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AGRONOMY RESEARCH CENTER

Long-term Tillage Study

T.D. West, T.J. Vyn and G.C. Steinhardt

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 Research Center in West-central Indiana. Our goal is 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 field cultivation 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 two inches to the side and two inches below the seed. Nitrogen source for corn was anhydrous ammonia, 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 leafs beetle, and spider mites was applied as needed.

Four corn hybrids and nine soybean varieties have been used during the 26 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 (Dr. Abney), 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 (Dr. Bledsoe).

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

	Year	Corn	Soybean		Year	Corn	Soybean
1	1975	5/2	5/6	14	1988	4/26	5/12
2	1976	4/29	5/10	15	1989	4/25	5/12

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

2000 Field Practices

Primary tillage included the use of an International Harvester 5 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 5 danish-tine sweep leveling bar was used for the chisel treatment. Secondary tillage for plow and chisel included the use of an International 15-foot pull type tandem disk and a John Deere 15-foot field cultivator with rear mounted spring tooth harrow.

Nitrogen was applied preplant at a depth of 6 to 7 inches with a 5-knife anhydrous ammonia applicator equipped with 1 coulter, 1 sealing wing, and 2 covering disks per knife. The covering disks were removed for no-till continuous corn to avoid residue plugging. The disks were also removed for all ridge plots to prevent “shaving” of the ridge shoulders. The outside knives (#1 and #5) were equipped to deliver 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. We chose not to use a "splitter" in the anhydrous hoses to the outside knives. Instead, we equipped the outside half-rate knives with single tubes and hoses and the full rate knives with double tubes and hoses.

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. When planting the ridge treatment, row-unit-mounted double vertical disks scraped less than 1 inch of soil off the ridge tops and stabilized the planter on the ridge tops. 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 8006 nozzles at 30-psi and 30-gallons water/a. 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 White model 7300 combine equipped with a 4 row cornhead. All soybean plots were harvested with a John Deere model 3300 combine equipped with a 10-foot grain platform with pickup reel.

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 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 northcentral 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 northcentral 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 2001. *Dr. Scott Abney*

- Cindy H. Nakatsu and Sylvie M. Brouder, Agronomy: Diversity of the Rhizosphere Bacterial Community of Corn and Soybean
  This was the fourth year of collecting corn and soybean plants from the long-term tillage plots. Collections were made of the disturbed (plowed) and undisturbed (no-till) soils, of the corn and soybean crops, grown in monoculture or in a two crop annual rotation. We continued to concentrate our studies on the rhizosphere soils of corn and soybean. The rhizosphere is the soil region in contact with plant roots and exudates from the roots can promote microbial growth. Characteristic profiles of the communities were obtained by denaturing gradient gel electrophoresis (DGGE) of PCR amplified 16S rDNA from soil extracted DNA. Using this method PCR products with different sequences migrate different distances in the denaturing gel producing distinct “fingerprint” patterns. The method is able to show the dominant rhizosphere bacterial populations, as indicated by bands with greater intensity. Observations from previous years indicated there are distinct microbial communities associated with root type, plant growth stage, and agronomic treatment. Statistical analysis showed that the microbial community fingerprints group according to plant growth stages within each agronomic treatment. Plant analysis showed that soil treatments resulted in distinct shoot and root growth patterns with significant differences observed in morphological and architectural aspects of the rooting systems of corn. Preliminary comparison of data between years suggests that some of the same populations can be observed yearly but yearly variables such as weather does impact community structure. This approach provides a means to understand factors influencing the microbial ecology of the rhizosphere and conversely, the influence microbial ecology has on plant development. *Dr. Cindy H Nakatsu*
- 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.

Table 2. Soil test results based on composite samples, Long-term Tillage Study, ARC, Fall 2000.

Tillage	**Crop**	**Depth**	**OM**	**Phos.**	**K**	**Mg**	**Ca**	**Soil pH**	**Buffer pH**	**CEC**
		Inches	%	ppm	ppm	ppm	ppm			meq/100g
Plow	CC	0-8	4.6	44 H	153 M	600 H	2350 M	6.2	6.7	20.7
No-till	CC	0-4	5.9	72 VH	299 VH	720 VH	2350 M	6.6	6.9	19.7
No-till	CC	4-8	4.9	59 VH	161 M	620 H	2200 L	5.5	6.4	23.8
Plow	CB	0-8	3.7	31 H	133 M	735 VH	2700 M	6.6	6.8	22.4
No-till	CB	0-4	5.4	67 VH	274 VH	820 VH	2750 M	7.0		21.3
No-till	CB	4-8	4.4	31 H	123 M	665 H	2450 L	5.8	6.6	22.9
Plow	BB	0-8	4.3	37 H	152 M	750 VH	2650 M	7.0		19.9
No-till	BB	0-4	4.1	62 VH	253 H	740 VH	2650 M	7.2		20.1
No-till	BB	4-8	4.3	29 M	142 M	675 VH	2500 M	6.2	6.7	22.1

CULTURAL PRACTICES USED 2000

Long-term Tillage Study, ARC, Purdue Univ.

