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 the time of inter-row cultivation in corn and after harvest in soybeans. Row width for corn is 30-inches. Both moldboard and chisel plowed corn plots were also inter-row cultivated, but not no-till. Row width for soybeans was 30-inches for soybeans in all treatments from 1975 to 1994. Starting in 1995, soybeans were drilled in 7.5-inch rows for plow, chisel and no-till treatments, but the ridge treatment remained at 30-inches. Due to the threat of soybean rust disease, all soybean treatments were switched back to 30-inch rows starting in 2005. We concluded that the mechanical damage to plants during possible fungicide application(s) most likely would have greatly reduced yield in the harvest area of drilled soybeans. Soybean plots were not inter-row cultivated in 2005 or 2006.

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. The nitrogen source for corn was anhydrous ammonia through 2000 (either pre-plant or side-dress) and liquid UAN (28%) (always side-dress applied) starting in 2001. 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.

Six corn hybrids and 10 soybean varieties have been used during the 32 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	17	1991	5/10	5/16
2	1976	4/29	5/10	18	1992	5/5	5/8
3	1977	5/10	5/6	19	1993	5/11	5/12
4	1978	5/3	5/19	20	1994	4/26	5/17
5	1979	5/9	5/17	21	1995	5/22	6/1
6	1980	5/5	5/15	22	1996	5/31	6/21
7	1981	5/22	5/28	23	1997	4/29	5/16
8	1982	4/30	5/11	24	1998	5/14	5/18
9	1983	5/10	5/12	25	1999	5/12	5/21
10	1984	5/2	5/14	26	2000	4/26	5/24
11	1985	4/25	5/16	27	2001	5/2	5/10
12	1986	4/29	5/28	28	2002	5/29	5/29
13	1987	5/5	5/7	29	2003	5/23	5/27
14	1988	4/26	5/12	30	2004	4/29	6/4
15	1989	4/25	5/12	31	2005	4/19	5/5
16	1990	4/26	5/21	32	2006	4/29	5/31

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

2006 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.

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. We removed 1-inch or less of soil and residue to take advantage of the ridge's warmer and dryer soil conditions.

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.

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.

Soybeans were planted with the Case-IH 955 planter in 30-inch rows in all treatments.

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 corn 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 on the plow and chisel plots so that these plots were left as level as possible with inter-row cultivation. The soybeans plots were not cultivated. 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.

Dr. Scott Abney, USDA-ARS, Botany and Plant Pathology.
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 early planted soybeans. This study will continue in 2007. *Dr. Scott Abney*.

Anita Gal, Rex Omonode, Tony Vyn. Carbon Sequestration and Greenhouse Gas Emission 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. Greenhouse gas emissions from the soil surface of selected plots have been measured during the growing seasons of 2004 to 2006. 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 32-year history of these long-term plots provides a very valuable background to assess the impacts of management.

Further information about our results are available from 2 published papers:

Gàl, A., T.J. Vyn, E. Michéli, E.J. Kladivko, and W.W. McFee. 2007. Soil carbon and nitrogen accumulation with long-term no-till versus moldboard plowing overestimated with tilled-zone sampling depths. Soil Tillage Research. In Press, Corrected Proof. Available on-line March 27, 2007.

Omonode, R.A., T.J. Vyn, D.R. Smith, P. Hegymegi, and A. Gàl. 2007. Soil carbon dioxide and methane fluxes from long-term tillage systems in continuous corn and corn-soybean rotations. Soil and Tillage Research, In Press. Corrected Proof. Available on-line Feb. 20, 2007.

