Long-term Tillage Study, ACRE

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Introduction

Early evaluation of reduced tillage systems in the Midwest centered on well-drained and/or erosive soils. Due to reduced water erosion and savings in soil moisture, systems leaving 70% or more of the soil surface covered with residue often increased yield potential on these soils. These findings could not be generalized, however, to the dark silty clay loam soils of the Eastern Corn Belt where soil moisture and erosion were less severe problems.

Beginning in 1975, a range of tillage systems have been compared annually on Chalmers silty clay loam soil (4% OM) at the Purdue Agronomy Center for Research and Education (ACRE) in West-central Indiana. Our goals are to determine long-term yield potential of the different systems and to determine changes in soil characteristics and crop growth that could be associated with yield differences. Plow, chisel, ridge, and no-till systems are compared for continuous corn, corn following soybeans, soybeans following corn, and continuous soybeans. There are 4 replications; individual plots are 30-feet wide and 150-feet long.

Soil and Crop Management

Cultural practices have been relatively consistent since the study began. Plowing and chiseling were done in the fall with 1 disking and 1 or 2 field cultivation passes for spring seedbed preparation. For the ridge system, ridges were made at cultivation in corn and after harvest in soybeans. Row width for corn is 30-inches. Row width for soybeans was 30-inches for soybeans from 1975 to 1994. Starting in 1995, soybeans were drilled in 7.5-inch rows for plow, chisel and no-till treatments. All 30-inch row treatments except no-till were inter-row cultivated once.

Starter fertilizer was used for all corn plots, but not for soybeans. Placement was 2-inches to the side and 2-inches below the seed. Nitrogen source for corn was anhydrous ammonia through 2000 and liquid UAN (28%) starting in 2001, either pre-plant or side-dress. Total nitrogen applied generally exceeded 180 lbs/acre of actual N. Phosphorus, potassium and lime were surface-applied as needed.

Corn planting dates ranged from April 25 to May 31 and soybean dates from May 3 to June 21; however, all tillage treatments were planted on the same day each year. One-inch fluted, 2-inch fluted or bubble coulters were used ahead of planter disk openers from 1975 to 1996. Starting in 1997, no coulters were used ahead of disk openers as per planter manufacturer recommendation; however, tined row cleaners were used in no-till corn treatments. For ridge-till planting, horizontal disks were used to scrape ridges at planting from 1980 to 1996 and then we switched to planter-mounted, double-vertical disks in 1997.

Burndown herbicides were applied to control existing vegetation when needed. Pre-emergence herbicides were applied with the planter pass from 1975 through 1996. Starting in 1997, pre-emergence herbicides were applied after planting in a separate operation. Post-applied herbicides were used for weed escapes. Where needed, plots were hand weeded to ensure that weed control did not limit yield. Insecticides were applied at planting for corn rootworm control. Chemical control for cutworms, stalk borers, bean leaf beetle, rodents, and spider mites was applied as needed.

Five corn hybrids and 10 soybean varieties have been used during the 30 years of this project.

Researchers Involved

Dr. Jerry V. Mannering, Harry Galloway and Donald R. Griffith initiated the experiment in 1975 and continued to direct it until their respective retirements in 1989, 1980, and 1995. Terry D. West has managed the experiment from 1979 until present. Dr. Tony J. Vyn became involved in 1998, after moving from Canada where he had been involved in tillage research for 20 years.

Numerous faculty and graduate students have conducted research on this experiment over the years. Most of the efforts were directed towards soil physical properties (Drs. Mannering, Kladivko and Steinhardt), soybean diseases (Drs. Abney and Westphal), corn and soybean production (Griffith and Dr. Swearingin), agricultural engineering (Dr. Parsons), soil microbiology (Drs. Nakatsu, Turco and Brouder), soil fertility (Dr. Mengel) and entomology (Bledsoe).

Table 1. Planting dates for corn and soybean, Long-term Tillage Study, ACRE.