Item	Corn Date	Corn Application	Soybean Date	Soybean Application
Nitrogen fertilizer	4/6	NH_3 @ 200 LB/a. N in row middles, N-serve, double-disk sealers on all plow and chisel, also no-till corn after soybean.		None
Secondary tillage	4/18	Disk once on plow and chisel treatments.	5/23	Disk once on plow and chisel treatments.
	4/25	Field cultivate once on plow and chisel treatments.	5/24	Field cultivate once on plow and chisel treatments.
Hybrid/Variety planted	4/26	Beck's 5405 (110-Day) Row cleaners on c/b and c/c no-till. Shifted no-till c/c to east. (Shift to west in 2000).	5/24	Pioneer 93B66
Seeding rate		30,000 seeds/a., Drum A, 24 pockets (variable rate controller).		Plow, chisel, no-till drilled: 193,500 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
Weed control	4/14	Burn-down on no-till and ridge: Gramoxone Extra 3 pt/a. Surfactant 1.5 pt/100 gallons water	4/14 & 5/16	Burn-down on no-till and ridge: Gramoxone Extra 3 pt/a. Surfactant 1.5 pt/100 gallons water
	4/26	Pre-emergence: Harness Extra 5.6L 5pt/a. Roundup Ultra 2 pt/a.	5/26	Pre-emergence: Dual II Magnum 1.67 pt/a. Lorox Plus 18 oz/a. Roundup Ultra 2 pt/a.
Cultivation	6/8	Plow and chisel treatments.	?	Ridge treatment only.
	6/8	Ridge treatment (re-ridge).	10/24	Ridge treatment (re-ridge).
Harvest	9/15	Center 4 of 12 rows, 150-feet.	10/10	Center pass, 150-feet.
Primary tillage	10/24	Fall plow on plow treatment.	10/24	Fall plow on plow treatment.
	10/25	Fall chisel on chisel treatment.	10/25	Fall chisel on chisel treatment.
Phosphorous, Potassium	10/23	0-45-0 @ 200 LB/a. 0-0-60 @ 300 LB/a. Bulk spread, 2 passes	10/23	0-45-0 @ 200 LB/a. 0-0-60 @ 300 LB/a. Bulk spread, 2 passes
Lime	10/23	2 ton/a. Bulk spread, 2 passes	10/23	

Stand, growth, and yield -- Corn.

Overall the corn yields on these plots were much lower than expected. Common corn rust (Fungus. *Puccinia sorghi*), stalk rots and diplodia ear rot (Fungus. *Diplodia maydis*) are some of the stress factors that had a negative impact on yield potential. A December 2000 Prairie Farmer Magazine article by Tom Bechman quoted Purdue Research Agronomist Bob Nielsen. "Believe it or not, high yield potential was the biggest stress of all! It became the magnifying glass that turned minor stresses into major ones, Nielsen says. Poor root health early linked to big rains started it, then cloudy days and leaf rust during grain fill added pressure. A dry August was the last straw. Plants tried delivering to that high-yield promise, even if it meant pulling nutrients out of stalks. Many of today's newer, highly touted hybrids are bred not to destroy themselves, but the drive toward high-yield potential was just too strong."

Stalk rot lead to severe lodging in most plots, however the combine was able to pick up most downed corn. The high populations may have contributed to the severity of stalk rot along with dry weather in August.

Diplodia ear rot was observed in the ARC Long-term Tillage corn plots during late summer of 2000. To evaluate infestation, observations of 10 ears in each of 4 locations in each plot were made on September 5, 2000. Percent of ears infected ranged from 6 to 17% (See Tables 3 and 4) and no doubt reduced yields. According to Greg Shaner, a Purdue University plant pathologist, more surface residue favors Diplodia ear rot and stalk rots. With this in mind, we would expect the no-till and ridge treatments to have the greatest infections. However, considering the close proximity of our plots, the pathogen could spread from plot to plot independent of tillage system and surface residue.

Table 3. Corn Diplodia ear rot infestation as affected by tillage and rotation, Long-term Tillage Study, ARC, Purdue Univ., 2000. †

Previous Crop	Tillage	Infected ears
		%
Corn	Plow	7
	Chisel	9
	Ridge	15
	No-till	11
Soybean	Plow	7b‡
	Chisel	17a
	Ridge	6b
	No-till	10b

†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 4. Analysis of variance summary, Diplodia ear rot data, Long-term Tillage Study, ARC, Purdue Univ., 2000.

Variable	Infected ears
	Significance Level
Tillage	.05
Previous crop	NS
Tillage x previous crop	.01

In no-till continuous corn, establishing a uniform stand can be difficult. As hybrids become more stalk rot resistant, the residue can still be very tough come spring planting. We have found that these tough stalks do not decay enough to be easily broken and smashed down by the planter. This has lead to uneven seed depth as the planter units bounce over the old corn stubs. Often root balls "bulldoze over" leaving a rough soil surface, also resulting in uneven seed depth. The corn residue is thickest on the old row and we have noted 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 sixth year of shifting the new rows. In 5 of the 6 years, we achieved these goals.

Continuous corn. Plant stands were equal for all tillage systems when measured at 4 weeks after planting (Table 5). Plant emergence and stands were satisfactory for all treatments. Considering the early planting date of April 26, no-till surprisingly showed significantly taller plants at 4 weeks after planting (P = 0.05) than plow and chisel. The ridge treatment also showed taller plant height at 4 weeks than plow and chisel, and this may reflect the warmer soil temperatures often found in the ridges. By 8 weeks after planting all tillage systems were equal in height. The no-till treatment yielded significantly lower (P = 0.05) than the other treatments. Plow, chisel and ridge yields were not statistically different from each other.

Corn following soybeans. Plant stands in all treatments were equal. As is continuous corn, no-till exhibited the tallest plants at 4 weeks after planting. Thus, for the first time in many years no-till early plant heights were superior to those after moldboard plowing following both corn and soybeans. By 8 weeks after planting there were no significant differences in plant height. There were no significant differences in grain moisture at harvest or grain yield. For the first time in 22 years rotation corn yields were no higher than those for continuous corn.

