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

[1]Funding for this study was provided by AURI.
[2]Extension Soil Scientist, Dept. Soil, Water, and Climate; Associate Professor, Dept. Of Entomology; Associate Professor, Dept. Of Horticultural Science; Assistant Scientist, Dept. of Soil, Water, and Climate.

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 ---					Total	Dry Matter	--- Dry Matter ---			Carrot
#	N	Insecticide	<4"	Forks	<⅞"	⅞ to 1¾"	>1¾"	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.

Treatment #	N lb/A	Insecticide	<4"	Forks	<⅞"	⅞ to 1¼"	>1¼"	Total Yield	Dry Matter Root %	Roots	Tops	Total	Carrot population plants/ft
			--- Root Diameter ---							--- Dry Matter ---			
			---------- cwt/A ----------							---- Tons/Acre ---			
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.

Treatment #	N lb/A	Insecticide	Nitrogen content Top	Root	Total	Nitrogen concentration Top	Root
			--------- 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.

Treatment #	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.

Treatment #	N	Insecticide	Date: 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.

---

[1]This project was supported by the University of Minnesota Agricultural Experiment Station at Rosemount and the USDA-ARS Soil and Water Management Unit in St. Paul.

[2]L. M. Wallach, D.R. Linden, R.H. Dowdy, R.R. Allmaras, and C.E. Clapp are Biological Sciences Research Technician, Soil Scientist, Soil Scientist, Soil Scientist, and Research Chemist of the USDA-ARS and the Soil, Water, and Climate Department of the U of MN, St. Paul, MN. K.L. Walters and J. Rowe are at the U of MN Agricultural Experiment Station at Rosemount.

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 for 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 80% 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		92-96 avg.	
		bu/ac	mt/ha	bu/ac*	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.

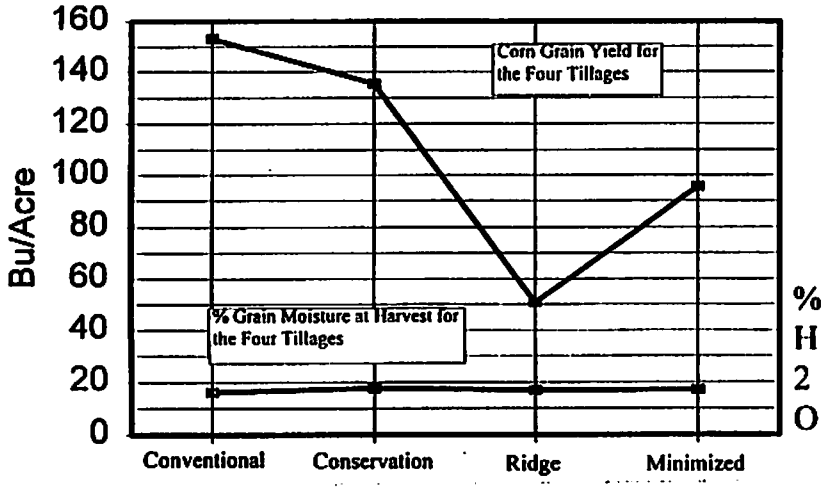
Table 2 A. tuberculata and L. terrestris Populations per square foot for the Tillage Study at Rosemount, 1996

