table 1) are applied to the corn phase each year with the residual effects measured in the soybean phase. Three additional N treatments were replicated four times around the edge of the core 16-tile-plot area and were planted to corn. These three treatments were analyzed along with the other four as a completely randomized design.

Fertilizer N was applied at a rate of 120 lb/A for all N treatments. The nitrification inhibitor, N-Serve was applied at 0.5 lb/A. Fall treatments were applied on November 6, 1995. Average soil temperature at the 4" depth on that date was 33°F with an average of 33°F over the following 10-day period. The spring preplant anhydrous ammonia and urea treatments were applied on May 1. The sidedress AA treatment was applied at the V3 stage on June 14.

The corn area (1995 soybean area) was field cultivated once before planting, while the soybean area (1995 corn area) was fall chiseled and field cultivated once prior to planting. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3730) was planted at 32,000 seeds/acre on May 17 with a JD Max-Emerge planter. Corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Harness (2.75 pt/A) plus Broadstrike Plus (0.25 lb/A) on May 25. Soybeans (Sturdy) were planted in 30" rows at 9 beans per foot of row on May 29. Weeds were chemically controlled with 3.0 lb/A Lasso preemergence (June 1) plus a post emergence application of Pursuit (1.1 oz/A) at the 1st trifoliate stage (July 25).

Two plots within each of the corn and soybean areas were not planted and were fallowed all summer. These four fallow plot areas were located on those tile plots that showed greatest water flow variability (1977-83). The purposes of these plots were to check the NO_3-N concentrations in the tile water in a fallow system and to utilize all 36 of the tiled plots, even though these four historically showed the highest flow variability.

Stand counts were taken at the V-5 stage and plots were thinned to a uniform population of 31,360 plants/acre. Chlorophyll content in the ear leaf was measured with a Minolta SPAD meter on August 2 (R1). Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yield and 60' of row for grain yield and moisture. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 4 feet from all plots on November 14. Chemical analyses of plant, water, and soil were performed by the Research Analytical Laboratory, University of Minnesota.

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[1] Partial funding provided by DowElanco and Minnesota Agric. Exp. Stn.

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RESULTS AND DISCUSSION

Plant

Stover N concentration, yield, and N uptake at physiological maturity were increased over the control by all of the N treatments (Table 1). Stover yield differences did not exist among the treatments that received N. However, stover N concentration and N uptake were generally greater for the preplant urea and sidedress AA treatments compared with the fall and spring preplant AA treatments. Chlorophyll content of the ear leaf at the R-1 stage was increased significantly above the control by all of the N treatments. When comparing the relative chlorophyll content of each N treatment to the content of the highest treatment, all showed adequate chlorophyll suggesting sufficient N (>96% relative chlorophyll) for optimum yield. Final population was excellent and was not affected by the treatments.

Table 1. Influence of time of N application, N source and nitrification inhibitor on whole plant N, stover yield, N uptake, leaf chlorophyll, and final population of corn following soybeans.

N Application		Stover			Relative	Final
Time	Inhibitor	N	Yield	N uptake	Chlorophyll	Population
		%	T DM/A	lb/A	%	ppA x 10^3
Primary trts						
AA Fall (11/6)	No	0.54	2.60	28.2	97.8	30.10
AA Fall (11/6)	Yes	0.52	2.60	27.0	96.2	30.03
AA PP (5/1)	No	0.48	2.64	25.4	97.7	29.72
AA PP (5/1)	Yes	0.50	2.56	25.3	96.6	29.79
Additional trts						
Urea PP (5/1)	No	0.67	2.97	39.6	100.0	30.10
AA SD (6/14)	No	0.64	2.64	33.6	97.8	30.20
Check (No N)	- -	0.38	2.08	15.7	71.4	29.86
Statistical Analysis Latin square (Primary trts)						
P > *F*:		0.58	0.91	0.62	0.63	0.54
LSD (0.05):						
CV (%):		13	6	13	2	1
Statistical Analysis Completely randomized (7 trts)						
P > *F*:		<0.01	0.02	<0.01	<0.01	0.25
LSD (0.05):		0.09	0.41	6.0	3.7	
CV (%):		12	11	15	3	1

Grain yield, N concentration, and N uptake, silage yield, and total N uptake were increased significantly over the control by all of the N treatments (Table 2). Grain yields were increased significantly over the fall AA treatments and the spring preplant AA treatment without N-Serve by preplant AA with N-Serve and the preplant urea treatment. A wet 8-day period beginning on June 16 may have caused some denitrification and/or leaching of nitrate below the upper portions of the root zone, which could explain the somewhat lower yields with the fall treatments and the preplant AA without N-Serve treatment. Including N-Serve with the spring AA would have delayed nitrification during this very cool spring and thereby optimized N availability to the corn. Also, the spring broadcast application of urea because of its incorporation within the seed zone likely was more available to the small corn plants, giving them an early boost and perhaps a greater root system. The timing of these events may also have been critical because ear size was being determined at this time. The urea treatment also produced the greatest grain N concentration and silage yield (Table 2). This resulted in significantly higher N uptake in both the grain and silage compared with most of the other N treatments. Differences in grain N concentration, grain N uptake, silage yield, and total N uptake were not significant among the fall and spring preplant applied AA treatments.

The General Linear Models procedure in SAS® was used to "contrast" the four primary treatments and determine if significant differences existed. The significance levels in Table 3 show no differences between fall AA with N-Serve and without N-Serve. However, both grain moisture and yield were less for the fall AA treatments compared to spring preplant AA when averaged across the N-Serve treatments. Grain yield for spring preplant AA with N-Serve was significantly greater than for preplant AA without N-Serve.

Water

Weather conditions during the 1996 growing season were cooler and slightly wetter than normal. Rainfall in June was 1.24" above normal followed by a very dry July when rainfall was 2.4" below normal. August rainfall was almost 3" above normal while November was the fifth wettest November on record at 2.4" above normal. Consequently tile drainage was heaviest in June and November when the lines flowed 18 and 10 days, respectively (Table 4). Drainage from the 16 corn plots averaged 3.79" with a 2.08" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 3.15" from the 16 plots and a range of only 0.43" among the four time/method treatments. Ideally, drainage should be uniform among the time/method treatments, however, normal soil and drainage variability exists in these plots and results in these unfortunate differences.

Table 2. Corn grain and silage production as influenced by time of application, N source, and nitrification inhibitor.

N application		Grain				Silage	Total N
Time	N-Serve	Yield	H_2O	N	N Uptake	Yield	uptake
		bu/A	%	%	lb/A	T DM/A	lb/A
Primary trts							
AA Fall (11/6)	No	152.6	29.9	1.16	84.1	6.21	112.3
AA Fall (11/6)	Yes	154.3	30.3	1.12	82.0	6.24	109.0
AA PP (5/1)	No	154.0	31.3	1.16	84.4	6.28	109.8
AA PP (5/1)	Yes	168.3	30.6	1.16	92.2	6.54	117.5
Additional trts							
Urea PP (5/1)	No	175.5	31.5	1.28	106.2	7.12	145.8
AA SD (6/14)	No	157.8	32.4	1.17	88.3	6.38	121.9
Check (No N)	--	104.9	34.4	0.86	42.9	4.57	58.6
Statistical Analysis Latin square (Primary trts)							
P > *F*:		0.03	0.06	0.84	0.20	0.34	0.45
LSD (0.05):		10.6					
CV (%):		4	2	6	7	4	7
Statistical Analysis Completely randomized (7 trts)							
P > *F*:		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):		22.9	1.7	0.11	18.1	0.90	21.2
CV (%):		10	4	7	15	10	13

Table 3. Significance levels for differences among the four primary treatments as determined by contrast statistics.

Parameter	Contrast		
	Fall without N-Serve vs Fall with N-Serve	Fall vs Spring	Spring without N-Serve vs Spring with N-Serve
	---------- Probability > *F* ----------		
Stover N Concentration	0.69	0.22	0.73
Grain N Concentration	0.45	0.66	0.96
Grain Moisture	0.38	0.02	0.12
Grain Yield	0.72	0.05	0.02
Stover Yield	0.99	0.96	0.50
Silage Yield	0.85	0.20	0.21
Final Population	0.81	0.18	0.83
Stover N Uptake	0.66	0.24	0.95
Grain N Uptake	0.65	0.14	0.12
Silage N Uptake	0.57	0.46	0.20
Relative Chlorophyll	0.30	0.90	0.47

Annual flow-weighted NO_3-N concentrations in the drainage water from the corn plots were highest for the fall AA without N-Serve and spring AA with N-Serve treatments (Table 5). But, the differences in monthly flow-weighted concentrations among the treatments really points to the relationship between time of N application and the time when excess rainfall and leaching occurred. In May, when very little drainage occurred, NO_3-N concentrations were highest for fall AA without N-Serve. During June when drainage was greatest, highest NO_3-N concentrations occurred with fall AA without N-Serve and spring preplant AA with N-Serve. The high concentrations with the latter treatment is surprising, but could indicate less denitrification with this treatment and subsequently higher yields. In November when drainage averaged about 0.4", significantly higher NO_3-N concentrations occurred with the spring preplant AA treatment with N-Serve. The late fall application of AA with N-Serve showed lowest NO_3-N concentrations throughout the year.

In the soybean plots, where N had been applied either in the fall of 1994 or spring of 1995, NO_3-N concentrations were consistently lower compared with the corn plots (Table 5). The average NO_3-N concentration was 8.2 mg/L with very little difference among the four N treatments. Nitrate-N concentrations under a 10-yr continuous fallow system (no fertilizer N applied) was 40% higher compared to the corn plots that received 120 lb N/A and 125% higher compared with the soybean plots.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1996.

N application		Month			Year[1]
Time	Inhibitor	May	June	November	Total
		-------------	acre-inches	-------------	
				Corn	
Fall (11/6)	No	0.06	4.34	0.33	4.76
Fall (11/6)	Yes	0.08	3.20	0.48	3.82
Spring (5/1)	No	0.14	3.34	0.37	3.90
Spring (5/1)	Yes	0.00	2.45	0.18	2.68
				Soybean	
Fall (10/28/94)	No	0.11	2.82	0.36	3.29
Fall (10/28/94)	Yes	0.13	2.64	0.37	3.15
Spring (4/25/95)	No	0.05	2.46	0.36	2.87
Spring (4/25/95)	Yes	0.07	2.83	0.39	3.30
				Fallow	
NONE		0.04	2.33	0.21	2.70

[1] Includes two days of flow in December.

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1996.

N application		Month			Year[1]
Time	Inhibitor	May	June	November	Average
		-----------	NO_3-N (mg/L)	-----------	
				Corn	
Fall (11/6)	No	10.7	14.4	8.9	14.1
Fall (11/6)	Yes	8.3	12.1	6.3	11.3
Spring (5/1)	No	9.6	13.6	8.1	12.8
Spring (5/1)	Yes	—	15.1	12.8	14.9
				Soybean	
Fall (10/28/94)	No	7.6	8.2	8.8	8.2
Fall (10/28/94)	Yes	8.5	7.1	8.6	7.3
Spring (4/25/95)	No	9.8	8.4	9.8	8.6
Spring (4/25/95)	Yes	10.0	8.4	10.0	8.6
				Fallow	
NONE		18.6	18.3	19.7	18.3

[1] Includes two days of flow in December.