	Year	Corn	Soybean		Year	Corn	Soybean
1	1975	5/2	5/6	16	1990	4/26	5/21
2	1976	4/29	5/10	17	1991	5/10	5/16
3	1977	5/10	5/6	18	1992	5/5	5/8
4	1978	5/3	5/19	19	1993	5/11	5/12
5	1979	5/9	5/17	20	1994	4/26	5/17
6	1980	5/5	5/15	21	1995	5/22	6/1
7	1981	5/22	5/28	22	1996	5/31	6/21
8	1982	4/30	5/11	23	1997	4/29	5/16
9	1983	5/10	5/12	24	1998	5/14	5/18
10	1984	5/2	5/14	25	1999	5/12	5/21
11	1985	4/25	5/16	26	2000	4/26	5/24
12	1986	4/29	5/28	27	2001	5/2	5/10
13	1987	5/5	5/7	28	2002	5/29	5/29
14	1988	4/26	5/12	29	2003	5/23	5/27
15	1989	4/25	5/12	30	2004	4/29	6/4

Table 2. Soil test results based on composite samples, Long-term Tillage Study, ACRE, Fall 2004.

		Soil pH			Soil P Concentrations			Soil K Concentrations		
Rotation	Tillage	0-4”	4-8”	Mean	0-4”	4-8”	Mean	0-4”	4-8”	Mean
					ppm	ppm	ppm	ppm	ppm	ppm
Con’t soybean	Plow	7.1	7.1a*	7.1a	60b	66	63b	175b	191	183b
	Chisel	7.4	7.1a	7.3a	96a	48	72ab	245a	168	206ab
	Ridge	7.3	6.5b	6.9b	111a	42	76ab	253a	149	201ab
	No-till	7.1	6.4b	6.8b	119a	52	85a	293a	171	232a
	Average			7.0			74			206
Corn/soybean	Plow	6.8	6.9a	6.8a	47c	48	48c	148c	152	150c
	Chisel	7.1	6.6a	6.9a	84b	49	66bc	202bc	141	171bc
	Ridge	6.9	5.9b	6.4b	111ab	50	80ab	269b	141	205ab
	No-till	6.7	5.5b	6.1b	124a	54	89a	344a	157	251a
	Average			6.5			71			194
Con’t corn	Plow	6.8ab	6.7a	6.7a	49b	55	52c	152c	171	161c
	Chisel	7.0a	6.2b	6.6a	94a	54	74b	236b	150	193bc
	Ridge	6.4b	5.6c	6.0b	107a	64	85ab	293ab	153	223ab
	No-till	6.5ab	5.4c	5.9b	117a	74	95a	328a	175	251a
	Average			6.3			77			207

*Means with the same letter are not significantly different.

2004 Field Practices

Primary tillage included the use of an International Harvester 5-furrow 18-inch bottom semi-mounted moldboard plow on the plow treatments. A DMI 7-shank coulter-chisel plow equipped with 4-inch twisted chisel points on 15-inch centers and a Danish-tine sweep leveling bar was used for the chisel treatment. Secondary tillage for plow and chisel included the use of an International 22-foot pull type tandem disk with spring tooth harrow and a Glencoe 10-foot field cultivator with rear-mounted, double-rolling baskets.

Nitrogen was sidedressed at a depth of 3 to 4 inches with a DMI NutriPlacr 2800 5-knife liquid nitrogen applicator equipped with 1 coulter per knife. The outside knives (#1 and #5) delivered 1/2 rate and after the first pass through the plots, an outside knife was placed back in the previous outside knife track to give a full rate. This method of knife placement gives us a marker for guiding the equipment for uniform application.

Corn was planted in 30-inch rows with a Case-IH model 955 4-row planter. Ripple coulters opened a slot for starter fertilizer placement.