Table 5. Agronomic performance of corn as affected by tillage and rotation, Chalmers silty clay loam, Long-term Tillage Study, ARC, Purdue Univ., 2000. †

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	7d‡	30700	10.8c	56.5	21.2	142.3a
	Chisel	40c	30500	11.5bc	57.3	20.8	142.1a
	Ridge	67b	30300	12.2ab	57.4	21.3	138.2a
	No-till	91a	30400	12.9a	58.2	21.7	129.8b
Soybean	Plow	3d	30900	10.8b	55.8	21.7	140.8
	Chisel	26c	30900	11.3b	54.4	21.3	137.8
	Ridge	67b	31500	11.8ab	55.2	21.5	139.3
	No-till	91a	30800	12.5a	58.0	21.4	134.4

†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 sixth successive 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 confirmed the presence of of Soybean Cyst Nematodes (SCN) in many of the plots. To reduce the negative impact of SCN on yield potential a SCN resistant variety was planted in 2000. This variety had a "choppy" plant height appearance when looking down the row early in the season. This was likely due to uneven seedling emergence. By late in the season, most plants were of uniform height within a plot. The soybean plants appeared less affected by SCN through the growing season when compared to last year. Along with the resistant variety, adequate rainfall allowed root growth to limit yield reductions due to SCN root damage.

Rotation soybean/corn: Ridge plant populations were significantly lower due to the reduced seeding rate at planting for 30-inch rows (Table 6). The ridge treatment exhibited the best plant emergence and growth through the first 4 weeks after planting. By 8 weeks after planting there were no significant differences in plant height. No significant insect or disease problems were noted. There were no significant yield differences among the treatments. The 30-inch row ridge plots were equal to the 7.5-inch drilled treatments. The average rotation advantage was approximately 20% in 2000, almost double the rotation advantage observed in the 26-year history of these plots.

Continuous soybean: Plant populations in the ridge treatment were significantly lower due to the reduced seeding rate at planting for 30-inch rows. Plant height was shorter at the 8-week measurement than for soybeans in rotation. The ridge treatment suffers from extremely high populations of SCN in some plots. We suspect that yields in all continuous soybean plots are somewhat affected by SCN. Dr. Scott Abney also observed some plants affected by Sudden Death Syndrome. It appears that 26 years of continuous soybeans may be a bit too much!

Table 6. Agronomic performance of soybean as affected by tillage and rotation, Chalmers silty clay loam, Long-term Tillage Study, ARC, Purdue Univ., 2000. †

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	4d§	151000a	6.8ab	22.8	11.4	55.3
	Chisel	33c	147000a	6.0bc	20.2	11.5	53.3
	Ridge	48b	114000b	7.6a	21.8	11.5	55.1
	No-till	93a	134000a	5.6c	20.3	11.5	53.3
Soybean	Plow	2d	138000a	6.0	19.8a	11.5	49.9a
	Chisel	12c	136000a	5.3	18.1ab	11.5	43.4b
	Ridge	26b	116000b	6.5	17.1b	11.7	40.5b
	No-till	81a	140000a	5.6	19.0a	11.7	48.0a

†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 7. Analysis of variance summary, tillage data, Long-term Tillage Study, ARC, Purdue Univ., 2000.

Variable	Residue cover after planting	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield Bu/a.
	------------Significance Level------------					
				Corn		
Tillage	.01	NS	.01	.10	NS	.01
Previous crop	NS	NS	NS	.08	NS	NS
Tillage x previous crop	NS	NS	NS	NS	NS	NS
				Soybean		
Tillage	.01	.02	.01	.02	NS	.01
Previous crop	.01	NS	.02	.03	.05	.03
Tillage x previous crop	.01	NS	NS	.09	NS	.01

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 26 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 8 and 9). 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 with yield with other systems, and the yield reduction may increase with time (Fig. 2). Part, but not all, of the yield loss may be due to reduced stand or non-uniform plant emergence.
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 changes little with time (Fig. 3). 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. 4 and 5). No-till soybean yield reductions are likely to be less frequent when grown in narrow rows.

Table 8. Corn Yield Response to Tillage and Rotation, Long-term Tillage Study, ARC, 1975-00.

Tillage	Corn/Soybean		Continuous Corn		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	174.6	- - -	166.3	- - -	5
Chisel	175.1	100	161.5	97	8
Ridge*	179.3	103	164.2	99	9
No-till	169.7	97	143.1	86	19

*Since 1980

Table 9. Soybean Yield Response to Tillage and Rotation, Long-term Tillage Study, ARC, 1975-00.

Tillage	Corn/Soybean		Continuous Soybean		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	52.3	- - -	47.9	- - -	9
Chisel	51.0	98	45.3	95	13
Ridge*	50.3	96	44.3	92	14
No-till	49.5	95	45.6	95	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.

Not for publication.

Feasibility of Fall Zone Tillage for Corn Production in Indiana

Melissa J. Arends, Tony J. Vyn, and Terry D. West, Dept. of Agronomy, Purdue University.

Introduction

Fall zone tillage can be considered as an alternative to intensive tillage systems when farmers are reluctant to initiate or continue with a pure no-till system. Fall zone tillage is a type of in-row loosening where only the intended row area for the subsequent crop is disturbed, leaving the interrow area covered with residue. Fall zone tillage allows for the option of planting row crops directly into the loosened area in the spring. Ideally, the fall zone-tilled strips will leave a mound in the fall approximately three to four inches high which will mellow down to about one to two inches in spring. This slight ridge, plus the loosening and residue disturbance associated with the fall zone tillage may improve soil drying and warming in spring compared to regular no-till rows. Earlier planting could be another advantage. Fall zone tillage may result in corn yields which are comparable to those with moldboard plow and disk systems, but superior to that after no-till alone. Biggest benefits are expected on poorly drained soils with high clay content. Ultimately, the adoption of fall zone-till would help to over come the challenges of planting corn in early spring on poorly drained fine-textured soils while still maintaining erosion control benefits, productivity, and profitability.

Objective

The objective of this research project was to evaluate the effects of fall zone tillage systems with varying depths and subsequent secondary tillage on (a) spring soil dry down, (b) soil physical properties in the seedbed, and (c) the response of corn compared to full-width and no-till systems. Ten different tillage treatments were evaluated to determine the optimum fall zone tillage depth and the need of subsequent secondary tillage. The purpose of this study was to introduce fall zone tillage as an alternative system to intensive tillage and pure no-till where needed.