Nitrate-N losses in the drainage water for 1996 varied considerably among the N treatments for corn, but losses under soybeans were not affected by the previous N treatments (Table 6). N-Serve reduced the NO_3-N losses by 5.2 lb/A when applied in the fall and by 2.0 lb/A when applied in the spring. Nitrate-N loss in the fallow system, where mineralization of soil organic matter was the NO_3 source, was similar to the average loss from the corn plots. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

Nitrate-N losses to the tile drainage water were normalized to tile water flow to minimize the influence of water flow volume among the N treatments on interpretation of the data (Table 7). Normalized values for corn were highest with the spring AA with N-Serve and fall AA without N-Serve treatments. Fall application of AA with N-Serve showed the lowest normalized value. Nitrate-N losses from the soybean plots as a function of the N treatments applied to corn in the previous year were considerably lower than from the corn plots. This probably reflects the low amount of residual N remaining from the 1994-95 treatments. Differences among the treatments were small, ranging from 1.58 lb NO_3-N/acre-inch of water for the fall AA with N-Serve treatment to 2.05 for the spring AA without N-Serve treatment. Normalized NO_3-N losses for the corn-soybean system ranked in the order: fall AA with N-Serve < spring AA without N-Serve = fall AA without N-Serve = spring AA with N-Serve. Continuous fallow gave the highest normalized loss of 4.0 lb NO_3-N/acre-inch of drainage. Additional years with adequate drainage losses are necessary to determine if these findings are consistent over time.

Table 6. Nitrate-N loss for each month from the corn, soybean, and fallow plots in 1996.

N application		Month			Year[1]
Time	Inhibitor	May	June	November	Total
		------------- NO_3-N (lb/A) -------------			
		Corn			
Fall (11/6)	No	0.2	13.9	0.6	14.7
Fall (11/6)	Yes	0.2	8.7	0.6	9.5
Spring (5/1)	No	0.3	10.0	0.7	11.1
Spring (5/1)	Yes	0.0	8.4	0.5	9.1
		Soybean			
Fall (10/28/94)	No	0.2	4.9	0.6	5.7
Fall (10/28/94)	Yes	0.2	4.1	0.7	5.0
Spring (4/25/95)	No	0.1	4.9	0.9	5.9
Spring (4/25/95)	Yes	0.2	5.4	0.8	6.4
		Fallow			
NONE		0.2	9.2	0.9	10.8

[1] Includes two days of flow in December.

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1996.

Crop System[1]	Time/Method of N Application			
	Fall No Inhibitor	Fall Inhibitor	Spring No Inhibitor	Spring Inhibitor
	------------ NO_3-N lost (lb/acre-inch of drainage) ------------			
Corn	3.09	2.48	2.85	3.39
Soybean[2]	1.72	1.58	2.05	1.93
Corn-Soybean System	2.53	2.08	2.51	2.59

[1] Continuous fallow (10 years without fertilizer N) = 4.00
[2] N applied for the 1995 corn crop at 120 lb N/A.

<u>Soil</u>

Residual soil nitrate-N (RSN) remaining in the 0-4' profile in November was about 2 times greater in the fallow plots compared to the plots that received the six N treatments (Table 8). All N treatments contained slightly more RSN in the 4-ft profile compared with the check (no N) treatment. Slightly higher RSN was found in the urea treatment with little difference among the five AA treatments. About one-half of the RSN in the 4-ft profile was found in the top foot.

Table 8. Residual soil nitrate-N in November 1996 from all fallow and corn plots as influenced by N treatment.

Profile depth	Fallow NO_3-N	N Treatment for Corn						
		Fall AA	Fall AA+NI	PP AA	PP AA+NI	Urea	SD AA	Check (No N)
feet	--- lb/A ---	-------------------- lb/A --------------------						
0 - 1	42	20	28	24	24	31	29	21
1 - 2	29	9	7	9	7	14	11	6
2 - 3	19	5	4	8	6	10	5	4
3 - 4	18	6	5	9	6	7	5	3
<u>Total in</u> 0 - 4' profile	108	40	44	49	42	62	50	33

RESIDUAL EFFECTS OF NITROGEN APPLIED TO ESTABLISHED REED CANARYGRASS

J. A. Vetsch, G. W. Randall, and M. P. Russelle[1]

ABSTRACT: Recently developed low-alkaloid varieties of reed canarygrass are being considered as an alternative forage for dairy enterprises. The objectives of this 5-year study were to determine the effect of single early-season and split applications of fertilizer N on the yield and quality of reed canarygrass. Very high N rates (up to 600 lb/A) were applied in 1994 to examine the effect on yield and to determine the potential for downward movement of excess N in the soil profile. Because substantial soil NO_3-N remained in the 0-4 ft profile in the fall of 1994 (when rates of ≥ 400 lb N/A were applied), we measured reed canarygrass yield and N uptake in 1995 and again in 1996 to determine the availability of residual N. Our results showed up to 8 percent recovery in 1996 from the fertilizer N applied in 1994. Three-year recoveries totaled 74, 64, and 57 percent for 400, 500, and 600 lb N/A rates, respectively. These results suggest that residual N can be effectively utilized by reed canarygrass and little residual nitrate will be lost to ground and surface water when optimum N rates are exceeded.

EXPERIMENTAL PROCEDURES

Ninety-six plots, measuring 10 ft by 20 ft, were laid out on established reed canarygrass (variety Palaton) in April 1994 on a Webster clay loam soil. Plots were fertilized in 1994 with varying rates of N as ammonium nitrate on April 11 and June 20 after first cutting. In 1995 and 1996 yields were taken from selected N rates (Table 1) to evaluate the residual effects of N fertilization in 1994. A single treatment (300 annually) received 300 lb N/A as ammonium nitrate in 1994, 1995 and 1996. Yields were taken by harvesting a 3 ft by 19 ft swath from each plot on June 13, July 25, and September 13. Forage was analyzed for moisture content and total Kjeldahl N. The total N analyses were conducted by Dr. Russelle's Laboratory in St. Paul.

RESULTS AND DISCUSSION

Dry Matter Yield, Total N Concentration, and N Removal by Harvest

Yield data, obtained in 1996 from selected treatments applied in 1994, were taken to determine the potential for plant recovery of residual N. Nitrogen fertilizer applied in 1994 significantly affected dry matter yields, total N concentration, and N removal in 1996 (Table 1). First and second harvest and total (annual) yields were increased significantly by 1994 rates ≥400 lb N/A compared to the control (zero N). A 1994 rate of 600 lb N/A resulted in a yield increase for the third harvest when compared to the control. Total N concentration and N removal were also increased significantly greater than the control by 1994 N rates ≥400 lb/A. The '300 annually' treatment (300 lb N/A in 1994, 1995, and 1996) had significantly greater total N concentration for all three cuts but did not result in greater dry matter yield and N removal. In general dry matter yields in 1996 were much lower than usual due to cold temperatures in May (4° F below normal), which resulted in reduced first cut yields, and very dry conditions from June 20 to August 5, which resulted in reduced second cut yields.

Table 1. Residual effects of N applied in 1994 on dry matter yield, total N, and N removal of reed canarygrass in 1996.

	Dry Matter Yield				Total N Concentration			Nitrogen Removal			
1994 Total N Rate	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	Total
lb N/A	----- T DM/A -----				----- % -----			----- lb N/A -----			
0	0.210	0.280	0.154	0.645	1.35	1.46	1.73	5.7	8.3	5.3	19.3
300	0.335				1.36			8.9			
350	0.418				1.42			11.7			
400	0.654	0.517	0.237	1.408	1.29	1.56	2.00	16.6	16.1	9.6	42.3
500	0.662	0.569	0.273	1.504	1.66	1.75	2.03	21.8	20.0	11.1	52.9
600	0.938	0.490	0.453	1.881	1.60	1.72	2.17	29.8	17.0	19.9	66.7
300 Annually[1]	0.771	0.289	0.382	1.441	2.57	3.22	3.13	38.6	18.3	23.8	80.7
Statistical Analysis											
Pr. > *F*:	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):	0.282	0.194	0.167	0.515	0.29	0.29	0.21	9.0	7.6	8.5	20.3
CV (%):	33	29	36	24	12	10	6	32	31	40	25

[1] 300 lb N/A applied annually in 1994, 1995 and 1996.

[1] Assistant Scientist and Professor, University of Minnesota Southern Experiment Station, Waseca; Soil Scientist, USDA-ARS-US Dairy Forage Research Center, St. Paul.

Annual N Removal and Apparent N Recovery

Apparent N recoveries were calculated from total N removed for 1994, 1995 and 1996 (Table 2). First year (fertilization year) recoveries were lower in 1994 compared to previous years. Therefore, considerable residual N was expected for plant growth in subsequent years. Nitrogen removal and apparent N recovery in 1996 (two years after fertilization) were considerably less than in 1994 (fertilization year) and 1995 (one year after fertilization). The combined N recovery was calculated by adding the N recovery from 1994, 1995 and 1996. The combined (three-year) recoveries of 74 and 64 percent at N rates of 400 and 500 lb/A respectively, are similar to recoveries obtained at these N rates in 1993. A three-year recovery of 57 percent at the 600 lb/A N rate was considerably lower than the two-year recovery of 77 percent at that N rate applied in 1993 (data from 1995 Bluebook). Observations at 600 lb N/A in 1996 (lower combined N recovery and significantly greater 3rd cut yield) suggest that some residual N may be available at the this N rate for the 1997 growing season. However, since combined recoveries were considerably lower than first year recoveries in 1992 and 1993, some N was probably immobilized or lost from the rooting zone.

Table 2. Annual N removal and apparent recovery of fertilizer N by reed canarygrass in 1996 as affected by N rate in 1994.

	Total Annual N Removal			Apparent N Recovery[1]			
1994 Total N Rate	1994	1995	1996	1994	1995	1996	Combined[2]
-- lb N/A --	-------- lb N/A --------			--------- percent ---------			
0	84	39	19	-	-	-	-
400	230	166	42	36	32	6	74
500	241	167	53	31	26	7	64
600	246	171	67	27	22	8	57

[1] Apparent N Recovery = (Total N removal - N removal from control) ÷ Total N applied in 1994.
[2] Recovery of N applied in 1994 by dry matter in 1994, 1995 and 1996.

Recommendation

This report concludes five years of research in N fertilization of reed canarygrass at Waseca. Based on this research the following recommendations for nitrogen fertilization of reed canarygrass can be made. Single early-season (April) applications of N are as effective as split applications for dry matter production. A single early-season application of 200 lb N/A is recommended for optimum yields. If growing conditions are excellent and a first cut yield > 2.3 T DM/A is obtained, then an additional 50 to 100 lb N/A may be warranted after first cutting. Nitrate concentration in the forage can reach toxic levels when single applications of N exceed 200 lb/A. Thus, forage nitrate concentrations need to be monitored and feed rations may have to be adjusted. At these recommended N rates for optimum production, we would not expect N loss from the soil profile.

EVALUATING SOIL N TEST METHODS ON A FIELD WITH A MANURE HISTORY

G. W. Randall, M. A. Schmitt, and J. A. Vetsch[1/]

ABSTRACT: Nitrogen can become available to the plant from previous applications of manure. The purpose of this study was to evaluate various soil N test methods to see if Minnesota's new soil N test needs to be modified or an additional test needs to be developed to more accurately predict soil N availability to crops in animal-based systems. Results from this trial indicate that the recommended rate of fertilizer N would have been improved at this site if a preplant, 0-2 foot soil sample would have been taken. This test would have suggested a 65-lb N credit from the 100-lb recommendation based on past crop, soil organic matter, and yield goal. The resulting 35-lb N recommendation would have optimized grain yield, which agrees extremely well with the data obtained.

Manure is often applied to the same fields each year by producers because of the proximity of the field to the livestock facility or because of an inadequate land base to facilitate less frequent applications. As a result, manure-N may accumulate over time and can then become available through mineralization to succeeding crops. The amount of N becoming available in any particular field is unknown. Thus, fertilizer N recommendations usually do not take into account these previous applications.