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

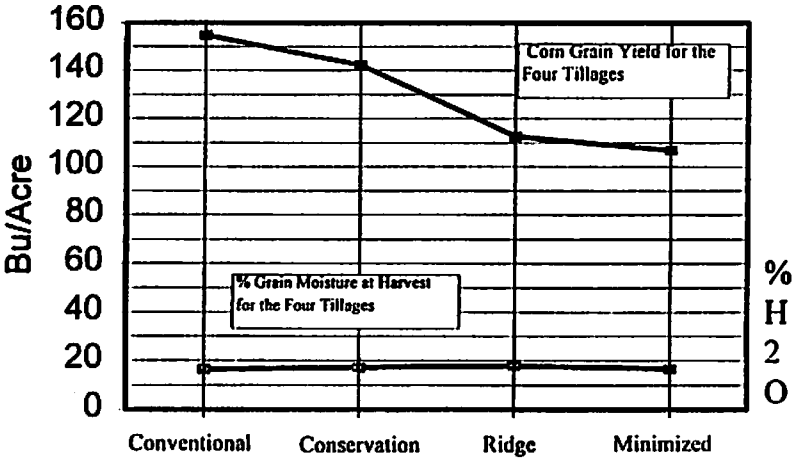
Fig. 1



Grain Yield Summary

Corn in '96 Following Soybeans

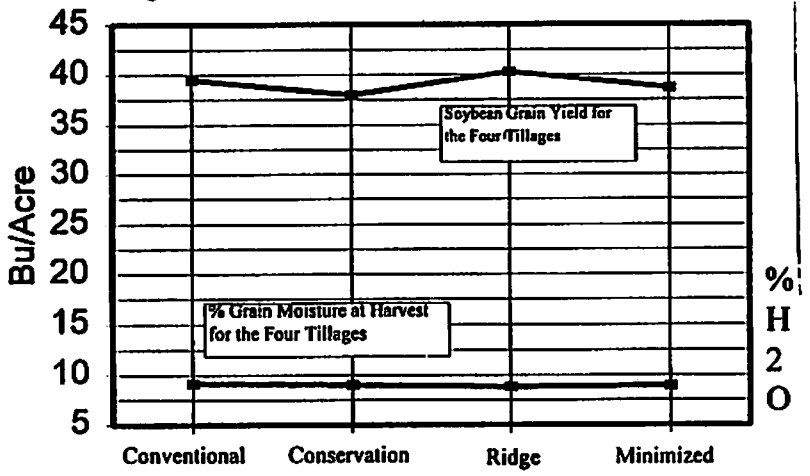
Fig. 2



Grain Yield Summary

Soybean in '96 Following Corn

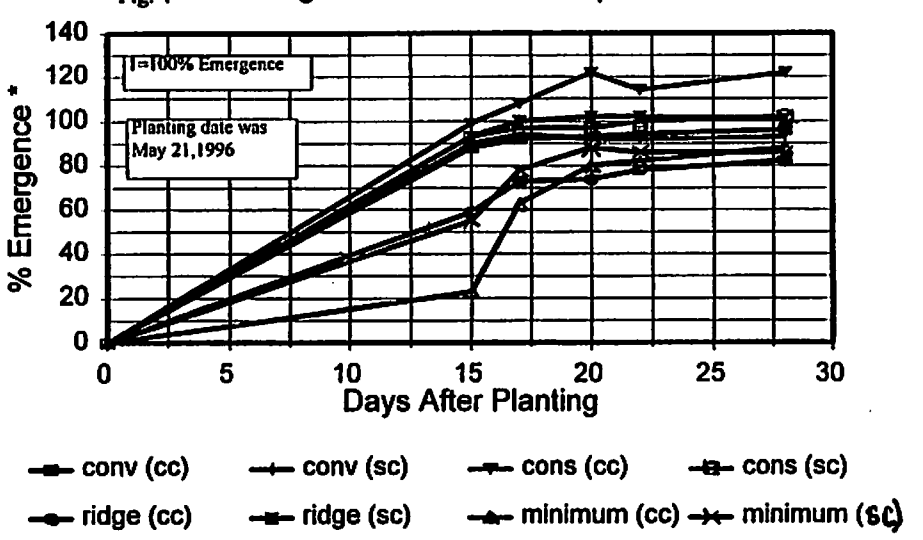