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.*

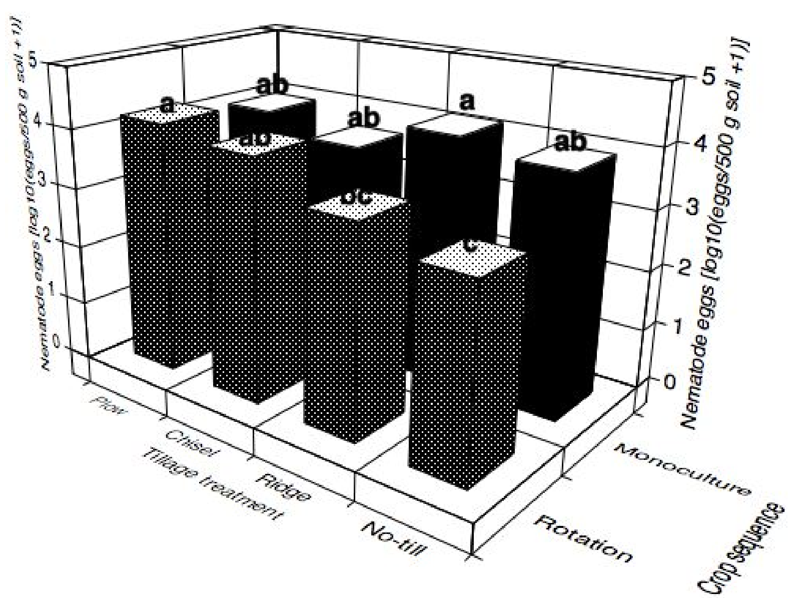


Fig. 1. Population densities of *H. glycines* at harvest of soybean in "rotation" (crop sequence of corn and soybean) or "monoculture" (continuous soybean). Nematode egg population densities were log-transformed before the combined analysis for 2003 and 2004 harvest data. Bars indexed with the same letter 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 93M80 planted in the "sacred" center 10-feet of each plot. Table 3 gives this data based on 3 replications (Reps 1, 2, and 4) because of a harvest equipment malfunction that affected 2 plots in replication 3. The Pioneer 93M80 variety yielded 30% more grain in rotation soybean, and 38% more in continuous soybean, than Williams 82 variety. Both varieties suffered from SDS symptoms in 2005, and the symptoms appeared worst in the chisel treatment.

Table 3. Agronomic performance of soybean as affected by tillage and rotation, Chalmers silty clay loam, Long-term Tillage Study, ACRE, Purdue Univ., 2006.†

		Williams 82		Pioneer 93M80	
Previous Crop	Tillage	Harvest moisture	Yield @13.0%	Harvest moisture	Yield @13.0%
		%	bu/a.	%	bu/a.
Corn	Plow	13.5	41.5	12.7	51.3
	Chisel	15.1	32.4	12.8	43.8
	Ridge	16.2	47.0	12.8	55.9
	No-till	16.9	49.4	12.8	51.7
Soybean	Plow	12.9	35.6	12.8	39.4
	Chisel	13.0	33.6	12.9	44.2
	Ridge	12.9	41.7	12.7	49.1
	No-till	12.8	39.0	12.8	45.6

†Average of 4 replications

Long-term Tillage Plots, ACRE.

CULTURAL PRACTICES USED 2006

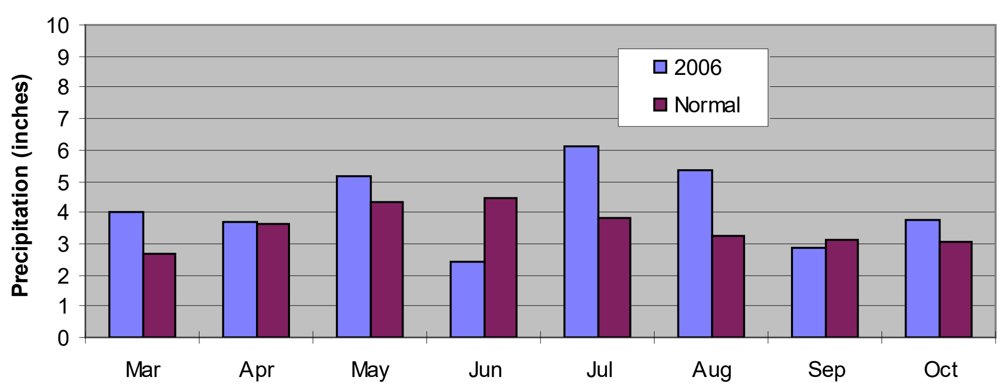
Long-term Tillage Study, ACRE, Purdue University