We used row-unit-mounted vertical disks to scrape the ridge tops when planting the ridge treatment. Ideally we would remove 1-inch or less of soil and residue to take advantage of the ridge's warmer and dryer soil conditions. When attempting to plant the ridge treatment after corn this year we had problems with root balls from the 2003 corn crop popping out of the soil rather than cleanly shearing off. The result was pockets or holes where we could not cover the seed adequately. We then adjusted the scrapers to remove about 2-inches of the ridge top to achieve a uniform seedbed free of the pockets. In other words we had to sacrifice the warmer and dryer soil conditions of the ridge treatment in order to have a level seedbed.   When planting after soybeans the scrapers were reset to remove 1-inch or less of soil and residue, thus preserving the benefits associated with ridge-till.

We planted the no-till continuous corn 6-inches beside the old row rather than on the old row. We also used unit-mounted row cleaners to clear the row area of residue when no-till planting into corn and soybean residue.

Soybeans were planted with a 10-foot John Deere 750 no-till drill in the plow, chisel and no-till treatments. In the ridge treatment, the soybeans were planted with the Case-IH 955 planter in 30-inch rows.

Herbicides were applied with a tractor mounted Century 30-foot sprayer. All herbicides were broadcast with flat fan 8004 nozzles at 30-psi and 20-gallons water/acre at 5-miles per hour.

All 30-inch row plots, except no-till, were cultivated with a 4-row Hiniker ridging cultivator to control weeds and aerate the soil. The ridging wings were raised (and inoperative for "level" cultivating) on the plow and chisel plots. Ridge-till soybean plots were re-ridged after harvest. All corn plots were harvested with a John-Deere/Almaco model 700 combine equipped with a 4-row corn head. All soybean plots were harvested the same John-Deere/Almaco model 700 combine equipped with a 10-foot grain platform with pickup reel and a straw chopper.

Summary of studies conducted on the tillage plots by researcher.

<u>Dr. Scott Abney, USDA-ARS, Botany and Plant Pathology.</u>

The overall objectives of the soybean pathology research in the Long-Term tillage plots are: 1) identify and describe incidence and severity of Sudden Death Syndrome and Phytophthora root rot in conventional vs. reduced-tillage soybean production systems; 2) characterize the role of selected fungicide and post-herbicide treatments associated with conventional and no-till systems on developmental progress of soybean diseases that will facilitate improved plant health; and, 3) continue identifying pathogenicity and virulence of *Phytophthora sojae* races and *Fusarium solani* strains isolated from soybeans with Phytophthora root rot and sudden death syndrome symptoms, respectively. This research is important to Indiana and the North Central region agriculture and is an integral part of Abney's on-going soybean pathology research project which emphasizes maintaining improved plant health as a means of reducing yield losses caused by Phytophthora root rot, sudden death syndrome and late season diseases. During the 1990s, diseases caused by *P. sojae* and *F. solani* have increased throughout the North Central region. Research data from field sites with a history of disease caused by these important soybean pathogens are critical to the success of the above objectives. Diseases caused by both pathogens occur in the Long-Term tillage plots and this test site is one of the best locations at the Purdue Agriculture Research Center to evaluate Phytophthora damage on soybeans. This study will continue in 2005. *Dr. Scott Abne*y.

Anita Gal, Tony Vyn. Carbon Sequestration Study.
A study was initiated in 2002 to study carbon sequestration. Six probes per plot to a depth of 1-meter were collected from the no-till and moldboard plow plots in continuous corn and in the corn-soybean rotation. The soil cores were divided into 0-5, 5-15, 15-30, 30-50, 50-75 and 75-100 cm intervals for the determination of soil carbon, soil nitrogen and soil bulk density. Once the analyses are complete, they should help us determine the relative effects of tillage and rotation treatments on relative carbon sequestration. These results will be combined with other efforts at Purdue University and 8 other universities in the United States of America that are part of the Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS). Our overall goal is to develop better recommendations on best management practices for greenhouse gas sequestration. The 30-year history of these long-term plots provides a very valuable background to assess the impacts of management.