Fig. 3



1996 Corn Emergence

Tillage and Rotation Comparison

Fig. 4

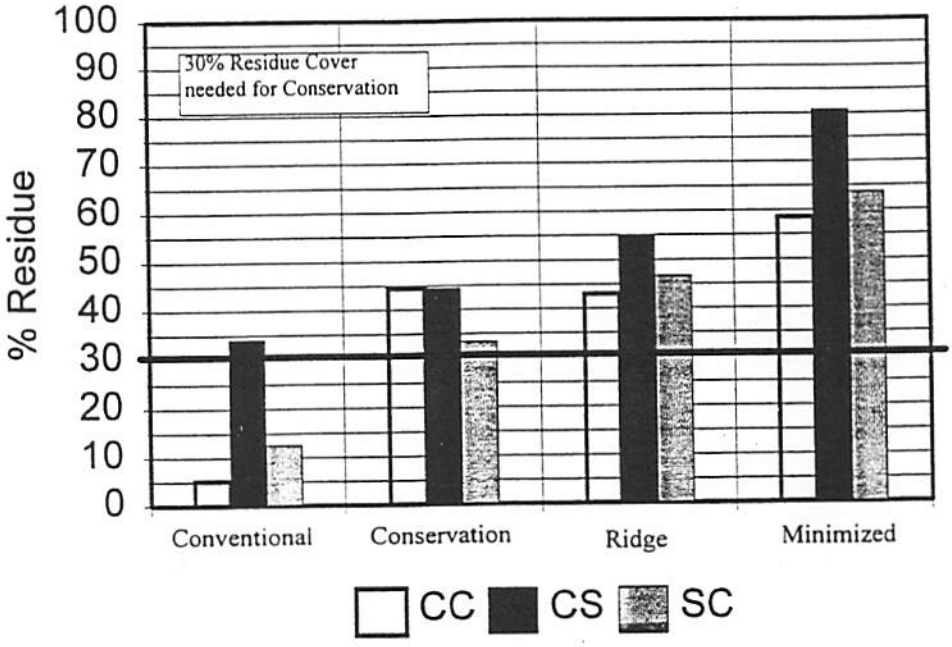


* Percent emergence is based on 28,000 seeds planted per acre

Residue Cover Comparison

Tillage and Rotation Effects

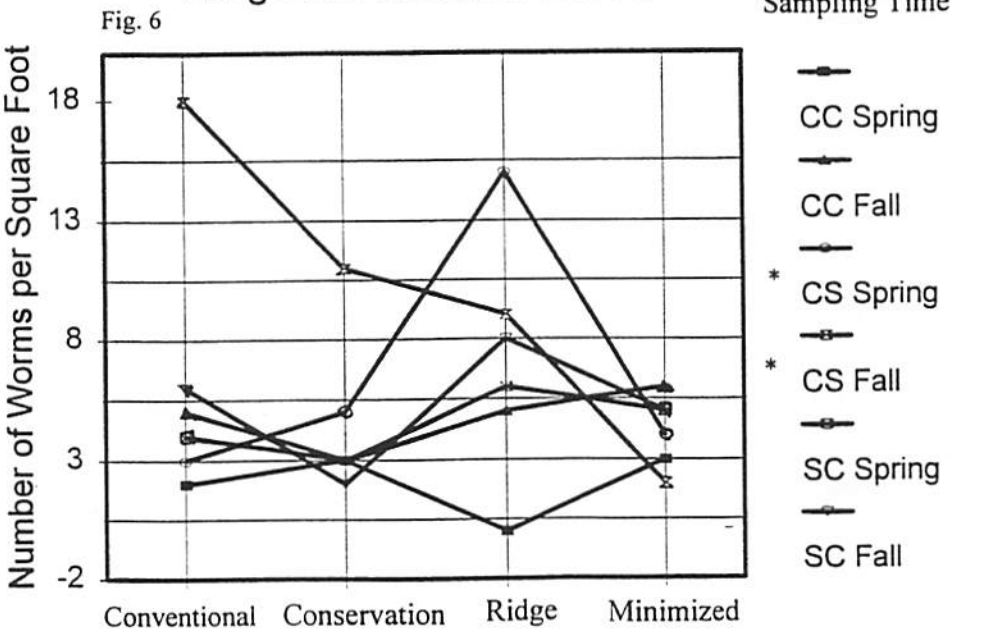
Fig.5