The purpose of this study is to evaluate various soil N tests in animal-based systems to see if our present soil N test needs to be modified or a new test developed to more accurately predict soil N availability to crops. To do this we must obtain experimental sites with a long-term manure history, apply a series of fertilizer N rates, determine the yield response to the fertilizer, and then calibrate this response or lack of response to soil N values obtained by various soil tests.

EXPERIMENTAL PROCEDURES

The site for 1996 was a Nicollet clay loam soil at the Southern Experiment Station in Waseca. This site had been cropped to alfalfa in 1992-4 and corn in 1995. It received 10000 gal/acre of dairy manure in the spring of 1995.

Nitrogen as urea was broadcast-applied and incorporated at rates of 30, 60, 90, 120, 150 and 180 lb N/A just before planting and was compared to an unfertilized check plot. A randomized complete block design with four replications was used for the experiment. Pioneer 3730 was planted on April 30 and thinned to a uniform population of 31050 plants per acre. Weeds were controlled very well with a combination of herbicides and cultivation.

Grain yields were combine harvested by taking 89 feet of row. Stover yields were hand harvested by taking 15 feet of row at physiological maturity.

Soil samples were taken from the control plots in 1 foot increments to a depth of 3 feet at three times during the season (preplant, emergence, and 10- to 12-inch tall corn). After harvest, samples were taken to a 4 foot depth from the 0, 90 and 180-lb treatments. Samples were analyzed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N).

Chlorophyll measurements were taken each week from the V9 stage of growth through R3. Thirty plants in each plot were measured and the average reported. SPAD meter values were normalized by calculating the relative value based on the highest treatment reading being equal to 100 percent.

RESULTS AND DISCUSSION

Corn yields were very good despite cool spring temperatures (Table 1). Statistical analyses showed that grain yields were optimized at the 30-lb N rate. Stover and silage yields increased with increasing N rate up to 150 and 180 lb N/acre, respectively. Stover and grain N concentration was optimized at 120 and 180 lb N/A, respectively. Removal of N in the stover, grain, and silage was optimized at the 150, 180, and 180-lb N rates, respectively. These rates are surprisingly high considering that grain yield was optimized with only 30 lb N/A. However, because stover yields continued to increase with N rates through 150 lb/A and N concentrations in the grain increased with increasing N rate, N removal by the plant did not reflect an economic grain yield response. The reason for this disagreement, which is rather unusual, may be that this hybrid continues to accumulate N at higher rates of applied N even though grain yield does not respond - - at least under the weather conditions encountered in 1996. Relative chlorophyll content throughout the season suggests that corn production was optimized at the 60-lb N rate, based on other studies where relative values greater than 95% indicated optimum yields.

[1/] Professor, Southern Experiment Station, Waseca; Assoc. Professor, Dept. of Soil, Water, and Climate, St. Paul; and Assistant Scientist, Southern Experiment Station, Waseca.

Table 1. Corn grain yield, silage yield, and relative chlorophyll content as influenced by N applied to fields with a manure history in 1996.

N Rate	Yield			N Conc.		N Removal			Relative Chlorophyll Content[1]					
	Grain	Stover	Silage	Stover	Grain	Stover	Grain	Silage	V9	V12	R1	R2	R2-3	R3
lb/A	bu/A	- T DM/A -		- percent -		--- lb/A ---			---------- percent ----------					
0	165	2.90	6.81	0.70	1.16	41	90	131	91	95	89	88	87	87
30	177	3.31	7.50	0.67	1.20	44	100	144	94	98	93	90	94	93
60	176	3.45	7.61	0.69	1.37	48	114	162	98	96	96	93	97	96
90	166	3.62	7.55	0.72	1.39	52	109	161	97	97	97	96	98	97
120	177	3.70	7.90	0.82	1.39	61	117	178	100	100	98	98	100	99
150	176	3.83	7.99	0.84	1.40	64	117	181	97	98	100	96	99	100
180	185	4.00	8.37	0.91	1.55	72	133	200	99	98	100	100	99	99
Pr. > *F*:	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.10):	11	0.29	0.35	0.09	0.10	9	12	12	3	2	2	3	2	2
CV (%):	5	7	4	10	6	13	9	6	3	2	1	3	1	2

[1] Relative to the treatment with the highest chlorophyll content

Soil NO_3-N analysis (Table 2) indicated carryover of nitrate-N throughout the 0- to 3-ft profile at the preplant sampling. Residual N values from samples taken at emergence and when the corn was about 10 inches tall were similar to the preplant N concentrations at the 2-3 foot depth only. Residual soil nitrate-N (RSN) in the surface foot was somewhat lower at the later sampling times suggesting some had been leached to lower depths, denitrified and/or taken up by the crop (10 inch corn). Carryover of RSN in the 0- to 4-ft profile at the end of the 1996 season was very low in the 0 and 90-lb N treatments with a slight accumulation at the 180-lb rate. It is interesting to note the higher NO_3-N concentrations below two feet, which suggests that some of the excess N applied was being leached from the upper portion of the profile.

Table 2. Soil NO_3-N as influenced by time and depth of sampling in a field with a manure history in 1996.

Sampling		Soil Nitrate-Nitrogen (Depth)					
Time	N Rate	0 - 1′	1 - 2′	2 - 3′	3 - 4′	0 - 2′	0 - 4′
	lb/A	--------------- ppm ---------------					lb NO_3-N/A
Preplant	0	9.6	9.7	9.1	6.8	9.6	141
V1 (emergence)	0	6.3	8.3	9.7		7.3	
V4 (10 inch corn)	0	5.6	8.5	8.6		7.0	
Post Harvest	0	4.2	1.4	0.6	1.5		30
"	90	3.7	2.2	2.3	3.9		48
"	180	5.5	5.4	6.8	6.5		97

SUMMARY

- Even though corn yields were quite good, the yield response of continuous corn to fertilizer N was limited in this field with a manure history.
- The present soil N test provided a N recommendation much closer to the optimum economic rate compared to not using the test. Thus, the test paid economic dividends even though it was not perfect.
- The potential for NO_3^- leaching to the groundwater is greatly increased by high levels of RSN accumulating in soils when fertilizer N is added without taking into account the release of N from previously applied manure.
- Further research appears necessary to more accurately predict the N availability in fields with a long-term manure history.

ENHANCING NO-TILLAGE SYSTEMS FOR CORN WITH STARTER FERTILIZER, ROW CLEANERS AND NITROGEN PLACEMENT METHODS[1]

J.A. Vetsch and G.W. Randall[2]

ABSTRACT: No-till production often gives slower corn growth, lower yields, and reduced profitability in the northern Corn Belt. A 2^3 factorial experiment was conducted on a tile drained Nicollet-Webster clay loam soil complex in 1996 to determine the effect of starter fertilizer, row cleaners, and N source/placement method on no-till production of continuous corn and corn after soybeans. Surface residue coverage prior to planting was >95% in both cropping systems and did not fall below 50% in late August in either system. Corn emergence was very slow due to cold soil temperatures in May but was enhanced about 1 to 2 days by the use of row cleaners in the continuous corn system. Midden counts, an indication of night crawler activity, were very low in continuous corn but increased to high levels in the corn-soybean rotation. Fewer middens were found with anhydrous ammonia (AA) compared to spoke-wheel injected UAN. Starter fertilizer (10 gal 10-34-0/acre) decreased final stand about 3 to 5% for both cropping systems. Early growth of continuous corn was stimulated by starter fertilizer and yields were increased 8.3 bu/acre when using AA as the N source but not when UAN was spoke-injected next to the row. Row cleaners increased continuous corn grain yield 4.6 bu/acre but had no effect on corn yields following soybeans. Corn yields following soybeans were not affected by N source or starter fertilizer. Preplant application of UAN + Agrotain reduced continuous corn yields by 7.5 bu/acre and corn yields following soybeans by 10.3 bu/acre compared to UAN spoke-injected at the V1 stage.

INTRODUCTION

No-till corn production in the northern portions of the Corn Belt has provided serious challenges to corn growers and often has not been economically competitive with conventional or slightly reduced tillage systems. This is especially true on the highly productive but more poorly drained clay loam soils of northern Iowa and southern Minnesota where approximately 8 million acres of corn are grown. These soils are cold at the time of planting and are slow to warm. Due to slow root development, early plant growth is retarded and delayed silking, high moisture at maturity, and reduced corn yields result. These systems and their effects occur most frequently with continuous corn but also are noticeable and do impact corn following soybeans. Yet, to meet guidelines of 30% surface crop residue coverage after planting on highly erodible land, no tillage is required following soybean. Thus, no tillage is strongly advocated by the USDA-NRCS on these soils and is promoted actively on soils that have less erosion potential.

Three management options may correct these problems or at least help no-till corn production to be more competitive. First, fluid starter fertilizer (10-34-0) placed with the seed as a "pop-up" may help stimulate early root and shoot growth, thereby allowing the plant to capture more sunlight energy in June for earlier maturity and higher yields. Second, using row cleaners to clear the residue from a 4 to 6" zone over the row should allow greater warming of the soil in the seed zone and better seed to soil contact to improve emergence. Third, placement of fluid UAN within 2 to 3" of the row with a spoke-wheel injector may stimulate early plant growth compared to injection of N midway between the rows.

The primary objective of the project is to determine the effects and interactions of starter fertilizer, row cleaners, and N source/placement method on corn grain yield in continuous corn and corn-soybean rotation no-till cropping systems. A secondary objective is to evaluate preplant, broadcast-applied UAN with Agrotain compared to post emergence, spoke-wheel injected UAN in both cropping systems.

EXPERIMENTAL PROCEDURES

The experiments were conducted on a tile drained Nicollet-Webster clay loam soil complex located at the Southern Experiment Station, Waseca, Minnesota. The tile lines were spaced 75' apart and all corn rows were perpendicular to the tile lines. The continuous corn plots were located on the same plots as in 1995, and the stalks had not been chopped. Corn also followed soybeans that had been planted in 1995 and corn in 1994. Each plot was 10' wide (4 - 30" rows) by 120' long. The experimental design was a 2^3 factorial with complete randomization within each of the four replicates. The UAN + Agrotain treatment was randomized within the other eight treatments and was compared to treatment No. 7 using contrast statistics.

Corn (Pioneer 3556) was planted on May 2 at a population of 32000 plants/acre with a John Deere Max-Emerge planter equipped with 1" fluted coulters. Row cleaners (Dawn) were used on one-half of the plots. Fluid 10-34-0 was applied with the seed at a rate of 10 gal/acre on one-half of the plots. Additional P was not applied because soil test Bray P_1 was 26 and 30 ppm (very high) on the continuous corn and corn-soybean rotation sites, respectively. Force insecticide was used to control corn root worm in the continuous corn. Weeds were very well controlled with a preemergence application of Harness plus Bladex. None of the plots were cultivated.

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[1] Funding provided by the Fluid Fertilizer Foundation and the University of Minnesota, Southern Experiment Station.

[2] Assistant Scientist and Professor, respectively, University of Minnesota, Southern Experiment Station.

Nitrogen as UAN (28% N) was broadcast applied with Agrotain to treatment No. 9 on April 18. At the V1 stage (May 31) UAN was spoke-wheel injected 4" deep about 2 to 3" from the row on one-half of the plots whereas anhydrous ammonia (AA) was injected about 7" deep midway between the rows. The N rate used was 160 lb N/acre for continuous corn and 120 lb N/acre for corn after soybeans.