Terry D. West, Tony Vyn, and Gary Steinhardt, Agronomy.
T. West, T. Vyn and G. Steinhardt studied long-term affects of tillage and rotation by measuring plant population, growth, and yield of corn and soybeans.

Drs. Andreas Westphal (Botany and Plant Pathology) and Tony Vyn (Agronomy)
Population densities of Soybean Cyst Nematode under different tillage systems in different crop sequences
The role of tillage intensity on population density development of *H. glycines* was investigated in long-term tillage plots, established in 1975 at the Agricultural Center for Research and Education, Purdue University. In this long-term experiment, main plots were crop sequence treatments: (1) continuous corn, (2) corn-soybean, (3) soybean-corn, and (4) continuous soybean. Subplots in a split-plot arrangement, were tillage treatments: (A) moldboard plow and secondary tillage, (B) chisel and secondary tillage, (C) ridge tillage, and (D) no tillage. In earlier years, the soybean cultivars used in the experiment had some resistance to *H. glycines*. Starting in 2003, a strip (comprised of 1/3 of the original plot area) in each soybean subplot was planted to the *H. glycines*-susceptible cultivar Williams 82 to allow nematodes to reproduce. In spring and fall of 2003 and 2004, soil samples were collected to a depth of 30 cm to monitor nematode population densities. In the combined analysis of rotational and soybean monoculture plots of both years, fall population densities of *H. glycines* decreased with decreasing intensity of tillage in the corn-soybean rotational soils, whereas population densities were not significantly different among tillage treatments in the monoculture soybean soils (Fig. 1). Tillage has fundamental effects on the soil environment that warrant further study on how these affect population densities of *H. glycines.*

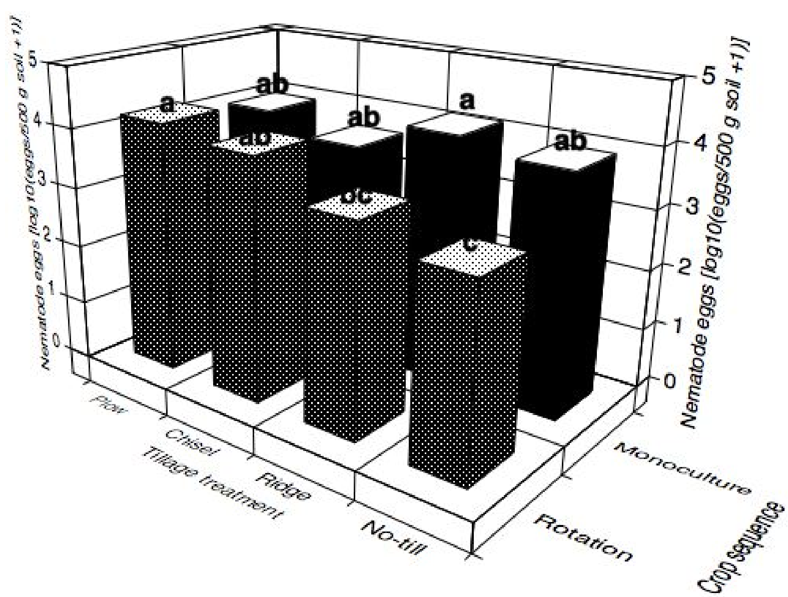

Fig. 1. Population densites of *H. glycines* at harvest of soybean in "rotation" (crop sequence of corn and soybean) or "monoculture" (continuous soybean). Nematode egg population densities were log-transformed before the combined analysis for 2003 and 2004 harvest data. Bars indexed with the same letter were not significantly different at $P \leq 0.05$.

The west 10-feet of each soybean plot was planted with Williams 82 as a part of Dr. Westphal's study of SCN and Sudden Death Syndrome. Grain samples were taken to compare with the Pioneer 93B67 planted in the "sacred" center 10-feet of each plot. Table 3 gives this data based on 3 replications (Reps 2-4) because of more extensive flooding problems in Rep 1. The Pioneer 93B67 yielded 14% more grain in rotation and 30% more in continuous soybean, than Williams 82 soybean. No-till soybean performed very well relative to conventional tillage practice in both varieties, and in both rotations.