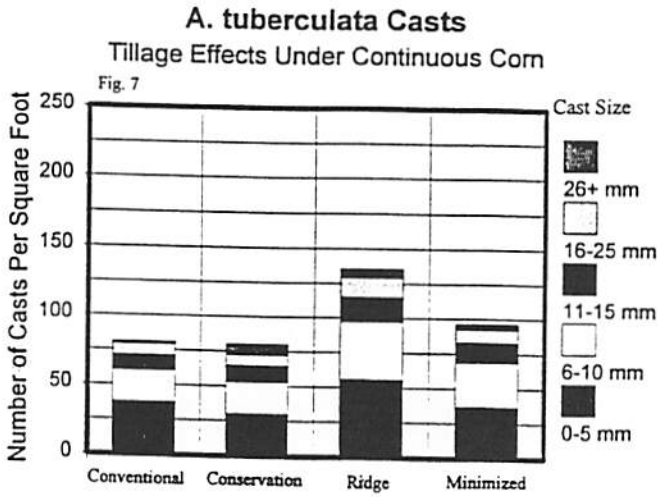
A. tuberculata Populations

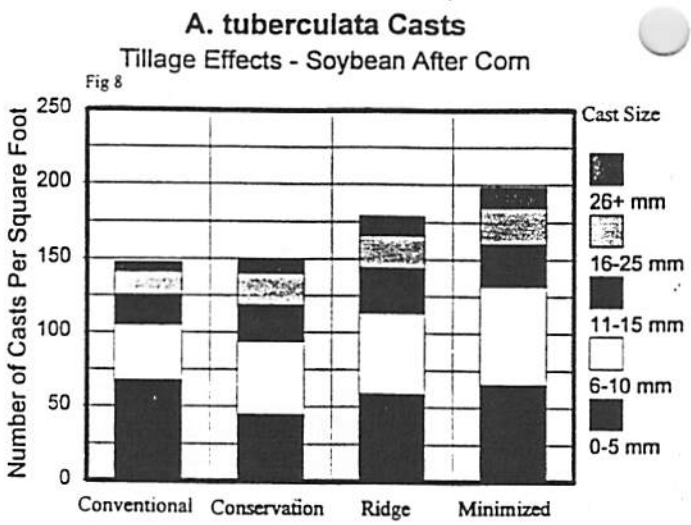
Tillage and Rotation Effects

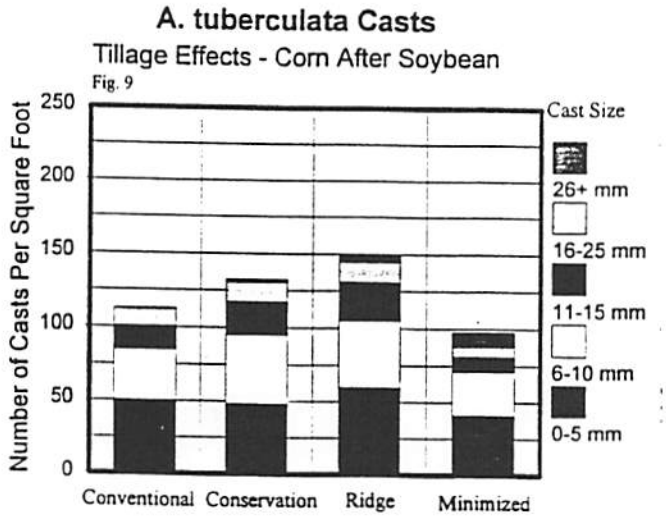
Fig. 6

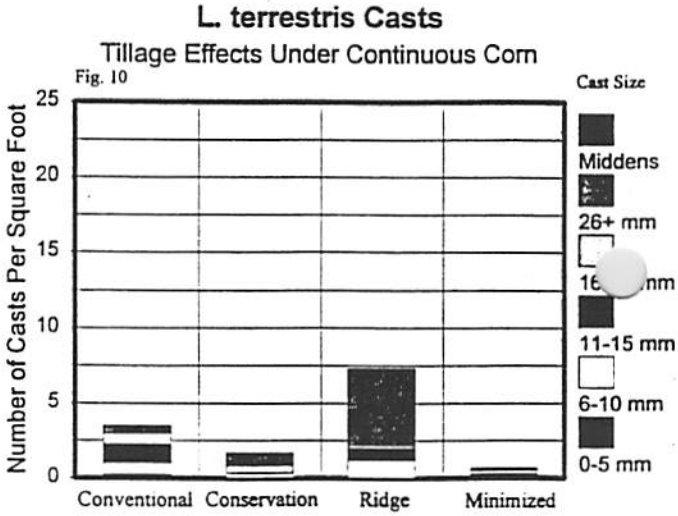


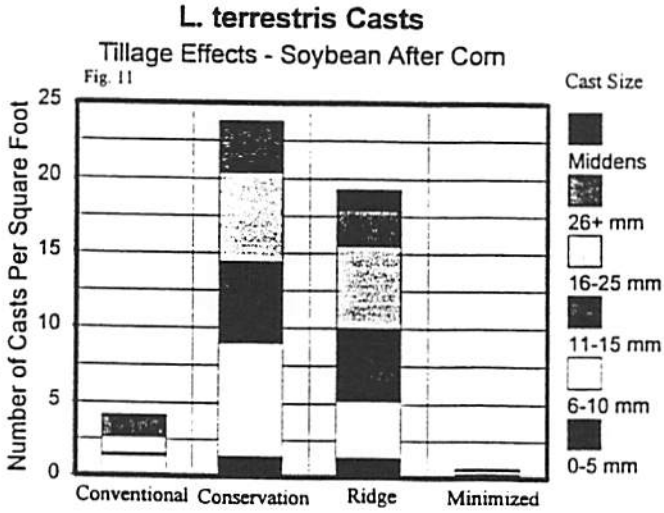
* This rotation has significantly more worms