Site Information

In the fall of 1998 the field experiment was established at the Agronomy Research Center (ARC). The soil type is a Drummer and Raub-Brenton Complex, which is somewhat poorly to poorly drained, silty clay loam to clay loam with 3-4.5% organic matter. The field had been in continuous no-till production for at least five years. The experiment was initiated after soybeans in a corn-soybean rotation for corn planted in 30-inch rows. The experiment was shifted to an adjacent no-till field in the fall of 1999 with a similar history so that two years of investigation involving first-year corn response to tillage could be completed by 2000. Both fields had systematic tile drainage.

Treatments

1) Fall Moldboard Plow
2) Fall Disk Only
3) Fall Zone-Till 13-inch Depth (John Deere 955 Deep Ripper)
4) Fall Zone-Till 8-inch Depth (DMI 2500 w/mole knife and berming disks)
5) No-till with 3 Coulters
6) No-till with Row Cleaners

Note: Treatments 3, 4, & 6 were compared with and without the Phillips Rotary Harrow in the spring. Treatment 2 was compared both with and without spring cultivation.

CULTURAL PRACTICES USED 2000 Feasibility of Fall Zone Tillage for Corn Production in Indiana, ARC, Purdue Univ.		
Field Operation	Date	Application Details
Fall Tillage	Oct. 1999	
Secondary tillage	4/18	Glenco Soil Finisher or Phillips Rotary Harrow
Hybrid planted	4/19	Pioneer 33A14 (113 day)
Seeding rate		30,000 seeds/a.
Starter fertilizer/planter		170 LB/a. 11.5-11.5-30, 2-inches to the side and 2-inches below the seed
Insecticide/planter		Force 3G, 5 oz/1000 row feet.
Weed control	4/20	Pre-emergence Harness Extra 5.6 5 pt/a. Roundup Ultra 1.5 pt/a. *All broadcast with flat fan 8006 nozzles at 30 psi and 30 gallons water/a., 5.0 mph.*
Nitrogen fertilizer	5/26	NH_3 @ 190 lb. N/a., sidedressed, no covering disks
Harvest	9/18	Hand harvest 15-meters of row per plot

Preliminary Results

Preliminary results for accumulated soil growing degree days, percent volumetric pre-plant soil water content, days from planting to 50% emergence, grain moisture, and grain yields are summarized in Table 11. For the purpose of this report, data from only 6 of the 10 tillage treatments is presented.

Table 11. Soil properties and agronomic performance of corn as affected by tillage, Fall Zone Tillage Study, ARC, Purdue Univ., 1999 and 2000. †

Treatment	Soil GDD 6 Days Prior to Planting	Pre-Plant Soil Water Content	Days to 50% Emergence	Grain Moisture	Grain Yield 1999	Grain Yield 2000
	(GDD Base 10ºC)	(%v/v)	(days)	(%)	(Bu/a.)	(Bu/a.)
Fall Moldboard	32.8a‡	22.8b	10.0c	17.7c	208	169
Fall Disk Only	28.8a	29.5a	11.4b	18.2bc	192	163
Fall Zone-till 13-inch	30.3a	23.8b	11.4b	18.6abc	191	162
Fall Zone-till 8-inch	27.1a	25.0b	12.3a	19.0ab	194	166
No-till w/ 3 Coulters	18.8b	30.2a	13.1a	19.4a	198	160
No-till w/ Row Cleaners	19.3b	31.0a	13.0a	19.1ab	197	161

†Average of 4 replications. Data presented as an average of 1999 and 2000 except for grain yields.

‡Data followed by the same letter are not significantly different according to a protected LSD(0.05) test.

Preliminary Conclusions

Cooler and wetter soils are often associated with no-till corn production. Our preliminary data confirms that soil temperature and moisture conditions prior to planting were inferior with no-till compared to conventional tillage. The initially cooler conditions are believed to have slowed corn emergence and early growth. Implementation of fall zone-till improved conditions in comparison to no-till. Fall zone-till resulted in warmer soil temperatures and faster soil drying in the row area prior to planting versus no-till. These improved conditions found with fall zone-till may allow for 2-3 days earlier planting in comparison to no-till. The two-year data supports previous studies that fall zone tillage provides improved soil conditions and enhanced crop performance in comparison to no-till.

Fall zone-till resulted in earlier emergence and drier grain at harvest than either no-till system although the development rate advances with zone-till may not always have been statistically significant. There were no significant differences in yield among the tillage treatments. A corn yield advantage of fall zone-till over no-till is more likely to occur when no-till yields are significantly lower than moldboard plow or disk systems. Potential advantages of fall zone-till relative to no-till maybe more apparent when you can take advantage of a 2-3 day early planting date and there are more early season stresses. The spring of 1999 and 2000 had 9% and 20% more accumulated corn GDD than normal from the time of planting to 30 days after planting. Overall results from the first 2-years of this study support the option of fall zone tillage as an alternative system to intensive tillage and pure no-till where needed.

Acknowledgements:

We are grateful for the in-kind support of (a) zone tillage equipment from Case-DMI (Goodfield, Illinois) and John Deere Ltd. (Des Moines, Iowa), (b) the Phillips Rotary Harrow from Precision Metal Fabrication (Saskatoon, Saskatchewan), and (c) corn seed from Pioneer Hi-Bred Ltd. (Tipton, Indiana).