Table 3. Agronomic performance of soybean as affected by tillage and rotation,
Chalmers silty clay loam, Long-term Tillage Study, ACRE, Purdue Univ., 2004. †‡

		Williams 82		Pioneer 93B67	
Previous Crop	Tillage	Harvest moisture	Yield @13.0%	Harvest moisture	Yield @13.0%
		%	Bu/a.	%	Bu/a.
Corn	Plow	13.9	44.8	14.1	55.1
	Chisel	14.1	46.3	14.0	52.4
	Ridge	14.0	51.8	14.0	54.5
	No-till	14.0	49.9	14.0	57.1
Soybean	Plow	14.1	40.3	14.1	51.6
	Chisel	14.2	41.0	14.3	52.2
	Ridge	14.0	43.7	13.9	54.0
	No-till	14.0	40.9	14.1	58.7

†Average of 3 replications.

Long-term Tillage Plots, ACRE.

CULTURAL PRACTICES USED 2004 Long-term Tillage Study, ACRE, Purdue University				
Item	Corn		Soybean	
	Date	Application Details	Date	Application Details
Secondary tillage	4/19 4/28	Disk once on plow and chisel plots Field cultivate once on plow and chisel plots	5/10 6/4	Disk once on plow and chisel plots Field cultivate once on plow and chisel plots
Hybrid/Variety planted	4/29	Beck's 5322 (109-Day) Row cleaners on c/b and c/c no-till. Shifted no-till c/c to east. (Shift to west in 2005)	6/4 6/23	Pioneer 93B67 Round-up Ready Group 3.5 Replant in reps 1 and 2.
Seeding rate		32,000 seeds/a., Drum B, 36 pockets (variable rate controller)		Plow, chisel, no-till drilled: 200,000 seeds/a. Ridge 30-inch rows: 140,000 seeds/a. (variable rate controller)
Starter fertilizer/planter		34-0-0 @ 96 LB/a., 2-inches to the side and 2-inches below the seed (sprockets driver 36, driven 30)		None
Insecticide/planter		Force 3G, 5 oz/1000 row feet, banded over row (Insecticide setting 1-7)		None
Rodenticide/planter		Pro-Zap zinc phosphide pellets in furrow for rodent control		None
Weed control	 4/26 4/30	Burndown: Roundup WeatherMax 2 pt/a. and 17 lbs ammonium sulfate per 100 gallons water on no-till and ridge-till Pre-emergence: Harness Extra 5.6L 5pt/a.	 4/26 6/4	Burndown: Roundup WeatherMax 2 pt/a. and 17 lbs ammonium sulfate per 100 gallons water on no-till and ridge-till Pre-emergence: First Rate 0.75 oz/a. Micro-tech (Lasso) 6 pt/a. Roundup Weather Max 2 pt/a.
Nitrogen fertilizer	5/30	200 lbs N as UAN (28%) @ 60 gallons/acre		None
Cultivation	6/7 6/7	Plow and chisel treatments Ridge treatment (re-ridge)	6/15 11/12	Ridge treatment only Ridge treatment (re-ridge)
Harvest	9/21	Center 4 of 12 rows, 150-feet	10/22	Center pass, 10-feet x 150-feet
Fall fertilizers	11/8		11/8	
Phosphorous		None		None
Potassium		0-0-60 @ 200 LB/a.		0-0-60 @ 200 LB/a.
Lime		None		None
Primary tillage	11/11 11/11	Fall plow on plow treatment Fall chisel on chisel treatment	11/11 11/11	Fall plow on plow treatment Fall chisel on chisel treatment