Surface residue measurements using the line transect method were taken at a 45° angle to the rows periodically during the season. Emergence rate was determined by daily counting the number of plants that had emerged from 30 feet of row in each plot. This was done until no more plants emerged (June 12). Final plant population was determined from 120 feet of row in each plot on June 21. Middens, a small hut formed from residue around a night crawler's burrow, were counted in a 10 ft^2 area in each plot at four times during the season. Extended-leaf plant heights were determined from 10 plants per plot on July 1. Grain yields and moisture content were taken on October 21 by harvesting the center two rows of each plot with a JD3300 plot combine. The stalks were not chopped prior to snowfall in November.

RESULTS

Continuous Corn

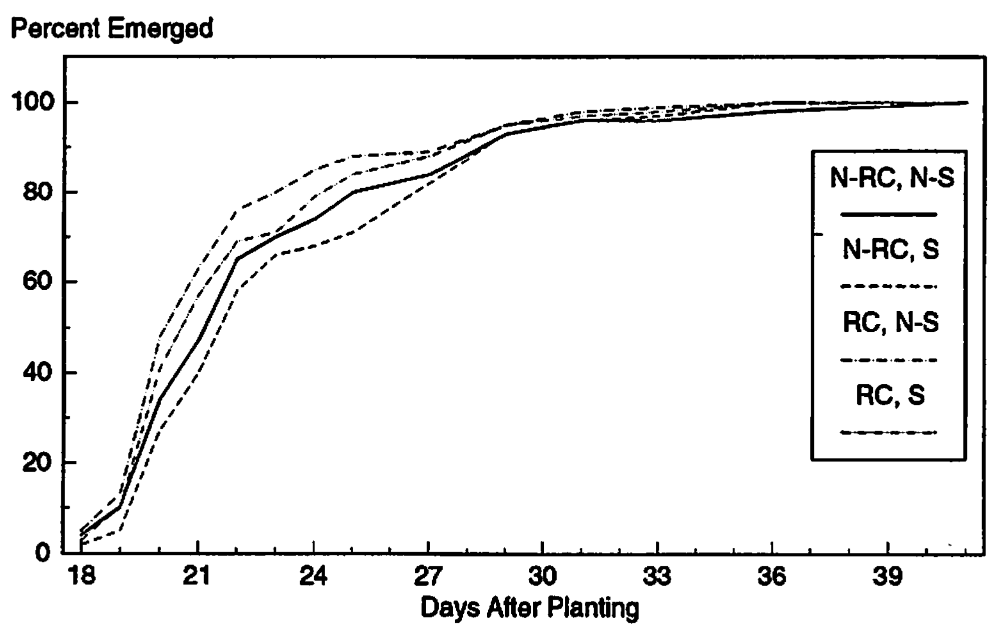
Surface residue coverage was extremely high throughout the season and is reflective of the high yields of very durable stover produced by the hybrid grown in 1994 and 1995 (Table 1). Coverage totaled nearly 100% on April 11 and decreased to about 70% by August 30. At the time of corn emergence coverage averaged about 90%. Residue cleaners did not have a lasting effect on clearing the residue from the row. High winds redistributed some of the residue back on the row before measurements were taken. Residue coverage was less after N application where AA was knifed in compared to the spoke wheel injection of UAN.

Table 1. Surface residue accumulation as influenced by row cleaners and method of N application in continuous corn and corn-soybean no-till cropping systems in 1996.

Trt. No.	N Source	Row Cleaner	Continuous Corn Date 4/11	5/30	7/17	8/30	Corn after Soybean Date 4/11	5/30	7/11	8/30
			%							
3	UAN	No	100	95	94	74	97	85	77	57
4	AA	No	98	91	77	64	97	77	58	53
7	UAN	Yes	99	98	92	74	98	81	74	60
8	AA	Yes	99	90	77	70	96	80	63	46
9	UAN	Yes	98	90	90	72	97	76	77	61

Corn emergence was very slow in 1996 due to cold temperatures in May (Figure 1). Soil temperature at the 2-inch depth on residue-free soil averaged only 56.1°F for the month. Corn did not begin to emerge until 18 days after planting and continued to emerge during the following 12-day period. Row cleaners resulted in 1 to 2-day earlier corn emergence. Starter fertilizer delayed corn emergence about 1 day.

Figure 1. Emergence rate of continuous corn as influenced by row cleaners and starter fertilizer in 1996.



Midden counts were extremely low in all continuous corn plots through July (Table 2). Counts were not taken again in 1996 because they were so low, indicating almost a complete lack of night crawler activity.

Plant heights, taken on July 1, were significantly increased about 2 inches by spoke-wheel injected UAN, row cleaners, and starter fertilizer compared to injected AA, no-row cleaners, and no starter fertilizer (Table 3). The highly significant interaction between N source and starter fertilizer was due to no increase in plant height with starter fertilizer when UAN was used but a 4.5" increase for starter fertilizer when AA was used. Apparently the N in the spoke-wheel injected UAN stimulated early plant growth and starter fertilizer was not necessary. Starter fertilizer, however, did enhance early growth when AA was applied 15" from the row.

Final plant population was not directly affected by N source or row cleaner use (Table 3). Starter fertilizer reduced plant population by 3% (850 plants/acre) when averaged across row cleaners and N sources. The significant interaction between N source and row cleaners was due to the plant population being 1200 plants/acre lower when row cleaners were not used and UAN was applied; however, when AA was applied, row cleaners had no effect on population.

Grain yield was increased 4.6 bu/acre with the use of row cleaners when averaged across N sources and starter fertilizer (Table 3). The main effects of N source and starter fertilizer did not affect corn grain yield; however, the interaction was highly significant. When UAN was used, yield was not affected by starter fertilizer. On the other hand, an 8.3 bu/acre response to starter was obtained when AA was used. Preplant broadcast application of UAN + Agrotain resulted in a statistically significant yield decrease of 7.5 bu/acre compared to the spoke-wheel application of UAN.

Table 2. Midden counts as influenced by row cleaners and method of N application in continuous corn and corn-soybean rotation no-till cropping systems in 1996.

Trt. No.	N Source	Row Cleaner	Continuous Corn Date 4/11	5/30	7/17	Corn after Soybean Date 4/11	5/30	7/11	8/30
			---------- Middens/10 sq. feet ----------						
3	UAN	No	0.1	0.3	0.0	2.4	5.3	9.5	19.0
4	AA	No	0.4	0.0	0.1	2.8	7.1	4.6	12.5
7	UAN	Yes	0.6	0.4	0.4	3.0	7.9	8.3	21.9
8	AA	Yes	0.3	0.3	0.1	2.4	6.5	3.5	13.4
9	UAN	Yes	0.5	0.8	0.3	3.6	9.0	9.8	23.1

Grain moisture was one-half point lower with the use of starter fertilizer when averaged across N sources and row cleaners (Table 3). Similar to grain yield, a highly significant interaction occurred between N source and starter fertilizer. Grain moisture was one point lower when starter fertilizer was used with AA, but moisture was not affected by starter fertilizer when UAN was used.

Nitrogen concentration in the corn grain was not affected by treatment main effects (N source, row cleaner, and starter fertilizer). The significant interaction between N source and row cleaner (P value 0.053) was a result of greater N concentration in the corn grain with UAN when row cleaners were not used compared to greater N concentration in the grain with AA when row cleaners were used. Grain N uptake was not affected by treatment application.

Corn-Soybean Rotation

Surface residue coverage was very high throughout the season because both soybean residue from 1995 and corn residue from 1994 were present (Table 1). Similar to continuous corn, wind redistributed the residue after planting, and measurements taken 4 weeks after planting showed no effect of row cleaners on surface residue coverage. Measurements taken 6 weeks after N application show consistently lower residue coverage with the AA treatment. At the end of August residue coverage still exceeded 50% and was consistently higher for the spoke-injected UAN treatments.

Corn emergence started 18 days after planting and was complete within a 10-day period (Figure 2). Emergence rate was not influenced by row cleaners or starter fertilizer.

Midden counts, an indication of night crawler activity, were much higher in the corn-soybean rotation compared to continuous corn and continued to increase during the season (Table 2). Prior to N application, no consistent differences were evident among the treatments. However, after N application midden counts were substantially lower for the AA plots compared to the UAN plots. This was likely due to the disturbance of their habitat by the knife injection of AA and possibly some mortality associated with the caustic nature of AA.

Figure 2. Emergence rate of corn following soybeans as influenced by row cleaners and starter fertilizer in 1996.

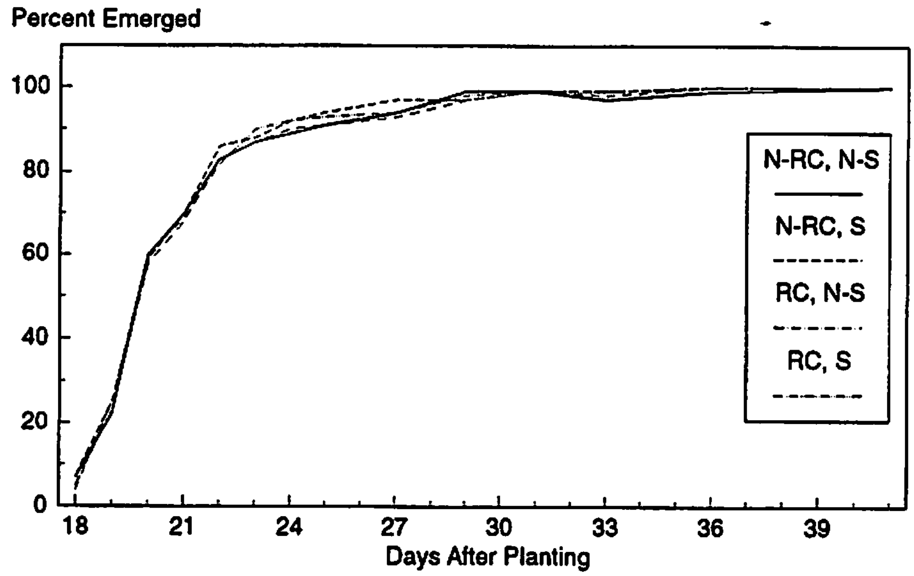


Table 3. Plant height, final population, corn grain yield, grain moisture, grain N concentration, and N uptake as affected by N source, row cleaners, and starter fertilizer in a no-till continuous corn system in 1996.

Treatments				Plant		Corn Grain			
No.	N Source	RC	SF	Height	Population	Yield	Moist.	N	N Up.
				inch	pl/acre	bu/acre	%	%	lb/acre
1	UAN	No	No	31.4	27100	130.1	21.2	1.12	69.0
2	AA	No	No	28.1	29060	126.9	21.8	1.07	64.0
3	UAN	No	Yes	31.2	26100	128.0	21.4	1.15	69.4
4	AA	No	Yes	31.4	27120	135.7	21.1	1.11	71.3
5	UAN	Yes	No	34.4	28350	137.5	20.9	1.07	68.9
6	AA	Yes	No	28.4	27150	129.3	22.1	1.17	71.5
7	UAN	Yes	Yes	34.3	27280	135.1	21.0	1.11	71.1
8	AA	Yes	Yes	34.0	27730	137.1	20.8	1.18	76.3
9	UAN Bdct	Yes	Yes	33.6	27770	127.6	20.8	1.11	67.1
Statistical analysis of main effects for 2^3 factorial design									
N Source (NS)									
UAN				32.8	27210	132.7	21.1	1.11	69.6
AA				30.5	27760	132.3	21.4	1.13	70.8
Pr. > F:				<0.001	0.156	0.830	0.093	0.527	0.544
Row Cleaner (RC)									
No				30.5	27340	130.2	21.4	1.11	68.4
Yes				32.8	27630	134.8	21.2	1.13	72.0
Pr. > F:				<0.001	0.459	0.025	0.273	0.502	0.075
Starter Fertilizer (SF)									
No				30.6	27910	131.0	21.5	1.10	68.4
Yes				32.7	27060	134.0	21.0	1.14	72.0
Pr. > F:				<0.001	0.034	0.126	0.019	0.326	0.066
Statistical analysis of interaction effects for 2^3 factorial design									
NS x RC (Pr. > F)				0.141	0.023	0.174	0.371	0.053	0.161
NS x SF (Pr. > F)				<0.001	0.646	0.011	0.005	0.843	0.222
RC x SF (Pr. > F)				0.273	0.120	0.861	0.336	0.874	0.927
NS x RC x SF (Pr. > F)				0.325	0.101	0.922	0.533	0.634	0.575
C.V. (%)				4.7	3.9	4.1	2.4	7.8	7.6
Contrast analysis of treatment 7 vs 9									
Injected vs Bdct. (Pr. > F)				0.497	0.496	0.051	0.621	0.905	0.306

Plant heights, taken on July 1, were about 4 inches higher for the starter fertilizer treatments when averaged across N source and row cleaner treatments (Table 4). Neither N source nor row cleaner affected plant height, and there were no significant interactions among N source, row cleaners, or starter fertilizer.