PINNEY PURDUE AGRICULTURAL CENTER

Long-term Tillage Study

T.D. West, G.C. Steinhardt, and T.J. Vyn

In this study we will be investigating crop residue/soil temperature/tillage relationships and their effects on crop growth and yield. In this northern Indiana location, cold soil temperatures limit no-till crop performance. Most farmers in this area use full width primary tillage with 2 secondary tillage passes to prepare a suitable seedbed. Our plans are to use a wide variety of tillage equipment to determine if there is a level of tillage that will preserve crop residues on the soil surface for erosion control, yet give satisfactory yields. The practices are designed to leave crop residue levels ranging from none to as much as possible with a number of levels in between. We are looking for the most effective mix to insure both soil protection and production. This has been a frequently expressed concern in northern Indiana, and one in which farmers have real interest.

This study will be a good start toward addressing questions that area farmers have raised about reduced tillage. We feel this is finally going to provide the comparisons that farmers have been asking for on the soils that are most troublesome. This study was set up in the field in 1996 with proper row direction and cropping sequence.

Crop Rotations	Tillage Treatments	Data to be Collected
Continuous corn	Fall chisel, spring disk and combo-mulch-finisher	Soil compaction
Corn/soybean	Fall chisel, spring combo-mulch-finisher	Residue cover
Soybean/corn	Fall aerator, spring aerator	Soil temperatures
	Fall disk, spring combo-mulch-finisher	Week 4 stand and height
	No-till	Week 8 height
		% grain moisture at harvest
		Yield

Table 12. Soil test results based on composite sampling, Long-term Tillage Study, PPAC, Fall 2000

Tillage	Crop	Depth	OM	Phos.	K	Mg	Ca	Soil pH	Buffer pH	CEC
		Inches	%	ppm	ppm	ppm	ppm			meq/100g
Chisel	CC	0-8	3.1	40 H	112 M	470 H	1600 L	6.1	6.7	15.8
No-till	CC	0-4	3.7	59 VH	213 H	485 H	1650 L	6.1	6.7	16.4
No-till	CC	4-8	2.6	26 m	90 m	420 h	1500 l	5.9	6.7	14.8
Chisel	CB	0-8	3.3	38 h	119 m	510 vh	1700 l	6.2	6.8	15.5
No-till	CB	0-4	2.9	63 vh	193 h	485 h	1650 l	5.9	6.7	16.4
No-till	CB	4-8	3.1	39 h	98 m	495 h	1750 L	5.7	6.6	17.9

CULTURAL PRACTICES USED 2000

Long-term Tillage Study, Fields B3 & C3, Pinney Purdue Agricultural Center

Item	Corn		Soybean	
	Date	Application	Date	Application
Spring tillage	4/3	One pass with aerator: Case-IH 7220 tractor w/duals, 7-mph, and 2.5-degree angle on aerator gangs.	4/3	One pass with aerator: Case-IH 7220 tractor w/duals, 7-mph, and 2.5-degree angle on aerator gangs.
Nitrogen fertilizer	4/13	NH_3 @ 175 LB/a. N, N-serve, 5-knife applicator w/double rate on outside knives, 3.8-mph.		None.
Secondary tillage	5/3	Disk.	5/3	Disk.
	5/4	Field cultivate.	5/4	Field cultivate.
Hybrid/Variety planted	5/6	Pioneer 3489 (108 day).	5/6	Pioneer 93B01 Roundup Ready.
Seeding rate		29,900 seeds/a.		180,000 seeds/a.
Starter fertilizer/planter		19-17-0 @ 126 LB/a., 2-inches to the side and 2-inches below the seed.		None.
Insecticide/planter		Force 3G, 5.5 oz/1000 row feet.		None
Weed control	4/16	Burndown: Roundup Ultra 2 pt/a. on no-till and aerator	4/16	Burndown: Roundup Ultra 2 pt/a. on no-till and aerator
	5/1	Pre-emerge: Bicep II Magnum 4.2 pt/a. Extrazine II 1.5 LB/a.	6/17	Post-emerge: Roundup 1 qt/a. AMS 17 LB/a. *Broadcast with 8008 flat fan nozzles on 20-inch centers at 5.5 mph, 20 gallons water/a.*
	6/3	Post-emerge: Accent SP 2/3 oz/a. Atrazine 4L 2pt/a. *Broadcast with 8008 flat fan nozzles on 20-inch centers at 5.5 mph, 20 gallons water/a.*		
Cultivation	6/19	Once as required by treatment.		None
Harvest	10/2	All 6 rows, 130-feet.	9/28	Whole plot, 130-feet.
P and K fertilizer	10/13	350 LB/a. of 0-15-40	10/13	350 LB/a. of 0-15-40
Fall tillage	10/17	Fall chisel with leveling bar. Fall disk, no harrow. Fall strip-till 8-inch depth.	10/17	Fall chisel with leveling bar. Fall disk, no harrow. Fall strip-till 8-inch depth.

Soil temperatures:

Soil temperatures were measured from the day after planting through the next 4 weeks using maximum-minimum thermometers placed in the new row at 2-inches from soil surface in 1 of the 4 replications. Temperatures were recorded daily and thermometers reset to capture the maximum-minimum temperatures for the next 24-hour period. No-till had the lowest average daily maximum soil temperature in both continuous corn and in rotation (Fig. 7). All levels of tillage increased the daily maximum soil temperature. Average minimum soil temperatures for all treatments were within a 2-degree range (Fig. 8).

Stand, growth, and yield -- Corn.

Continuous corn. The planter was shifted 6-inches to the side of last year's old row in no-till. There were significant differences for stand among treatments (Table 13). Stands were reduced in the chisel/field cultivator and the disk/field cultivator treatments, likely due to rough soil surface conditions. The aerator treatment also left a rough surface with an abundance of root balls dislodged from the soil. However these loose root balls were brushed aside with the row cleaners and did not reduce stands. The aerator did not reduce residue cover compared to no-till as in previous years, likely due to high winds after planting that redistributed residue. Plant height at 8 weeks was tallest for treatments with the least residue. The no-till treatment yielded significantly less (.01 level) than the other treatments.