Weather and soil conditions in 2004

April rainfall was 1.12-inches compared to a normal rainfall of 3.65-inches (Fig. 3). Secondary tillage in the tilled plots provided an excellent seedbed. Corn was planted on April 29th in ideal soil conditions. Weather conditions from date of planting through the end of May resulted in excellent seed germination and plant emergence for corn. However, the frequent rainfall in May prevented the planting of soybeans until June 4th. The next six days were dry and the soybeans emerged satisfactorily. The following three days (June 11-13) brought rain totaling 8.51-inches flooding most of rep 1 and parts of the other 3 reps. Fortunately, the rest of June had slightly over 1-inch of rain, which allowed the flooding to recede and the soils to dry enough for replanting of some soybean plots. July and August had near normal rainfall and sufficient growing degree day accumulation to allow for excellent plant growth and development. September was exceptionally dry with only 0.51-inches of rain. Corn was harvested on September 21st. The first half of October continued the trend of little rainfall with accumulations of trace amounts until a period rain settled in starting October 13th. Soybean was harvested October 22nd. In summary, this growing season experienced ideal planting conditions in April, a wet May, record setting flooding in June, and excellent moisture and sunshine in July and August. A dry September and October allowed for crop maturity and good harvest conditions.

Stand, growth, and yield -- Corn.

In no-till continuous corn, establishing a uniform stand can be difficult. The corn residue is thickest on the old row and we had previously observed seeds planted in contact with residue, not in contact with soil. Variable seed depth and inconsistent contact with the soil can result in non-uniform germination, reducing yield potential. We have shifted no-till corn after corn rows 6-inches (enough to clear the planter gauge wheels) to the side of last year's rows. By shifting the new rows, we wanted to gain more uniform seeding depth, improve seed to soil contact, and achieve more uniform seedling emergence. This is the 10th year of shifting the new rows. We achieved these goals in 9 of the 10 years.

Continuous corn: Tillage and planting went well in all treatments except ridge-till. We used row-unit-mounted vertical disks to scrape the ridge tops when planting the ridge treatment. Ideally we would remove 1-inch or less of soil and residue to take advantage of the ridge's warmer and dryer soil conditions. At this depth setting we had problems with root balls from the 2003 corn crop popping out of the soil rather than cleanly shearing off. The result was pockets or holes where we could not cover the seed adequately. We then adjusted the scrapers to remove about 2-inches of the ridge top to achieve a uniform seedbed free of the pockets. In other words we had to sacrifice the warmer and dryer soil conditions of the ridge treatment in order to have a level seedbed. Planting into the wet soil made it difficult to close the seed slot and may have resulted in side wall compaction. Although we achieved plant stands equal to the other treatments (see Table 4) the grain yield for ridge-till continuous corn was significantly (at the 0.05 level) less than the plow treatment. The 12 bushels/acre reduction (6%) this year is well below the 25 year average of less than 2 bushels/acre (1%). Perhaps some of yield loss can be attributed to seedling stress in the less than ideal seedbed.

Excellent seedbeds were established in the plow and chisel treatments with the two secondary tillage passes. No-till also planted easily with good seed to soil contact. We achieved similar stands among all treatments with no significant differences. The significantly shorter corn at 4-weeks after planting in the plow treatment is puzzling and we have no explanation for this. Plant growth continued normally through 8-weeks after planting, although the soil was saturated following the 8.5-inches of rain in a 3-day period in June. Replication 1 had standing water for more than a week; therefore we did not include it in the Tables 4 and 5. Pollination was very good with minimal silk clipping from insects. No-till corn grain yields were significantly lower than the other treatments in continuous corn.

Corn following soybeans: Plant stands were not equal in all treatments. The ridge system was significantly lower than the other treatments. As in continuous corn, plant height was shorter in the plow treatment, and again there seems to be no logical reason for this. Note that no-till was significantly taller at 4 and 8 weeks after planting compared to the other treatments. The no-till treatment did not seem to greatly suffer from the water saturated soils following the heavy rains in June. There were no significant differences in grain moisture at harvest. The plow treatment yielded the most at 213.2 bushels/acre, but was not significantly different than the other treatments.