. ıant population was not affected by N source or row cleaner use, but similar to continuous corn, it was reduced about 5% (1400 plants/acre) with starter fertilizer when averaged across N sources and row cleaners (Table 4).

Corn grain yield following soybeans was not affected by N source, row cleaners, or starter fertilizer (Table 4). However, yields averaged about 28 bu/acre more than did continuous corn. Preplant broadcast application of UAN + Agrotain resulted in a statistically significant yield decrease of 10.5 bu/acre compared to the spoke-wheel injection of UAN. This was similar to the continuous corn plots and suggests that broadcast UAN may be immobilized by the high amount of residue on the soil surface.

Grain moisture content at harvest was not affected by any of the treatments.

Nitrogen concentration in the corn grain was not affected by treatment main effects (N source, row cleaner, and starter fertilizer). The significant interaction between N source and starter fertilizer (P = 0.047) occurred because grain N concentration was not affected by starter fertilizer when UAN was used; whereas grain N increased 0.09 percentage points with starter fertilzier when AA was used.

Table 4. Plant height, final population, corn grain yield, grain moisture, grain N concentration, and N uptake as affected by N source, row cleaners, and starter fertilizer in a no-till corn-soybean rotation in 1996.

Treatments				Plant		Corn Grain			
No.	N Source	RC	SF	Population	Height	Yield	Moist.	N	N Up.
				pl/acre	inch	bu/acre	%	%	lb/acre
1	UAN	No	No	29090	34.5	158.2	23.1	1.15	85.6
2	AA	No	No	28660	32.3	160.4	23.0	1.18	89.0
3	UAN	No	Yes	27390	37.0	158.3	23.0	1.14	84.9
4	AA	No	Yes	27620	37.9	163.8	23.2	1.24	96.2
5	UAN	Yes	No	28550	34.7	158.2	22.9	1.21	90.7
6	AA	Yes	No	29370	33.6	160.8	23.2	1.12	84.9
7	UAN	Yes	Yes	27230	38.1	163.8	22.3	1.18	91.8
8	AA	Yes	Yes	27860	37.2	159.5	22.7	1.23	92.4
9	UAN Bdct	Yes	Yes	27720	38.5	153.3	22.3	1.19	85.8
Statistical analysis of main effects for 2^3 factorial design									
N Source (NS)									
UAN				28060	36.1	159.6	22.8	1.17	88.3
AA				28380	35.2	161.1	23.0	1.19	90.7
Pr. > F:				0.454	0.150	0.478	0.376	0.406	0.366
Row Cleaner (RC)									
No				28190	35.4	160.2	23.1	1.17	88.9
Yes				28250	35.9	160.6	22.8	1.18	90.0
Pr. > F:				0.886	0.380	0.854	0.283	0.685	0.686
Starter Fertilizer (SF)									
No				28920	33.7	159.4	23.0	1.16	87.6
Yes				27520	37.6	161.4	22.8	1.20	91.3
Pr. > F:				0.003	<0.001	0.365	0.327	0.197	0.157
Statistical analysis of interaction effects for 2^3 factorial design									
NS x RC (Pr. > F)				0.324	0.734	0.266	0.547	0.083	0.067
NS x SF (Pr. > F)				0.769	0.150	0.682	0.682	0.047	0.182
RC x SF (Pr. > F)				0.955	0.602	0.924	0.283	0.829	0.839
NS x RC x SF (Pr. > F)				0.606	0.175	0.235	0.866	0.551	0.888
C.V. (%)				4.1	4.3	3.7	3.2	6.2	8.1
Contrast analysis of treatment 7 vs 9									
Injected vs Bdct. (Pr. > F)				0.540	0.740	0.020	1.000	0.960	0.229

THE EFFECTS OF RESIDUE MANAGEMENT AND HERBICIDE APPLICATION METHODS ON LOSS OF AGRICULTURAL CONTAMINANTS IN SURFACE WATER [1]

N.C. Hansen, J.F. Moncrief, and S.C. Gupta [2]

ABSTRACT

Tillage and herbicide application method are being evaluated on runoff plots in Scott County, Minnesota. This report includes the first and second years of a three year continuous corn study in which runoff losses of sediment, herbicides, phosphorus, and chemical oxygen demand are being evaluated. Tillage treatments are moldboard plow, chisel plow, and ridge tillage and the preemergent herbicides alachlor and cyanazine are applied by broadcasting or banding methods. Tillage effects on runoff and contaminant loss differed between snowmelt and rainfall induced runoff. Snowmelt runoff represented the largest fraction of annual runoff and was in the order of ridge till>chisel plow>moldboard plow. For rainfall induced runoff, the order was moldboard plow>chisel plow>ridge till. Surface residue associated with the ridge till and chisel plow systems was effective in reducing soil loss, especially following planting and before canopy closure. Phosphours loss in rainfall runoff was lower from the ridge till system than from the other tillage systems but on an annual basis the three tillage systems lost similar amounts of total P. For ridge tilled plots the majority of P loss was lost as soluble P in snowmelt runoff, while for chisel and moldboard plowed plots, P losses came from snowmelt and rainfall induced runoff. Total loss of COD was lower in the ridge till system than in the chisel and moldboard plow systems.

Banding of herbicides significantly reduced herbicide loss for the moldboard and chisel plow systems. Losses from the ridge till system were low regardless of application method. Following cultivation, weed control was similar for both herbicide application methods, and yield did not differ. However, if cultivation was not performed, high weed pressure and yield losses would be expected when herbicides are applied in a band. For broadcast application, runoff losses of alachlor and cyanazine were in the order of moldboard plow > chisel plow > ridge till. Thus, herbicide banding and/or conservation tillage are effective management tools for reducing herbicide losses to surface runoff.

INTRODUCTION

Contamination of surface and ground waters from sediment and land applied agricultural chemicals is a significant concern. Among the contaminants, nitrate, phosphorus, and sediment have received the most attention. The primary concern with the Minnesota River is biochemical oxygen demand (BOD), phosphorus (P), and suspended solids primarily from diffuse sources during high flow years. Several high use herbicides have been detected in the Minnesota River and its tributaries. Use of tillage approaches that manage crop residue, such as no-till, ridge till, and chisel plowing systems, have been promoted for sustainable production and for reducing runoff and contaminant losses from agricultural fields. These methods are effective in reducing upland erosion during the critical period between planting and canopy development and therefore reducing the contribution of sediment to streams and rivers. This study was designed to assess the impact of moldboard plowing vs. ridge tilling or chisel plowing on runoff and loss of sediment, herbicides, phosphorus, oxygen demand. The specific objectives of this study are

1. To compare runoff, contaminant loss, and yields from plots managed with moldboard plow, chisel plow, or ridge till based systems.
2. To evaluate seasonal differences in runoff and contaminant losses from various tillage systems.
3. To assess and demonstrate the impacts of herbicide application method on the loss of pesticides in surface water.

MATERIALS AND METHODS

The plots are located on the Ed Nytes farm in Scott County, Minnesota. They are situated on a cropped hillslope with southerly aspect and 10% slope. The field drains into Raven Creek, a tributary of Sand Creek in the Lower Minnesota River basin. Soil types at the site are Clarion silt loam (Typic Hapludoll, fine-loamy, mixed, mesic) and a Lakeville-Burnsville gravely sandy loam (Typic Hapludalfs, coarse-loamy, mixed, mesic). In 1995, eight rectangular runoff plots were established. Treatments were ridge

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[1] Support for this project was provided by the Metropolitan Council. Their support is greatly appreciated.
[2] N.C. Hansen is a graduate student and J.F. Moncrief and S.C. Gupta are professors in the Department of Soil Water and Climate at the University of Minnesota, St. Paul, MN 55108

MATERIALS AND METHODS

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Water samples were retrieved immediately following each runoff event and determinations are made for total sediment, total phosphorus, soluble phosphorus, chemical oxygen demand, and herbicide concentrations. Sediment trapped in the collection pans and tipping buckets was also collected, dried, and weighed following each event. Total solids were determined gravimetrically on evaporated sample aliquots. Chemical oxygen demand was determined using the accu-TEST COD method. Soluble P determination was made colorametrically on prefilterd samples (0.45 um). Total P was determined colorametrically on samples following a complete nitric/perchloric acid digestion. Aqueous phase herbicide isolation was by prefiltration with Whatman GFF glass fiber filters followed by C-18 solid phase extraction. Analysis was performed using high resolution, fused silica capillary gas chromatography coupled with a mass spectrometer. The liquid phase fraction generally represents 80-90% of total herbicide loss for alachlor and cyanazine.

Corn was planted on May 20, 1995 (Pioneer 3737) and May 02, 1996 (Pioneer 3751). Alachlor (lasso) and cyanazine (bladex) were applied on May 24, 1995 and May 17, 1996 by either banding or broadcasting. Applications were made with a CO_2 backpack sprayer at a delivery rate of 20 gallons per acre. Broadcast application was made using Delvan 80° flat fan nozzles and the rates were 2.0 quarts a.i./acre for alachlor and 1.8 quarts a.i./acre for cyanazine. Banded application was done in a ten inch band over the 30 inch row and application rates were one third of the broadcast rates. All treatments were cultivated one time on July 05, 1995 and on June 26, 1996.

Rain depth and intensity were monitored with a tipping-bucket rain gauge. Snow depth and density were determined manually with a snow tube throughout winter and spring. Percent residue cover and percent weed cover is measured by the NRCS line transect method before and after planting and cultivation. Yield was assessed by hand harvesting two 30 foot rows for each plot.

RESULTS AND DISCUSSIONS

Precipitation and Runoff

Total rainfall recorded on site from the period of March 10 to December 31, 1995 was 24.0 inches, resulting in 16 individual runoff events. Total depth of runoff for this time period averaged 1.6 inches for moldboard plowed plots and 0.88 inches for ridge till plots. Figure 1 shows the cumulative rainfall and runoff hydrographs for both tillage treatments. Volume of runoff was not affected by herbicide application method. The 1995 cumulative runoff is dominated by the snowmelt event (March 10-12) and a high intensity rainfall event occurring shortly after planting (June 07). For the snowmelt event, runoff averaged 0.30 inches from ridge till plots and 0.03 inches from moldboard plowed plots. Ridge tilled plots retained two times more snow on the surface than the moldboard plowed plots and had ten times the volume of runoff. Moldboard plowing minimizes snowmelt runoff by leaving a rough surface with large surface depressional storage. Ridges trap more snow and have little storage area when ridges are built parallel to the slope. The snowmelt event of March 10 does not represent the total snowmelt for 1995 because the plots were installed after the major snowmelt events for that year. The June 07 runoff event resulted from a 1.5 inch rain storm occurring in less than one hour and is the most intense rain event that has occurred during this study. This event occurred after planting and before canopy closure, which corresponds to the period of highest susceptibility to erosive loss. Average runoff from the moldboard plowed plots for this event was 1.0 inches and for ridge tilled plots was 0.5 inches.