This is the first year out of 4 that the aerator treatment yielded significantly higher than no-till. The aerator in continuous corn leaves a extremely rough and haphazard distribution of residue. Often this lead to seed depth being non-uniform and poor seed to soil contact. With the addition of row cleaners to the planter this year, these problems were greatly reduced, perhaps allowing aeration of the soil to improve yields compared to no-till. Moral of the story: Use row cleaners in heavy residue conditions.

Rotation corn/soybeans. The aerator reduced residue cover somewhat compared to no-till, but the effect was not significant (Table 13). The aerator and no-till plant stands at 4 weeks after planting were significantly greater than the tilled treatments (.05 level). There were no significant yield differences among treatments. This fact illustrates that no-till corn can yield competitively versus full width tillage when planted in rotation.

Table 13. Agronomic performance of corn as affected by tillage and rotation, Sebewa loam, Long-term Tillage Study, Pinney Purdue Agricultural Center, 2000. †

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	Chisel/disk/field cultivator	34b‡	27500b	13.2	45.5a	20.3b	164.1a
	Chisel/field cultivator	24b	27800b	13.7	46.6a	19.7bc	170.3a
	Disk/field cultivator	42b	27500b	13.6	46.2a	19.1c	165.9a
	Fall aerator, spring aerator	89a	29200a	14.1	41.8b	20.7b	162.0a
	No-till	89a	29100a	13.8	40.4b	21.8a	153.4b
Soybean	Chisel/disk/field cultivator	8b	27300c	14.0	50.7	19.6	174.8
	Chisel/field cultivator	8b	27800bc	14.3	50.7	19.9	177.8
	Disk/field cultivator	8b	28200b	14.0	51.5	19.3	177.2
	Fall aerator, spring aerator	44a	29800a	13.7	49.6	19.3	172.4
	No-till	56a	29300a	13.6	48.8	19.4	173.4

†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 14. Analysis of variance summary, tillage data, corn, Long-term Tillage Study, PPAC, 2000.

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

Stand, growth, and yield -- Soybeans

There were no significant differences in stands at 4 weeks after planting (Table 15). Crusting of the soil surface was evident in the tilled treatments resulting in reduced stands, but not significantly. Plant growth was uniform through the growing season. Grain yields ranged from 47.2 to 56.9 bushels per acre. No explanation of these differences is offered.

Table 15. Agronomic performance of soybean as affected by tillage, Sebewa loam, rotation soybean/corn, Long-term Tillage Study, Pinney Purdue Agr Center, 2000.†

Tillage	Residue cover after planting	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield @15.5%
	%	ppa	in	in	%	Bu/a.
Chisel/disk/field cultivator	21b‡	144000	2.8	8.3	12.2	50.0ab
Chisel/field cultivator	24b	163000	3.1	9.2	12.0	52.9ab
Disk/field cultivator	31b	161000	3.0	8.3	11.9	56.9a
Fall aerator, spring aerator	68a	181000	3.0	8.7	12.0	49.0ab
No-till	79a	188000	3.1	8.2	12.0	47.2b
ANOV sig. level	.01	NS	NS	NS	NS	.03

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

Long-term Yields

Table 16. Yield summary by year, Bu/a., Sebewa loam, Long-term Tillage Study, PAC.†

Previous Crop	Tillage	1997	1998	1999	2000	2001	2002	97-00 Avg.
				Corn				
Corn	Fall chisel, disk, field cultivate	187.2	188.4	141.5	164.1			170.3
	Fall chisel, field cultivate	194.5	187.1	146.8	170.3			174.7
	Fall disk, field cultivate	184.3	180.4	133.5	165.9			166.0
	Fall aerate, spring aerate	181.4	157.2	123.9	162.0			156.1
	No-Till	184.9	156.0	124.4	153.4			154.7
	CC Average	186.5	173.8	134.0	163.1			164.4
Soybeans	Fall chisel, disk, field cultivate	206.9	195.6	166.7	174.8			186.0
	Fall chisel, field cultivate	211.3	186.6	171.2	177.8			186.7
	Fall disk, field cultivate	205.6	196.1	169.0	177.2			187.0
	Fall aerate, spring aerate	207.8	170.7	160.0	172.4			177.7
	No-Till	204.6	169.9	166.8	173.4			178.7
	CB Average	207.2	183.8	166.7	175.1			183.2
	Average	196.9	178.8	150.4	169.1			173.8
				Soybean				
Corn	Fall chisel, disk, field cultivate	60.4	48.6	46.8	50.0			51.4
	Fall chisel, field cultivate	61.9	48.3	49.5	52.8			53.1
	Fall disk, field cultivate	60.5	45.1	46.0	56.8			52.1
	Fall aerate, spring aerate	61.2	49.9	43.5	49.0			50.9
	No-Till	60.8	51.0	41.2	47.2			50.1
	BC Average	61.0	48.6	45.4	51.2			51.5

†Average of 4 replications.

Table 17. Agronomic performance of corn as affected by tillage and rotation, Sebewa loam, Long-term Tillage Study, Pinney Purdue Agricultural Center, 1997-2000. †

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	Chisel/disk/field cultivator	21d‡	26500ab	13.2a	52.6a	19.4b	170.3ab
	Chisel/field cultivator	26d	26100b	13.5a	53.9a	19.2b	174.7a
	Disk/field cultivator	57c	26000b	12.1b	50.4b	19.4b	166.0b
	Fall aerator, spring aerator	77b	27000a	11.6b	47.1c	19.8b	156.1c
	No-till	84a	26900a	11.5b	45.8c	20.4a	154.7c
Soybean	Chisel/disk/field cultivator	5c	26700b	14.3a	58.2a	19.1	186.0a
	Chisel/field cultivator	7c	27200ab	13.5ab	58.2a	19.1	186.7a
	Disk/field cultivator	11c	27300ab	13.4abc	56.9a	19.2	187.0a
	Fall aerator, spring aerator	43b	27500ab	12.3d	53.2b	19.1	177.7b
	No-till	57a	28000a	12.6bcd	53.1b	19.4	178.7b

†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 18. Analysis of variance summary, tillage data, corn, Long-term Tillage Study, PPAC, 1997-2000.