Table 4. Agronomic performance of corn as affected by tillage and rotation,
Chalmers silty clay loam, Long-term Tillage Study, ACRE, Purdue Univ., 2004. †

Previous Crop	Tillage	Residue cover after planting	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield @15.5%
		%	ppa	in	in	%	Bu/a.
Corn	Plow	4d‡	29800	14.1b	59.2b	18.3	201.3a
	Chisel	31c	30400	17.1a	67.8a	16.3	198.2ab
	Ridge	50b	30500	16.9a	66.3a	16.8	189.3b
	No-till	93a	30200	17.0a	61.3b	17.1	179.0c
Soybean	Plow	2c	30100a	13.8c	60.3b	18.4	213.2
	Chisel	9c	30100a	16.8b	68.8b	17.4	209.1
	Ridge	47b	29000b	16.5b	69.5b	18.4	207.3
	No-till	85a	30600a	18.7a	72.3a	16.5	207.1

†Average of 3 replications.
‡Within rotations, data followed by the same letter are not significantly different according to Student-Newman-Kuels Test (P= .05).

Stand, growth, and yield -- Soybeans.

For the 11th consecutive year we drilled the plow, chisel, and no-till treatments at 7.5-inch row spacing, while the ridge treatment was planted at 30-inch row spacing. Seeding rates were set higher for the drilled treatments. Soil samples taken in 1999 and 2002 confirmed the presence of Soybean Cyst Nematodes (SCN) in many of the plots. To reduce the negative impact of SCN on yield potential we have planted SCN resistant varieties since 2000.

Rotation soybean/corn: Surprisingly, ridge plant populations were not significantly lower due to the reduced seeding rate at planting for 30-inch rows (Table 5). This can be partially explained by the erratic plant stands caused by seedlings dying in the saturated soils after the June rains and by soil crusting that prevented many plants from emerging. Plant height was not significantly different at 4 and 8 weeks after planting. We did note some plants infected with Sudden Death Syndrome (SDS). These were more often found in chisel plots. The 30-inch row ridge plots yielded equal to the 7.5-inch drilled treatments. This points out the competitiveness of the ridge-till system compared to drilling soybeans in a full-width tillage system in this study. Rotation soybeans yielded only 1% more than continuous soybeans in 2004, similar lack of yield responses to rotation with corn was also observed in 5 other years in the 30 year history(i.e. 1979, 1981, 1983, 1984, 1990). Overall yields were above the 30-year average for rotation soybeans following corn.

Continuous soybean: Plant populations (Table 5) in the ridge treatment were not significantly lower due to the reduced seeding rate at planting for 30-inch rows for the same reasons as in soybean following corn. Although there were obvious plant height differences between tillage systems they were not significant. We suspect that yields in all continuous soybean plots were somewhat affected by SCN. We also observed some plants affected by Sudden Death Syndrome. Continuous soybean yields were surprisingly competitive with soybean following corn, yielding just 1% less when the 30-year average has continuous soybean yielding 9% less than soybean following corn.

Table 5. Agronomic performance of soybean as affected by tillage and rotation, Chalmers silty clay loam, Long-term Tillage Study, ACRE, Purdue Univ., 2004. †

Previous Crop	Tillage	Residue cover After planting	Stand‡ 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield @13.0%
		%	ppa	in	in	%	Bu/a.
Corn	Plow	3c§	163500	5.3	28.0	14.1	55.1
	Chisel	19b	164400	5.3	29.5	14.0	52.4
	Ridge	26b	123700	6.3	31.7	14.0	54.5
	No-till	87a	164900	4.8	29.1	14.0	57.1
Soybean	Plow	1b	161600ab	5.1	25.5	14.1	51.6
	Chisel	3b	206100a	7.4	30.5	14.3	52.2
	Ridge	12b	125100b	6.3	28.5	13.9	54.0
	No-till	61a	166300ab	5.2	27.3	14.1	58.7

†Average of 3 replications.
‡Plow, chisel, and no-till are 7.5-inch drilled, ridge is 30-inch rows.
§Within rotation, data followed by the same letter are not significantly different according to Student-Newman-Kuels Test (P= .05).