For 1996, annual rainfall was below average at 23.3 inches. Runoff for 1996 averaged 7.6 inches for ridge tilled plots, 6.8 inches for chisel plowed plots, and 3.2 inches for moldboard plowed plots (figure 1). Snowmelt runoff was 90 percent of the annual total for ridge tilled and chisel plowed plots and 80 percent for moldboard plowed plots. Moldboard plowed plots had less runoff than the other tillage systems because runoff is limited by surface roughness prior to planting. However, for events just after planting in early May, runoff from moldboard plowed plots was greater than for ridge tilled and chisel plowed plots (figure 2). These differences were less significant later in the summer. This illustrates that residue cover is effective in reducing runoff during the critical period following planting and prior to canopy closure. Although runoff after planting is less than 10% of annual runoff, this corresponds to the period of greatest susceptibility to erosion and herbicide losses. In general, the volume of runoff from ridge tilled and chisel plowed plots was greater than for moldboard plowed plots during snowmelt events and rain induced events prior to planting. Following planting, runoff volume was in the order of moldboard>chisel>ridge till and was inversely related to the percent surface residue cover left by each tillage system (Table 1).

Table 1. Percent cover between crop rows of moldboard plowed, ridge tilled, and chisel plowed plots. Determination were made using the NRCS line transect method on April 01, June 15, and September 14 for 1995 and April 26, June 25, and July 23 for 1996.

		Pre-plant %	Post-plant/ Pre-cultivation %	Post-cultivation %
1995	Moldboard	13	7	1
	Ridge till	96	89	29
1996	Moldboard	10	18	14
	Ridge till	93	63	50
	Chisel plow	40	33	21

Erosive Loss

Total solids lost from plots during 1995 averaged 6000 lbs/acre for moldboard plowed plots and 560 lbs/acre for ridge tilled plots (figure 3). The June 07 event dominated annual sediment loss and illustrates the effectiveness of crop residue in reducing erosion during high intensity rainfall events. This event also illustrates that the most severe soil loss occurs from single intense rainfall events. For the June 07 event, runoff volume from ridge till plots was half that of moldboard plow plots and sediment concentration was four times less. Runoff events occurring during June were responsible for 98 % of the annual loss of sediment from moldboard plowed plots. For ridge tilled plots, sediment loss during the snowmelt event was a significant portion of the annual total.

For 1996, the loss of total solids was 1900 lbs per acre for moldboard plowed plots, 1400 lbs per acre for chisel plowed plots, and 780 lbs per acre for ridge tilled plots (figure 3). Soil loss in 1996 was less than in 1995 because 1996 was drier than 1995 and spring precipitation was not as intense. However, a large percentage of soil loss still occurred in the month of June. The ridge till system was very effective in reducing erosion during this critical period while the chisel plow system was less effective but was better than the moldboard plow based system.

Phosphorus Loss

Loss of soluble P from moldboard plowed plots averaged 0.23 lbs/acre during the 1995 experimental period, while ridge till plots averaged 0.17 lbs/acre (figure 4). Concentrations of soluble P during snowmelt runoff were relatively high for both tillage systems and the high runoff volume from ridge tilled plots contributed a substantial fraction of the annual P loss. In rainfall induced runoff events, lower runoff volume for ridge tilled plots than for moldboard plowed plots was offset by higher concentrations of soluble P. In reduced tillage systems such as ridge till, the surface soil can have elevated P levels due to lack of incorporation and the residue can also be a source of soluble nutrients in runoff water. On four individual events, loading of soluble P from ridge till plots exceeded that from moldboard plots despite a smaller volume of runoff. Loss of total P (for 11 events between 6/6 and 9/30) was 3.3 lbs/acre for moldboard plowed plots and 0.65 lbs/acre for ridge tilled plots (figure 5). In 1995, the majority of total P lost was particulate P and thus, ridge tilled plots had a lower loading of total P than moldboard plowed plots. It appears, however, that the snowmelt runoff is a critical part of annual P transport. The data from 1995 only includes one snowmelt event from snow that fell after the major snowmelt occurred.

1996, the dominant form of phosphorus loss differed greatly between snowmelt and rainfall induced runoff events. During snowmelt erosion was low, and the majority of P lost was in the soluble form. During rainfall induced runoff, the majority of P lost was associated with eroded sediments. Soluble and total P losses during snowmelt were greatest from ridge tilled plots in 1996, with 80 percent as soluble P (figures 4 and 5). During rainfall, total P loss followed the order of total solids loss and was moldboard>chisel>ridge till. The reduction in loss of total phosphorus in the ridge till system during rainfall was offset by the higher losses of soluble P in snowmelt and the annual total P loss did not differ among tillage (range 3.3 - 3.6 lbs acre^{-1}). Thus, the contribution of soluble P lost during snowmelt must be considered when conservation tillage systems are recommended for control of phosphorus in runoff.

Chemical Oxygen Demand

In 1995, the total loss of COD was 188 lbs/acre for moldboard plowed plots and was 45 lbs/acre for ridge tilled plots, with the majority coming from the June 07 event for both tillage systems (Figure 7). The snowmelt runoff event did not contribute a large amount of COD to the annual total. In 1996, losses runoff of COD were 170, 150, and 120 lbs/acre for chisel plowed plots, moldboard plowed plots, and ridge tilled plots respectively. Although total COD losses were similar for moldboard and chisel plowed plots, they differed in seasonal contribution. Chisel plowed plots lost more COD during the snowmelt period, while moldboard plowed plots lost more from rain induced runoff. The majority of loss from ridge tilled plots was also during the snowmelt events and losses from rain induced runoff were much less than moldboard and chisel plowed plots. Losses of COD from rainfall induced runoff were 100, 71, and 48 lbs/acre for moldboard, chisel, and ridge till respectively. Thus, losses of COD differed seasonally among tillage systems and total loss was lowest for the ridge till system.

Herbicide Loss

oss of herbicides to surface water is of greatest concern when a runoff event occurs within one or two weeks following iemical application. In 1995, herbicide application was made on May 24 and four subsequent runoff events were chosen for herbicide analysis. Light rains that did not induce runoff followed herbicide application and some of the chemical likely moved below the zone susceptible to runoff loss. A small runoff event occurred on June 05 and both herbicides were detected in runoff samples (Tables 3 and 4). For both tillage treatments, banded application significantly reduced the amount of herbicide loss. Loading from moldboard plowed plots was greater than from ridge tilled plots for both application methods due to the greater volume of runoff. Additional herbicide analysis was made for June 23, 25, and 26 events. There was no runoff from ridge till plots for the June 23 and 25 events and only a very small volume for the June 26 event. These events show a significant reduction in herbicide loss due to band application in either tillage method. Banding reduced the mass of herbicide applied to one third that of broadcasting but reduced the runoff losses of herbicide by 5 and 12 times for alachlor and cyanazine respectively. Ridge tillage reduced total herbicide loss by limiting the amount of runoff.

In 1996, herbicide application was made on May 17 and seven runoff events followed. The effect of application method on herbicide concentration is illustrated in figure 7. Concentrations of alachlor and cyanazine were high in the first event following application and decreased exponentially thereafter. Banding significantly reduced the concentration of both herbicides in runoff. Tillage effects on herbicide concentration were generally not significant and were variable with time. However, tillage did affect losses of herbicide because of differences in runoff volumes among the tillage systems. The effects of application method, tillage system, and their interaction on losses of alachlor and cyanazine are shown in figure 8. For broadcast application, runoff losses were in the order of moldboard>chisel>ridge till. Banding reduced total losses for the moldboard and chisel plowed plots. For the ridge till system, losses were low regardless of application method because the volume of runoff was low for these events. Thus, conservation tillage and/or banding may be effective management strategies for reducing herbicide losses to runoff.

The success of band application of herbicides depends on the ability to control weeds in-between the bands by cultivation. For some years, wet soils prevent cultivation and significant weed pressure and yield reductions will result when banding was used rather than broadcast application. For this study, weed density was measured before and after cultivation. Before cultivation, weed cover was 62% between the rows on plots with banded herbicide application and was 27% on plots with broadcast herbicide application. However, following a single cultivation, weed cover was reduced to 1% for both treatments. Yeed density did not differ with application method within the 10 inch band.

Yield

Corn yields in 1995 averaged 118 bu/acre for moldboard plowed plots and 107 bu/acre for ridge tilled plots. In 1996 yields were 129, 123, and 116 bu/acre for moldboard plowed, ridge tilled, and chisel plowed plots respectively. Effects of tillage and herbicide application method were not significant for either year.

Table 3. Loading of Alachlor from select runoff events from moldboard plowed plots (MB) and ridge till plots (RT).

	Total Loading of Alachlor (mg/hectare)					
Event Date	Runoff (in)		Banded Application		Broadcast Application	
	MB	RT	MB	RT	MB	RT
June 05-06	0.12	0.06	1761	227	6454	1309
June 23	0.04	0.0	68.1	--	577	--
June 25	0.06	0.0	65.5	--	238	--
June 26	0.08	0.001	94.1	1.65	729	0.83
Total	**0.30**	**0.061**	**1989**	**228**	**7998**	**1310**
% of Applied			0.25	0.03	0.36	0.06

Table 4. Loading of Cyanazine from select runoff events in 1995.

	Total Loading of Cyanazine (mg/hectare)					
Event Date	Runoff (in)		Banded Application		Broadcast Application	
	MB	RT	MB	RT	MB	RT
June 05-06	0.12	0.06	356	496	7780	6801
June 23	0.04	0.0	90.6	--	1271	--
June 25	0.06	0.0	238	--	838	--
June 26	0.08	0.001	366	6.4	1691	3.9
Total	**0.30**	**0.061**	**1051**	**502**	**11580**	**6805**
% of Applied	--	--	0.15	0.07	0.57	0.33

CONCLUSIONS

- Annual runoff was highest from ridge tilled plots because of higher snowmelt runoff. Fall moldboard plowing limited snowmelt runoff, but chisel plowing did not.

- Surface residue associated with the ridge tilled and chisel plowed plots reduced runoff and erosion from spring rains following planting and before canopy closure. Annual soil loss was in the order of moldboard plow>chisel plow>ridge till.

- Phosphorus losses differed seasonally among tillage systems. Ridge tilled plots had higher losses of P in snowmelt runoff than the other tillage systems and soluble P was the dominant form. Phosphorus losses from rain induced runoff followed the order of soil loss and particulate P was the dominant form. On an annual basis, total P losses were similar for all tillage systems.

- Chisel plowed and ridge tilled plots had lower losses of broadcast applied herbicides than moldboard plowed plots.

- Banding reduced herbicide losses from moldboard and chisel plowed plots. Losses from ridge tilled plots were low regardless of application method.