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

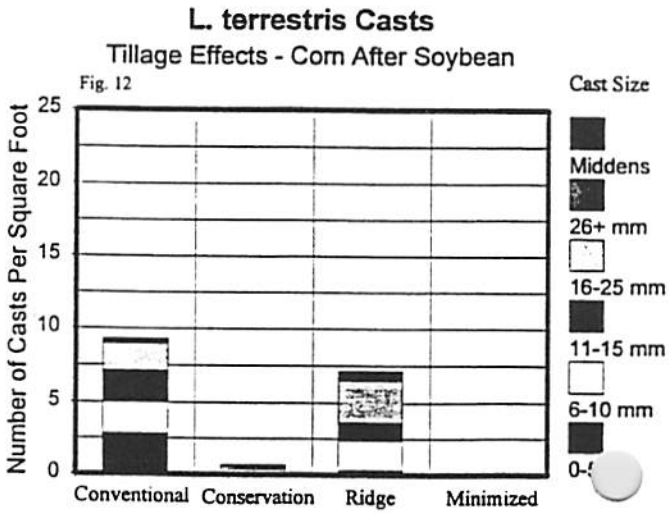

L. terrestris Casts
Tillage Effects - Corn After Soybean
Fig. 12
Number of Casts Per Square Foot
25
20
15
10
5
0
Conventional
Conservation
Ridge
Minimized
Cast Size
Middens
26+ mm
16-25 mm
11-15 mm
6-10 mm