Table 6. Analysis of variance summary, tillage data, Long-term Tillage Study, ACRE, Purdue Univ., 2004.

Variable	Residue cover after planting	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield Bu/a.
	----------Significance Level----------					
	Corn					
Tillage	.01	.05	.01	.01	NS	.01
Previous crop	.01	NS	NS	NS	NS	.01
Tillage x previous crop	.01	NS	NS	.01	NS	.05
	Soybean					
Tillage	.01	.02	NS	NS	NS	NS
Previous crop	.01	.06	NS	NS	NS	NS
Tillage x previous crop	.02	NS	NS	NS	NS	NS

Long-term Yields

Results from this study provide insight into long-term yield potential of corn and soybean with different tillage systems on dark prairie soils of the Central and Northern Corn Belt. While equipment, cultivars, and seeding rates were changed periodically, tillage treatments were not altered during the 30-years of this continuing experiment.

Both tillage system and rotation influenced stand, growth and yield of corn and soybean in these studies. In continuous corn, tillage system also influenced grain moisture. With planting conditions similar to those in this study, the following conclusions appear to be justified:

1. Both corn and soybean yields are greater in rotation than in continuous cropping for all tillage systems (Tables 7 and 8). The positive response to rotation is greatest for no-till corn. However, within the 3 tilled treatments (plow, chisel, and ridge) soybean yields increased more (percent basis) with rotation than did corn yields.
2. When corn follows corn, yields with chiseling and ridging may be reduced slightly (3% or less) compared with plowing. No-till continuous corn yield on dark, poorly drained soil is likely to be reduced, compared to yields with other systems, and the yield reduction may increase with time when planted on the old row (Fig. 4). Part, but not all, of the yield loss prior to 1995 may be due to reduced stand or non-uniform plant emergence. Since planting beside old row starting in 1995, the yield gap has been reduced.
3. When corn follows soybean, yields with plow and chisel are likely to be about the same. Yields from the ridge system may be slightly better (3%) than plow and chisel. No-till corn yields may be slightly reduced (2%) compared to plow and chisel, but the relative yields of no-till change little with time (Fig. 5). Yield reductions with no-till corn are not due to lower populations.
4. No-till soybean yields are likely to be reduced slightly, compared with plowing, but yield differences may be reduced with time (Fig. 6 and 7). No-till soybean yield reductions are likely to be less frequent when grown in narrow rows.

Table 7. Corn Yield Response to Tillage and Rotation, Long-term Tillage Study, ACRE, 1975-04.

Tillage	Corn/Soybean		Continuous Corn		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	177.6	- - -	169.6	- - -	5
Chisel	178.0	100	165.2	97	8
Ridge*	182.6	103	168.0	99	9
No-till	173.6	98	147.2	87	18

*Since 1980

Table 8. Soybean Yield Response to Tillage and Rotation, Long-term Tillage Study, ACRE, 1975-04.

Tillage	Corn/Soybean		Continuous Soybean		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	53.1	- - -	48.5	- - -	9
Chisel	51.5	97	46.3	95	11
Ridge*	51.3	97	45.6	94	13
No-till	50.7	95	46.8	96	8

*Since 1980

The Journal of Production Agriculture article titled "Effect of Tillage and Rotation on Agronomic Performance of Corn and Soybean: Twenty-Year Study on Dark Silty Clay Loam Soil" gives a detailed report of this research project. This article can be found in volume 9, no. 2, page 241 to 248, 1996. A reprint can be obtained by contacting Terry D. West, Agronomy Department.