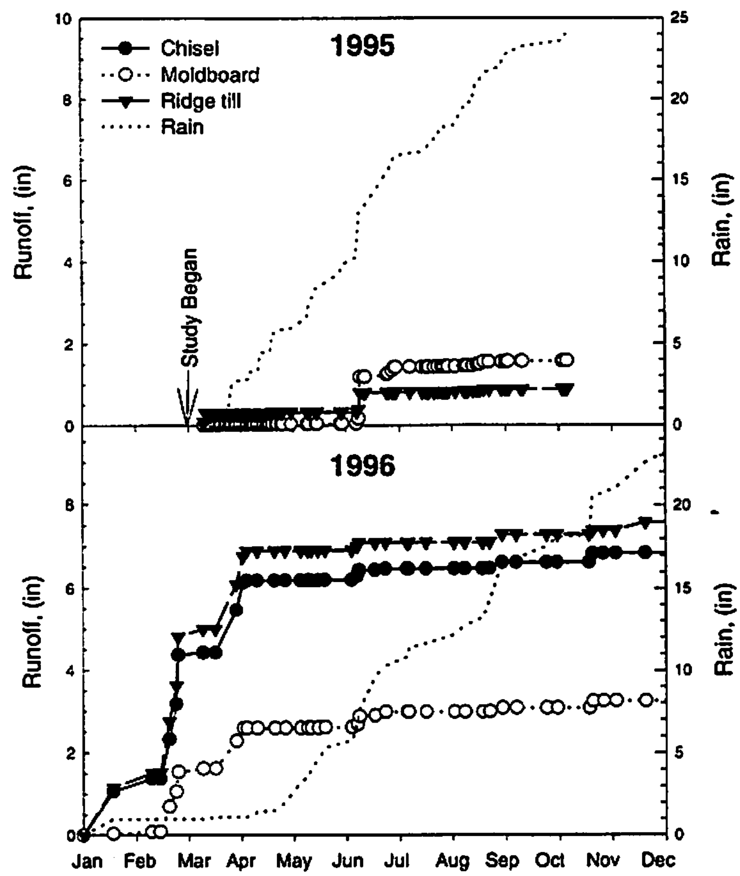

Figure 1. Cumulative Runoff and Precipitation

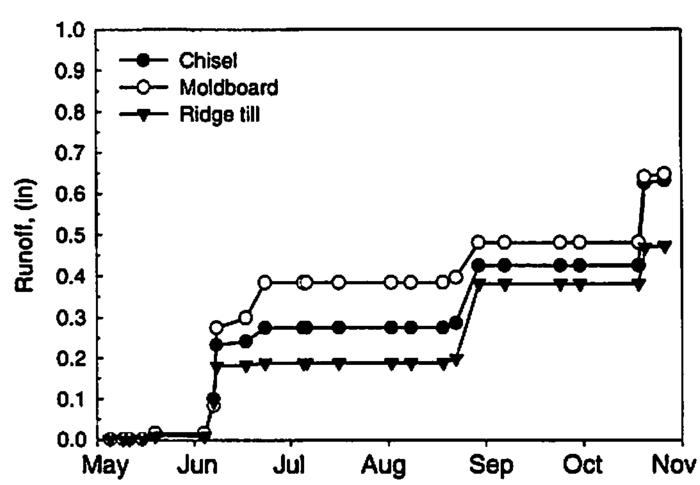

Figure 2. 1996 Runoff following planting

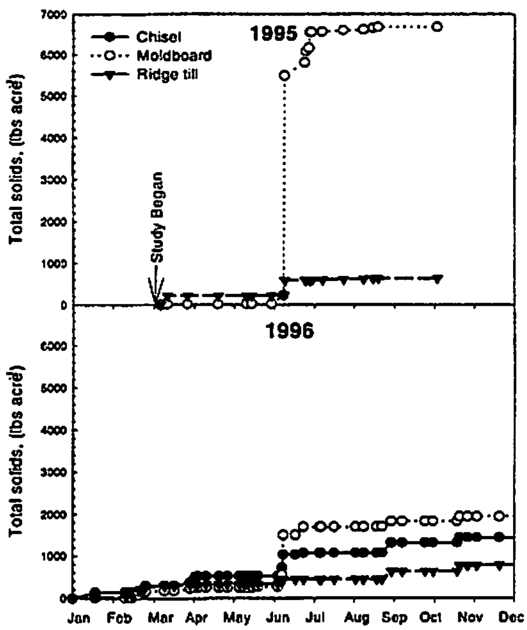

Figure 3. Cumulative Loss of Total Solids

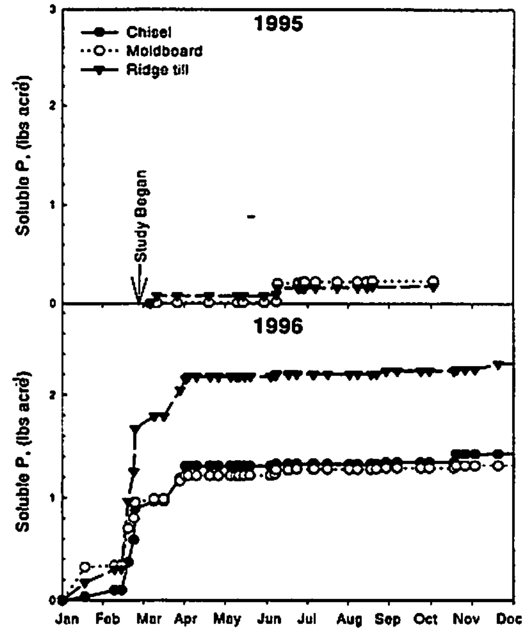

Figure 4. Cumulative Loss of Soluble Phosphorus

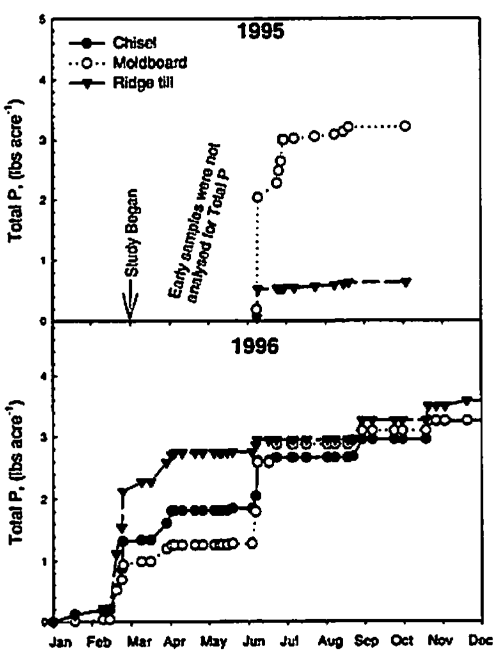

Figure 5. Cumulative Loss of Total Phosphorus.

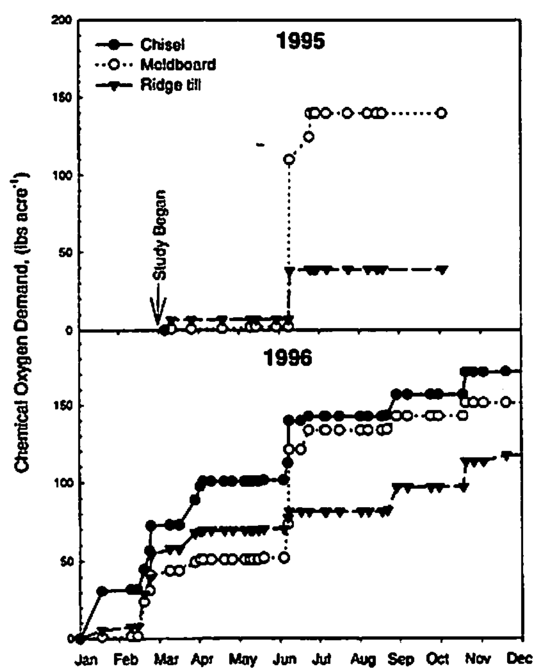

Figure 6. Cumulative Loss of Chemical Oxygen Demand.

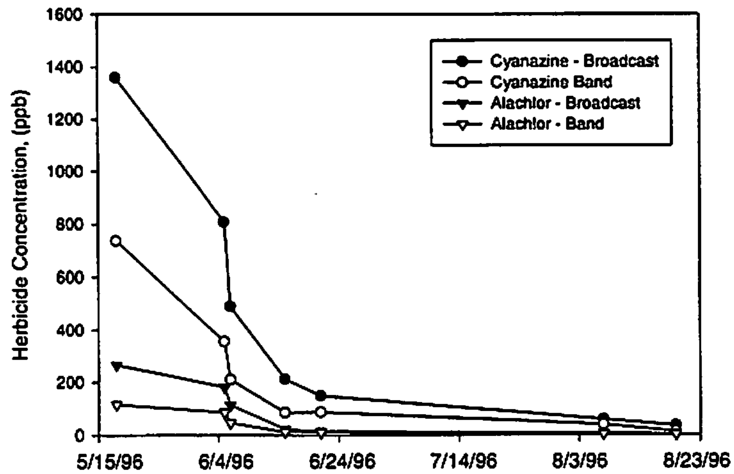

Figure 7. Impact of banding on herbicide concentration in runoff for 1996.

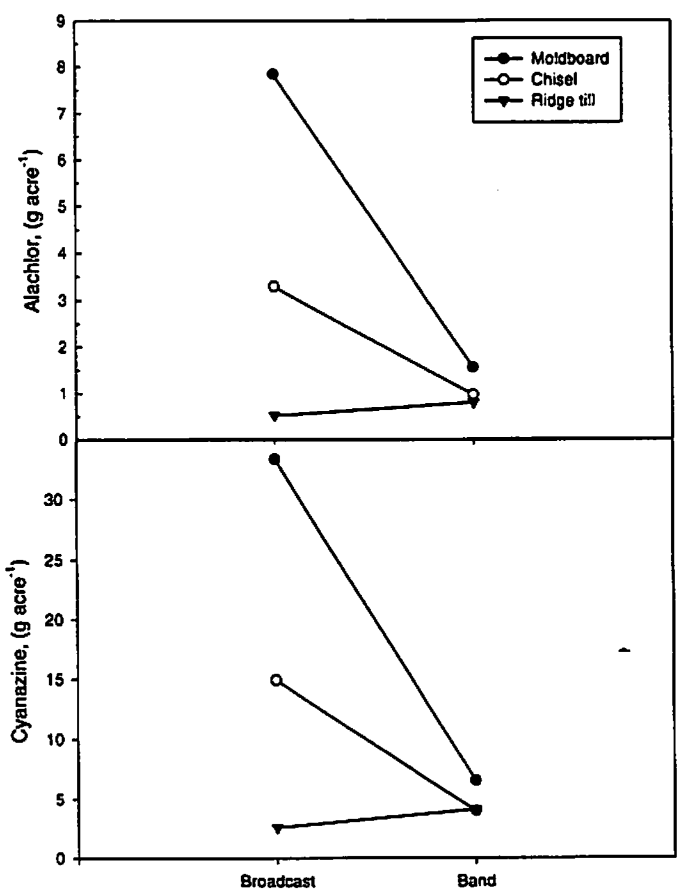

Figure 8. Tillage and herbicide application method impacts on 1996 losses of alachlor and cyanazine.

EFFECT OF NITROGEN AND SULFUR ON CANOLA - 1996

R.K. Severson, C.D. Holen, G.W. Rehm[1]

Abstract

Specific fertility recommendations for nitrogen and sulfur are currently not available in Minnesota. This study evaluates the effect of three rates of nitrogen and four rates of sulfur applied to canola in a split-plot design on yield, test weight and oil percent. Nitrogen rates had no effect on yield or test weight and significantly decreased oil percentage as nitrogen rates were increased. Sulfur rates statistically did not effect yield, test weight or oil percent however a trend was evident that yield and oil percent increased with the addition of sulfate-sulfur averaged over nitrogen rates.

Introduction

The annual worldwide production of canola is approximately 4 million acres. Canada and the European Economic Community account for about one third of the world production. Minnesota and North Dakota are the major U.S. production states with about 20,000 acres grown annually. Canola is a relatively new alternative crop being produced in northwestern Minnesota. Current fertility recommendations are based solely on research conducted in Canada. Previous research in Canada has shown that canola utilizes about three times the sulfur compared to small grains. The objective of this study was to evaluate four sulfur rates on canola at three nitrogen rate yield goals.