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

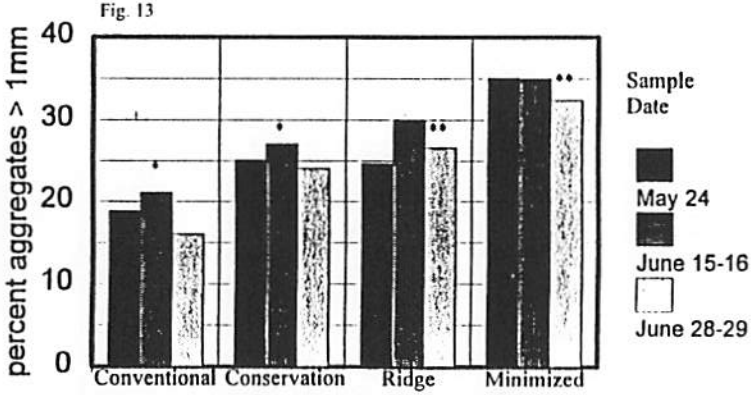
Treatment			% Aggregates > 1mm					
Tillage	Rotation		s1*		s2*		s3*	
			top**	bottom***	top	bottom	top	bottom
Conventional (T1)	Cont.Corn	CC	14.507	23.49	20.82	19.87	16.863	21.63
	Soy/Corn	SC	22.873	28.453	21.613	19.533	14.493	22.317
	Corn/Soy	CS	19.127	23.483	20.973	21.003	16.83	17.033
Conservation (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



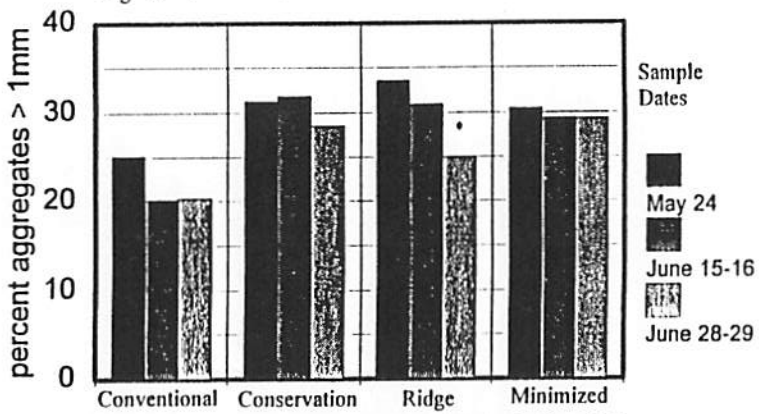
* Conventional tillage had the least aggregates of this size for all sample dates, but on the June 15-16 sample date this conservation tillage sample was similarly as low.

** 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

by Tillage for 7.5-30cm samples

Fig. 14



* 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' block design with three replications. The plots are isolated by plastic to a depth of 6'. The four cropping systems included: continuous 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

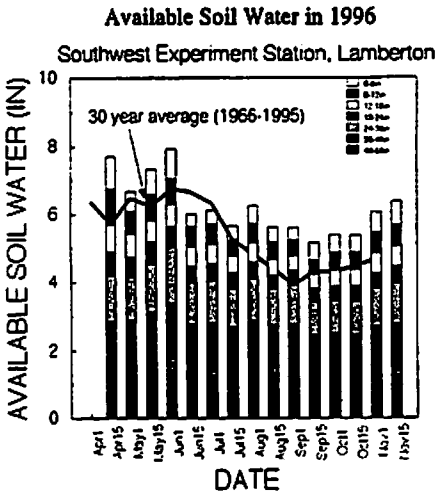


Figure 1. Available Soil Water sampled during the 1996 growing season at the Southwest Experiment Station.

[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

N-Rate (lb/A)	Anhydrous Ammonia Fall	Anhydrous Ammonia Spring	Anhydrous Ammonia Sidedress	Anhydrous Ammonia $LSD_{0.05}$	Urea Fall	Urea Spring	Urea Sidedress	Urea $LSD_{0.05}$
	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 various row management (RM) treatments and differ for corn and soybean crops.

Subplots within corn - 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)

Subplots within soybeans - 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.