Item	Corn		Soybean	
	Date	Application Details	Date	Application Details
Secondary tillage	4/28	Disk once on plow and chisel plots	4/28	Disk once on plow and chisel plots
	4/29	Field cultivate once on plow and chisel plots	5/30	Field cultivate once on plow and chisel plots
Hybrid/Variety planted	4/29	Pioneer 31N28 (119-Day) Row cleaners on c/b and c/c no-till. Shifted no-till c/c to east. (Shift to west in 2007)	5/31	Pioneer 93M80 Round-up Ready Group 3.8
Seeding rate		32,000 seeds/a., Drum B, 36 pockets		140,000 seeds/a.
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		Pro-Zap zinc phosphide pellets in furrow for rodent control
Weed control	4/10	<u>Early burndown:</u> Roundup WeatherMax 2 pt/a. 2,4-D ester ½ pt/a. 17 lbs ammonium sulfate per 100 gallons water on no-till and ridge-till	4/10	<u>Early burndown:</u> Roundup WeatherMax 2 pt/a. 2,4-D ester ½ pt/a. 17 lbs ammonium sulfate per 100 gallons water on no-till and ridge-till
	4/29	<u>Burndown plus pre-emergence:</u> Roundup WeatherMax 2 pt/a., Harness Extra 5.6L 5pt/a ammonium sulfate 17 lbs/100 gallons water.	6/1	<u>Pre-emergence:</u> First Rate 0.75 oz/a. Micro-tech (Lasso) 6 pt/a. Roundup WeatherMax 2 pt/a.
Nitrogen fertilizer	6/10	250 lbs N as UAN (28%) @ 75 gallons/acre		None
Cultivation	6/16	Plow and chisel treatments		None
	6/16	Ridge treatment (re-ridge)	11/3	Ridge treatment (re-ridge)
Harvest	10/16	Center 4 of 12 rows, 150-feet	10/25	Center pass, 10-feet x 150-feet
Fall fertilizers				
Phosphorous		None		None
Potassium		None		None
Lime		None		None
Primary tillage	11/09	Fall plow on plow treatment	11/09	Fall plow on plow treatment
	11/09	Fall chisel on chisel treatment	11/09	Fall chisel on chisel treatment

Weather and soil conditions in 2006

March rainfall was 4.02-inches compared to a normal rainfall of 2.65-inches (Fig. 1). April was slightly higher than normal. Secondary tillage in the tilled plots provided an excellent seedbed. Corn was planted on April 29th in ideal soil conditions. A wet and cold 10-day period in May along with other planting commitments delayed soybean planting until May 31st. Although several inches of rain fell in that 10-day period our research plots never had standing water on them. Weather conditions in the second half of May resulted in satisfactory seed germination and plant emergence for corn and soybeans. June rainfall was approximately 1/2 of normal. Both corn and soybeans suffered to some degree. The month of July provided a total of 6.12-inches of rain and gave the needed relief to both crops. August had abundant rainfall and sufficient growing degree day accumulation to allow for excellent plant growth and development. September was near than normal with 2.84-inches of rain. October was wetter than normal making fall tillage on wet soils necessary. In summary there was adequate soil moisture for most of the growing season with exception of the 3 to 4 week dry period in June. Plenty of rainfall in August and September helped crops achieve excellent growth and yields. The wet October led to fall tillage in wetter than desired soil conditions.

Figure 1. Monthly precipitation for April through October, 2006 compared to normal, ACRE.



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 12th year of shifting the new rows. We achieved these goals in 11 of the 12 years.

Continuous corn: Tillage and planting went well in all treatments. We used row-unit-mounted vertical disks to scrape the ridge tops when planting the ridge treatment. The disks were set to remove 1-inch or less of soil and residue to take advantage of the ridge's warmer and dryer soil conditions. There were no problems this year with root balls popping up and leaving holes in the row area.

Excellent seedbeds were established in the plow and chisel treatments with the two secondary tillage passes. No-till planting resulted in good seed to soil contact. There were no significant differences in plant stands at 4 weeks after planting (Table 4). Plant height at 4 and 8 weeks after planting was significantly shorter for the plow treatment compared to the other treatments. This is puzzling and there appears no reason for this plant height difference. Pollination was satisfactory with little silk clipping.