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

Table 19. Agronomic performance of soybean as affected by tillage, Sebewa loam, rotation soybean/corn, Long-term Tillage Study, Pinney Purdue Agr Center, 1997-2000.†

Tillage	Residue cover after planting	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield @15.5%
	%	ppa	in	in	%	Bu/a.
Chisel/disk/field cultivator	22c‡	154000b	3.2	12.1a	11.8	51.4
Chisel/field cultivator	29c	151000b	3.3	12.4a	11.7	53.1
Disk/field cultivator	51b	153000b	3.2	11.2b	11.8	52.1
Fall aerator, spring aerator	75a	177000a	3.3	10.9b	11.6	50.9
No-till	81a	170000a	3.3	10.8b	11.9	50.1
ANOV sig. level	.01	.03	NS	.01	NS	NS

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

Table 20. Corn Yield Response to Tillage and Rotation, Long-term Tillage Study, PPAC, 1997-2000.

Tillage	Corn/Soybean		Continuous Corn		Yield Gain for Rotation
	Bu/ac	% of c/d/fc yield	Bu/ac	% of c/d/fc yield	%
Chisel/disk/field cultivator	186.0	- - -	170.3	- - -	9
Chisel/field cultivator	186.7	100	174.7	103	7
Disk/field cultivator	187.0	101	166.0	97	13
Fall aerator, spring aerator	177.7	95	156.1	92	14

No-till	178.7	96	154.7	91	16

Feasibility of One Pass Tillage in Northern Indiana

Principal Investigators: Terry D. West, Tony J. Vyn and Gary C. Steinhardt.

Objectives

1. To determine the feasibility of a new single-pass mulch tillage tool for corn and soybean production relative to no-till and conventional tillage systems.
2. To compare surface residue cover and soil physical properties left after a single pass mulch tillage system (in either fall or spring) relative to other conservation tillage alternatives.
3. To upgrade the current secondary tillage equipment at the Pinney Purdue Agricultural Center to permit timely operations, fuel savings, less residue bunching, and more satisfactory seedbed conditions than are currently possible.

Duration: Research plots: 1999 to 2001 and possibly longer

Justification and Relevance:

Reduced tillage has many advantages in terms of efficiency, erosion control and cost savings. These have been documented in numerous studies. There is a continuing perception that in cooler climates no-till leads to delayed planting, reduced plant stands and reduced yields in corn. These perceptions have resulted in a reduction in no-till corn acreage in Indiana, particularly in the northern part of the state. The Conservation Technology Information Center estimates that, for Indiana as a whole, only 21% of the corn acreage was planted with no-till in 2000.

Chisel plowing is the most common tillage system prior to corn in Indiana. Since soybeans leave little residue cover to begin with, and because farmers who chisel usually perform two passes of secondary tillage, essentially no residue cover remains after planting. There have been very few investigations of single-pass tillage systems which in fall (stale seedbed) or spring (without any prior primary tillage) might permit sufficient residue cover for erosion control while resulting in yields superior to no-till.

Long-term research (1975-00) in west central Indiana (Agronomy Research Center) has documented significant corn yield reductions with no-till when corn followed corn, but not when corn followed soybeans. Average corn yields were only 3% lower with no-till compared to moldboard plowing after soybeans. Soil temperatures with no-till were significantly lower than moldboard, chisel and ridge-till systems in the first month after planting. Spring temperatures are even colder at locations farther north. Thus, planting delays and potential yield reductions with no-till corn may be even greater on poorly drained soils in Northern Indiana.

To fully explore a range of tillage system/crop residue relationships, a "one-pass" high clearance tillage implement is used in this study. Current two-pass or three-pass tillage treatments could be replaced with the one-pass treatment that - if proven successful - could save farmers machinery, fuel and labor costs. Single-pass concepts that need more investigation are those in the fall followed by spring no-till planting (i.e. stale seedbed) or those just before planting in spring. Preliminary indications are that some new implements can do this single-pass, full-width tillage while maintaining 30% residue cover (the minimum level to be rated as conservation tillage).

This research project is very important if we are to provide farmers with timely and vital information. There are insufficient replicated studies, and too many farmers are not making valid comparisons between full width tillage, reduced tillage and no-till. These plots can help show the possibilities for reduced tillage on the colder soils, and possibly affect the way that farmers think about reduced tillage and no-till planting of corn. This may not solve the problem of no-till planting of corn but it will, with more years of data, show farmers the relative risk and rewards so more informed decisions can be made.

Site Information

This field experiment was established in the spring of 1999 in field "D" for continuous corn and rotation soybeans after corn, and in the fall of 1999 in field "F" for corn after soybeans at the Pinney Purdue Agricultural Center near Wanatah, IN. The soil type is Sebewa loam. "This nearly level or depressional, deep, very poorly drained soil is on broad flats or in slight depressions where it is intermingled with poorly drained or very poorly drained soils" according to the Soil Survey of Porter County, 1981.

Table 21. Soil test results based on composite sampling, Field D, Fall 2000.