---

[1] L.D. Klossner, and D.R. Huggins are Assistant Scientist, and Assistant Professor at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. 1996 Corn Plot Management

Corn Sub-Treatments Within Tillage Systems

Tillage System	Sub Trt*	Planter	Row Cult	Fertilizer	Seed and Starter Fert.	Spring Tillage	Weed Control (ai)
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
no fall tillage	2	JD 4-row	6/28/96	135 lb N/A	Pioneer 3531		Harness 2 ½ pt/A
				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
chisel plow	2	JD 4-row	6/26/96	135 lb N/A	Pioneer 3531	5/7/96	Harness 2 ½ pt/A
				6/25/96	30,000/A		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
no fall tillage	2	JD 4-row	6/26/96	135 lb N/A	Pioneer 3531	5/7/96	Harness 2 ½ pt/A
				6/25/96	30,000/A		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
Flex Tillage (97)	2	JD 4-row	6/26/96	135 lb N/A	Pioneer 3531	5/7/96	Harness 2 ½ pt/A
				6/25/96	30,000/A		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 5/31/96
	3	JD 4-row	None	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/30/96	Trt 4 and 5 Parker 200,000/A planted 5/30/96		Poast Plus1 ½ pts/A 7/9/96
	4	JD 752	None				
	5	JD 752	None				
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 5/31/96
	3	JD 4-row	6/28/96	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/30/96	Trt 4 and 5 Parker 200,000/A planted 5/30/96		Poast Plus1 ½ pts/A 7/9/96
	4	JD 752	6/28/96				
	5	JD 752	6/28/96				
Conventional	1	JD 4-row	6/26/96		Trt 1, 2, and 3 Parker 150,000/A	Disc 5/29/96	Dual II 2 ½ pts/A 5/31/96
Primary Tillage	2	JD 4-row	6/26/96				Poast Plus 1½ pts/A 7/9/96
Moldboard plow	3	JD 4-row	6/26/96	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/30/96	Trt 4 and 5 Parker 200,000/A planted 5/30/96		
Fall 95	4	JD 752	None				
	5	JD 752	None				
Reduced	1	JD 4-row	6/26/96		Trt 1, 2, and 3 Parker 150,000/A	Disc 5/29/96	Dual II 2 ½ pts/A 5/31/96
Primary Tillage	2	JD 4-row	6/26/96				Poast Plus 1½ pts/A 7/9/96
Chisel plow	3	JD 4-row	6/26/96	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/30/96	Trt 4 and 5 Parker 200,000/A planted 5/30/96		
Fall 95	4	JD 752	None				
	5	JD 752	None				
Spring Tillage (96)	1	JD 4-row	6/26/96		Trt 1, 2, and 3 Parker 150,000/A	Disc 5/29/96	Dual II 2 ½ pts/A 5/31/96
Flex Tillage (97)	2	JD 4-row	6/26/96				Poast Plus 1½ pts/A 7/9/96
no fall tillage	3	JD 4-row	6/26/96	Trts 3 and 4 60 lb N/A (NH_4NO_3) broadcast 5/30/96	Trt 4 and 5 Parker 200,000/A planted 5/30/96		
	4	JD 752	None				
	5	JD 752	None				

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

Table 3. Analysis of Variance

Corn - 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).

---

[1] C.A. Perillo, P. M. Porter, D.R. Huggins, L.D. Klossner are Assistant Scientist, Assistant Professor, Assistant Professor, and Assistant Scientist at the Southwest Experiment Station, Lamberton, MN 56152.

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.)

		Management Level				
Rotation	Crop	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.)

		Management Level				
Rotation	Crop	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).

		Rotation Length		
Experiment	Crop	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

[1] C.A. Perillo, P.M. Porter, S.Q. Quiring are Assistant Scientist, Assistant Professor, and Senior Plot Technician at the Southwest Experiment Station, Lamberton, MN 56152.

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.

[1] P.M. Porter (assistant professor - Lamberton, MN 56152), R.K. Crookston (professor) are in the Department of Agronomy and Plant Genetics. J.G. Lauer and E.S. Oplinger (associate and full professor) are in the Department of Agronomy, Univ. of Wisc. T.R. Hoverstad (scientist) is at Waseca.

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 w 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).

[1] P.M. Porter (assistant professor - Department of Agronomy and Plant Genetics), C.A. Perillo (assistant scientist), S.R. Quiring (senior plot technician) are located at the Southwest Experiment Station, Lamberton, MN 56152. R.K. Crookston (professor) , Dep. of Agronomy and Plant Genetics.