Experimental Procedure

This study was conducted in Polk county near Fosston in 1996. Three nitrogen main effect treatments were established based on yield goals of 2000, 2500 ad 3000 pounds of canola per acre. Sulfur rates of 0, 20, 40 and 60 pounds of sulfate-sulfur were applied in a split-plot design to the main effect treatments. Ammonium sulfate was used as the sulfur source and supplemented with ammonium nitrate to achieve nitrogen rates of 130, 162.5 and 195 pounds per acre. Treatments were randomized and replicated in four blocks. Phosphorus and potassium were broadcast applied to all plots based on soil test results. All fertilizer treatments were applied prior to planting canola. Treflan was applied pre-plant incorporation at a rate of .75 pounds active ingredient per acre. All plots were planted on May 12, 1996 and re-planted on June 12, 1996 due to a severe crusting problem. Pioneer 45-A-71 canola variety was planted at a final population of 15 plants per square foot. At harvest canola yields were measured with a Hege plot combine and corrected to 10% moisture content. Oil percentage was analyzed by Dr. Jim Hanzel at North Dakota State University.

Summary of Results

There was a significant reduction in oil percentage with increased nitrogen rates and no effect on yield or test weight. Averaged across nitrogen rates, no significant differences were found, however, the addition of sulfur showed a trend to increase yield and oil percentage as sulfur rates increased with no effect on test weight.

Status

This research project was started in 1996 and will be conducted in Polk county again in 1997.

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NITROGEN CONSERVATION IN A LIQUID DAIRY MANURE MANAGEMENT SYSTEM WITH FLUSH WATER RECYCLING[1]

S. M. Braum and J. F. Moncrief[2]

Abstract:

Dairy farms in SE Minnesota often have a strongly positive nitrogen balance. Nitrogen losses to the atmosphere from manure storages are desirable if they occur through denitrification. Such losses reduce the amount of nitrogen that needs to be land applied, thereby reducing possible excess fertilization which could lead to water pollution. The occurrence and amounts of gaseous nitrogen losses from a liquid manure management system with recycled flush water were investigated on a dairy farm in Winona Co. with 150 to 165 cows. The prevailing mode of nitrogen loss was found to be ammonia volatilization. Denitrification losses were negligible. The average daily loss rate varied from 24.1kg N d^{-1} to 43.3kg N d^{-1}.

Introduction

As they do in all across the U.S., dairy herd sizes on many individual farms are increasing in SE Minnesota to maintain or increase profitability. Along with producing more milk to sell, larger herds also generate larger amounts of wastes. When confined to buildings or small outside lots, the large amounts of wastes generated require proper handling to allow continuous operation of the facilities and to prevent hygienic problems. While the economic value of nutrients in manure for crop production is still worth consideration, the potential for environmental damage from excessive amounts of these nutrients, especially N, becomes increasingly important. In cases where the imbalance between nutrient supply from manure and their removal by crops is particularly big due to excess nutrient influxes from bought feed, fertilizer or N-fixation (alfalfa), the costs of compliance may exceed the benefits derived from the wastes. The problems of nitrogen excess and possible surface and groundwater contamination are magnified for dairy farms in SE Minnesota because of the prevailing crop rotation (alfalfa, com, soybean), the karst geology with rapid groundwater recharge and the topography of an old, highly dissected erosional land surface with steep slopes and rapid runoff.

Constructed earthen storage basins have become a widespread means of storing animal wastes. In this LCMR-funded project, we are investigating the flow and transformations of nitrogen in a waste management system on a dairy farm in Winona Co. in SE Minnesota over the course of two years. The possibility of gaseous nitrogen losses from the system during storage is of particular interest, since such losses reduce the amount of nitrogen that needs to be disposed of by land application.

Manure management systems can lose nitrogen to the atmosphere as ammonia (NH_3), nitrous oxide (N_2O), and dinitrogen (N_2). Ammonia and ammonium (NH_3, NH_4^+) are always present in manure, commonly comprising 33% of the total N in liquid manure. Several factors influence the volatilization of ammonia. Volatilization can occur anywhere liquid manure is exposed to the atmosphere; scum mats and ice covers consequently reduce ammonia volatilization. It increases with increasing pH and temperature of the liquid manure. N-losses from a manure system as nitrous oxide (N_20) and dinitrogen gas (N_2) require the existence of a nitrification-denitrification cycle. Nitrate (NO_3^-) can be generated under aerobic conditions by microbial oxidation of ammonia. If nitrate then enters into an anaerobic environment, it can be microbially reduced to nitrous oxide or dinitrogen, which are then lost from the manure to the atmosphere.

The research site is the Charles Meyer dairy farm in Winona Co. The dairy herd on the Meyer farm was 150 head in 1995, which increased to 165 in 1996. The milk yields (herd average) were 28,000lb or 12,700kg in 1995 and 27,000lb or 12,300kg in 1996. The farm operates an earthen manure storage basin with two cells. The wastes from the dairy barn and the milkhouse enter the first cell through a submerged pipe. Most of the solids are retained in the first cell, either by sinking to the bottom or by forming a floating scum mat on the surface. The liquid under the mat equilibrates with the second cell through a second submerged pipe in the dam separating the two cells. Liquid from the second cell is pumped into a storage tank and used to flush the barn, completing the cycle. The calculated combined maximum volume of the storage cells is 8,400m^3 at the specified depth of 2.44m (8ft). Due to sludge deposition, this depth is no longer available throughout the basins, somewhat reducing the actual storage volume. Twice a year, the contents of cell I are stirred up and pumped out and applied onto cropland with a traveling irrigation gun. This draws down the second basin until its level is below the connecting pipe, leaving approximately 1,054m^3 of liquid in cell II to continue flushing the barn. To avoid an overflow, liquid is pumped occasionally from the second cell for land application.

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[1]This project was funded by the Legislative Commission on Minnesota Resources

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Experimental Procedure

Manure composition: Manure samples were taken at regular intervals from both cells over the course of two refill periods from 1995 to 1996. The samples were analyzed for total N, ammonia/ammonium, nitrate, total phosphorus, pH, and total, volatile and ash sol content.

System volume determination: After Meyer farms applied manure pumped from the first cell during the first week of May 1996, 2600g of Li was added to the liquid remaining in cell II. The lithium acted as a chemical tracer. By determining the Li-concentrations in both cells over time, the mixing and turnover of cell liquids could be monitored. If complete mixing occurred, a uniform Li-concentration would establish itself. The time it took to reach uniformity throughout the storage basins was the time required for complete mixing. At that point, the Li-concentration was a direct measure of the total volume of liquid circulating through the system. The volume combined with the concentrations of N, P and K gave us the total amounts present of these nutrients. This allows us to evaluate nitrogen losses to the atmosphere as well as planning for the application of the manure as fertilizer. The Li-tracer was useful for the whole period of 167 days from emptying the cells in the spring until the emptying in the fall of 1996, when the storage was again completely full without any freeboard.

Nitrogen budgeting: For comparison with the amount of nitrogen measured in the manure storage, the amounts of nitrogen excreted over the given refill periods were calculated by subtracting the nitrogen in the milk from the nitrogen supplied by the feed ration. Feed ration amounts and analyses were kindly provided by the Meyers. In 1995, the daily ration per cow contained 677g of N and in 1996 it was 771g of N. The nitrogen content of the milk was assumed to be a constant 0.512%.

Results and Discussion

Convergence of the Li-concentration in the two cells of the storage occurred several weeks before the end of the second refill period, indicating uniform mixing (see Fig. 1). At the end of the second refill period, the lithium tracer added at its beginning minus the amount removed from cell II in August allowed us to calculate the liquid volume of the manure storage when it is completely full. The system volume was determined to be 6,711m^3, 3,229m^3 in cell I and 3,482m^3 in cell II. These values were also used in the calculations for the end of the first refill period, since the storage had been completely full then, too.

The amounts and chemical forms of nitrogen in the storage basins were monitored over the two refill periods. For both periods, comparison of the total nitrogen present in the storage at the end of the refill period to the amount that entered the system through feed indicated that substantial losses of nitrogen had occurred. The losses were calculated as follows:

10/18/1995 to 5/1/1996: 195 days of refill	
N added with feed: 150 * 195 * 0.677kg =	19.8t
N removed by milk: (12,712kg / 365) * 150 * 195 * 0.00512 =	5.2t
N excreted by the herd: 19,802kg - 5,216kg =	14.6t
N left in cell II at beginning: 1,054m^3 * 1.149kg m^{-3} =	1.2t
Potential total N in the storage: 14,586kg + 1,211kg =	15.8t
N found in storage at end: 3,229m^3 * 2.014kg m^{-3} + 3,482m^3 * 1.319kg m^{-3} =	11.1t
=> N lost: 15,797kg - 11,096kg =	4.7t

The 4.7t represents a 29.8% loss of nitrogen over the 195 days. This is an average daily loss of 24.11kg N.

5/9/1996 to 10/23/1996: 167 days of refill	
N added with feed: 165 * 167 * 0.771kg =	21.2t
N removed by milk: (12,258kg / 365) * 165 * 167 * 0.00512 =	4.7t
N excreted by the herd: 21,245kg - 4,738kg =	16.5t
N left in cell II at beginning: 1,054m^3 * 1.304kg m^{-3} =	1.4t
N removed from cell II by pumping in 8/96: 499m^3 * 2.111kg m^{-3} =	1.1t
Potential total N in the storage: 16,507kg + 1,374kg - 1,053kg =	16.8t
N found in storage at end: 3,229m^3 * 1.547kg m^{-3} + 3,482m^3 * 1.324kg m^{-3} =	9.6t
=> N lost:16,828kg - 9,605kg =	7.2t

The 7.2t represents a 42.9% loss of nitrogen over the 167 days. This is an average daily loss of 43.25kg N.

Most of the nitrogen in the manure was in the organic form. Ammoniacal nitrogen (NH_3 and NH_4^+) represented between 34% to 50% of the total N. Nitrate was detected only sporadically in very small concentrations. Since nitrification is a prerequisite for denitrification, nitrogen losses by denitrification must be assumed to have been negligible also. The pathway for nitrogen loss from the system must therefor be ammonia volatilization. At the beginning of the study it was hoped that substantial losses would occur by denitrificatio Such losses are preferable to losses as ammonia because the nitrogen is then lost primarily as dinitrogen which is not available plant uptake and therefor non-polluting. Larger amounts of nitrous oxide could be problematic because N_2O is a greenhouse gas, however, it constitutes generally only a small fraction of the nitrogen lost in denitrification. Substantial atmospheric losses as ammonia are a mixed blessing. While they certainly help reduce the amount of environmentally active nitrogen that needs to be disposed of through land application on the farm in question, such losses are actually contributions of available N to the ecosystem. Ammonia in the atmosphere can be taken up directly by plants, or it can enter the soil by precipitation or dry deposition. This leads to increased soil nitrogen and soil acidification, which are especially problematic in poorly buffered and nitrogen-limited natural ecosystems. For these reasons, ammonia in the atmosphere is considered a severe environmental problem in Europe, with emissions from livestock operations being the most important source.

The losses that occurred from the system at the Meyer farm have two possible areas of origin: the livestock buildings and the manure storage cells, because at these two locations, the manure is exposed to the atmosphere. Measurements of the ammonia volatilization from the manure storage will be made in the first half of 1997 to assess its share of the losses. We will also continue to monitor nitrogen in the system to determine if the higher rate of loss for the second refill period was due to climatic factors (summer vs. winter), or if it was caused by the installation of a more efficient aeration system in the spring of 1996in cell II.

Fig.1: [Li] in Cells I and II