The plow and chisel treatments yielded surprisingly well this year. In fact, yields in the plowed treatment were equal for continuous corn and those for corn grown in rotation with soybean. The trend over the 32-years of this study is for continuous corn in the plow treatment to yield an average of 8 bushels per acre less than the corn in rotation with soybean. This was also our second year for this long-season hybrid (Pion. 31N28, 119 CRM). The chisel yields were not significantly different than plow yields. The results with the ridge system, which yielded a statistically significant 24 to 31 bushels per acre less than chisel and plow, respectively, was also unexpected. This yield difference also occurred in 2005. In the 10 years previous to 2005, ridged corn yielded equal to full-width tillage systems. The no-till corn did not suffer from slower germination and growth through the season as it does most years. Harvest grain moisture with no-till was significantly higher than after the other treatments. No-till appeared to have more barren plants and poorer pollination than the other treatments, perhaps because of later silk development and more silk clipping damage than in the other treatments.

Corn following soybeans: Plant stands were equal in all treatments. Plant height at 8 weeks after planting was quite variable with chisel being significantly highest, plow and ridge equal, and no-till significantly the shortest. This variability is more often associated with continuous corn tillage systems. There were no significant differences in grain moisture at harvest. There were no significant yield differences among the tillage systems. Over the last 10 years of this study, no-till has averaged only 2 bushels per acre less than plow or chisel. This year, no-till yielded 9 to 10 bushels less per acre than plow, chisel, and ridge. This difference may be attributed to greater silk clipping in the no-till. No-till silked a few days later than the other treatments. Those insects feeding on the last of the tilled treatment silks then moved to the fresh silks of the no-till corn.

Table 4. Agronomic performance of corn as affected by tillage and rotation,
Chalmers silty clay loam, Long-term Tillage Study, ACRE, Purdue Univ., 2006. †

Previous Crop	Tillage	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield @15.5%
		ppa	in	in	%	bu/a.
Corn	Plow	30900	13.9b	40.6b	23.2b	217.2a
	Chisel	31100	16.5a	45.8a	22.7b	211.3a
	Ridge	30500	17.0a	45.2a	23.8b	187.1b
	No-till	31400	17.0a	45.4a	26.1a	169.2c
Soybean	Plow	30900	15.5	40.8b	23.0	212.6
	Chisel	31500	16.6	44.1a	22.1	213.5
	Ridge	32100	16.2	41.6b	24.2	212.4
	No-till	31100	15.2	37.7c	23.6	203.7

†Average of 3eplications.
‡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.

From 1995 through 2004 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. In 2005, we went back to 30-inch rows for all treatments. This was due to the threat of soybean rust disease. In order to spray fungicides if an outbreak occurred, the mechanical damage to drilled rows of the "sacred" harvest area would have severely impacted the yields. Any damage to 30-inch rows would be minimal, so we switched to the 30-inch rows.

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: Plant populations at 4-weeks after planting were equal and satisfactory for all treatments (Table 5). Slight differences in plant height at 4 weeks after planting were noted, but by 8-weeks after planting there were no significant differences. The ridge treatment yielded highest with 55.9 bushels per acre but not significantly different from plow and no-till. The chisel treatment yielded 43.8 bushels per acre which was significantly lower than the ridge treatment but not different from plow and no-till. We did note the chisel treatment had the most plants infected with Sudden Death Syndrome (SDS), and that might explain the unusual yield response following chisel.

Continuous soybean: Plant populations were satisfactory although there were significant differences among treatments (Table 5). Again, all treatments were planted in 30-inch rows. We suspect that yields in all soybean plots were affected by SCN. We also observed many plants affected by Sudden Death Syndrome. Plow, ridge and no-till all yielded 6 to 12 bushels per acre better in rotation compared to continuous soybean. The chisel treatment in rotation was within 1 bushel per acre of continuous soybeans.

Table 5. Agronomic performance of soybean as affected by tillage and rotation, Chalmers silty clay loam, Long-term Tillage Study, ACRE, Purdue Univ., 2006. †

Previous Crop	Tillage	Stand‡ 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield @13.0%
		ppa	in	in	%	bu/a.
Corn	Plow	127400	7.6ab	27.8	12.7	51.3ab
	Chisel	128100	7.9a	27.7	12.8	43.8b
	Ridge	130700	7.9a	28.2	12.8	55.9a
	No-till	128000	7.4b	27.0	12.8	51.7ab
Soybean	Plow	126300ab	7.8	26.6	12.8	39.4
	Chisel	130100a	7.7	27.1	12.9	44.2
	Ridge	124300b	7.6	27.2	12.7	49.1
	No-till	129600a	7.6	27.9	12.8	45.6

†Average of 4 replications.
‡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., 2006.

Variable	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield bu/a.
	Significance Level				
	Corn				
Tillage	NS	.01	.01	.02	.01
Previous crop	NS	NS	.01	NS	.04
Tillage x previous crop	NS	.05	.01	NS	.01
	Soybean				
Tillage	NS	.07	NS	NS	.03
Previous crop	NS	NS	NS	NS	.02
Tillage x previous crop	.03	.04	NS	NS	NS

Soybean analysis for 2005-2006 (2 years), all 30 inch rows, Long-term Tillage Study, ACRE

Table 7. Agronomic performance of soybean as affected by tillage and rotation, Chalmers silty clay loam, Long-term Tillage Study, ACRE, Purdue Univ., 2005-2006. †

Previous Crop	Tillage	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield @13.0%
		ppa	in	in	%	bu/a.
Corn	Plow	123500	5.7	24.0	13.1	54.3a‡
	Chisel	119500	5.8	23.2	13.1	47.6b
	Ridge	126100	5.7	23.0	13.2	58.4a
	No-till	118200	5.3	21.5	13.1	55.2a
Soybean	Plow	121500	5.6	22.6	13.1	44.3
	Chisel	122700	5.6	22.6	13.1	47.0
	Ridge	118600	5.5	22.1	13.0	49.2
	No-till	122100	5.6	22.7	13.1	46.8

†Average of 4 replications.
‡Within rotation, data followed by the same letter are not significantly different according to Student-Newman-Kuels Test (P= .05).

Table 8. Analysis of variance summary, tillage data, Long-term Tillage Study, ACRE, Purdue Univ., 2005-2006.

Variable	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield bu/a.
	Significance Level				
Tillage	NS	NS	NS	NS	.01
Previous crop	NS	NS	NS	NS	.01
Tillage x previous crop	NS	NS	.01	NS	.06

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 32-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 9 and 10). 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. 2). 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 (3%) compared to plow and chisel, but the relative yields of no-till change little with time (Fig. 3). Yield reductions with no-till corn are not due to lower plant populations.
4. No-till soybean yields are likely to be reduced slightly, compared with plowing, but yield differences may be reduced with time (Fig. 4 and 5). No-till soybean yield reductions are likely to be less frequent when grown in narrow rows (note the yield responses from 1995 to 2004), but no-till yields can be similar to those after plowing even in 30” row widths (note the yield responses in 1990-94, and again in 2005-06). We acknowledge that variety selection plays a large role in the relative yield responses of soybean to wide row widths and to no-till systems. However, soil-borne disease incidence was not the highest in long-term no-till for the pathogens evaluated (see earlier sections).

Table 9. Corn Yield Response to Tillage and Rotation, Long-term Tillage Study, ACRE, 1975-06.

Tillage	Corn/Soybean		Continuous Corn		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	179.7	- - -	172.3	- - -	4
Chisel	180.0	100	167.7	97	7
Ridge*	184.3	103	169.1	98	9
No-till	175.2	97	148.3	86	18

*Since 1980

Table 10. Soybean Yield Response to Tillage and Rotation, Long-term Tillage Study, ACRE, 1975-06.

Tillage	Corn/Soybean		Continuous Soybean		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	53.3	- - -	48.2	- - -	11
Chisel	51.3	96	46.3	96	11
Ridge*	51.8	97	45.8	95	13
No-till	50.9	96	46.8	97	9

*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.