Tillage	Crop	Depth	OM	Phos.	K	Mg	Ca	Soil pH	Buffer pH	CEC
		Inches	%	ppm	ppm	ppm	ppm			meq/100g
Chisel	CC	0-8	5.9	26 M	146 M	610 H	2500 L	5.7	6.5	24.0
No-till	CC	0-4	6.0	35 H	224 H	650 H	2500 L	5.8	6.5	24.5
No-till	CC	4-8	5.8	16 L	101 M	610 H	2500 L	5.6	6.5	23.8
Chisel	CB	0-8	7.1	23 M	136 M	525 H	2250 M	6.1	6.7	19.6
No-till	CB	0-4	4.8	32 M	237 H	595 H	2300 M	6.2	6.7	20.7
No-till	CB	4-8	5.6	18 L	109 M	540 H	2200 L	5.8	6.6	20.6

Table 22. Soil test results based on composite sampling, Field F, Fall 2000

Tillage	Crop	Depth	OM	Phos.	K	Mg	Ca	Soil pH	Buffer pH	CEC
		Inches	%	ppm	ppm	ppm	ppm			meq/100g
Chisel	CB	0-8	3.3	22 M	133 M	520 VH	1800 L	5.9	6.7	17.3
No-till	CB	0-4	4.0	20 M	155 M	475 VH	1650 L	6.2	6.8	15.0
No-till	CB	4-8	3.6	21 M	116 M	475 H	1650 L	5.9	6.7	16.1

Equipment Description

Conventional chisel plow: Glencoe Soil Saver, front disk gang, 7-shank, 4-inch twisted points, soil leveler on rear.
One pass tillage tool (See photo): Case-IH 4400 18-foot Combo-Mulch Finisher, front disk gangs with adjustable depth and angle.

- Equipped with Vibra®Chisel, Vibra®Shank, or Vibra®Edge shanks as per treatment (VC, VS, VE).
- Equipped with 3 bar spike tooth harrow/double rolling baskets as per treatment (3BDR).
- Equipped with 5 bar spike tooth harrow/single rolling basket as per treatment (5BSR).

Strip-till: Remlinger 6-row Precision Strip-Till unit.
Disk: International Harvester 22-foot tandem disk.
Planter used in corn after corn: 6-row John Deere 7000 equipped with Dawn spike tooth row cleaners.
Planter used in corn after soybeans: 4-row Case-IH 950 Cyclo equipped with spike tooth row cleaners.
Drill used in soybeans after corn: 15-foot Case-IH 5400, coulter caddy, spring tooth harrow.

Table 23. Equipment abbreviation table.

Equipment	Abbreviation
Shank type	
Vibra®Edge	VE
Vibra®Shank	VS
Vibra®Chisel	VC
Spike tooth harrow type	
3 bar	3B
5 bar	5B
Rolling basket type	
Single	SR
Double	DR
Example: VE3BDR = Vibra®Edge + 3 bar spike tooth harrow + double rolling basket	

Case-IH 4400 Combo-mulch Finisher

Continuous Corn

CULTURAL PRACTICES USED 2000
Feasibility of One Pass Tillage in Northern Indiana, Continuous Corn

Item	Date	Application	
Phosphorous	4/11	250 LB/a of 0-46-0.	
Tillage	11/4/1999	Fall chisel with ridge leveling sweeps	
	4/13	42x: VibraChisel + 5 bar + single roller	
	5/3	Chop stalks, 4250 Case-IH tractor, gear II-3, 5 mph.	
	5/6	One pass treatments as required	
Hybrid planted	5/6	Pioneer 34F80Bt (109 day)	
Seeding rate		29,900 seeds/ac. JD7000 planter equipped with row cleaners.	
Starter fertilizer/planter		19-17-0 @ 125 LB/a., 2-inches to the side and 2-inches below the seed	
Insecticide/planter		Force 3G, 5.5 oz/1000 row feet.	
Weed control	5/7 & 6/?	Pre-emerge:	Post-emerge:
		Bicep II Magnum 4.2 pt/a.	Accent Sp 2/3 oz/a.
		Extrazine II 1.5 LB/a.	Atrazine 4L 2 pt/a.
		Roundup 1.5 pt/a.	
		Broadcast with 8008 flat fan nozzles on 20-inch centers at 5.5 mph, 20 gallons water/a.	
Nitrogen fertilizer	6/12	NH_3 @ 180 lb. N/a., sidedressed, no covering disks	
Cultivation	6/19	All treatments except no-till	
Harvest	10/2	Center 6 of 12 rows	
P and K fertilizer	10/13	350 LB/a. of 0-15-40	
Tillage	10/17	Fall chisel with ridge leveling sweeps	

All tillage systems left enough residue cover for adequate soil erosion protection except the 2-pass system of conventional chisel plus Vibra®Edge 3 bar double roller (Table 24). No-till had significantly more residue cover than the other treatments. Conventional chisel plus Vibra®Edge 3 bar double roller left significantly less residue than the other treatments. There were significant differences in plant week 4 stand and grain moisture at harvest. No-till had the slowest plant growth through 8 weeks after planting, although differences were not significant. The yields ranged from a high of 152.9 bushels/acre to a low of 144.7 bushels/acre.

Table 24. Feasibility of One Pass Tillage in Northern Indiana Study, Continuous Corn, Sebewa loam, Pinney Purdue Agr Center, Wanatah, IN, 2000.†

Treatment	Residue cover after planting	Plant spacing S.Dev.	Week 4 stand	Week 4 height	Week 8 height	Grain moisture at harvest	Grain yield at 15.5%
	%	Inches	Plants/a.	Inches	Inches	%	Bu/a.
5. VE5B	54b‡	3.3	26900cd	13.4	45.2	19.7bc	152.9
8. VE3BDR, minimal disk	54b	2.9	27900abc	13.1	47.6	19.8bc	151.6
10. VC5BSR	64b	3.0	28600a	13.5	48.0	21.7a	149.8
4. VE5BSR	59b	3.0	27100cd	13.5	46.2	20.2abc	149.2
1. Conv. chisel, VE3BDR	25c	3.1	26500d	13.3	49.5	19.6bc	148.7
3. VE3BDR	59b	2.8	27300bcd	13.8	46.9	17.4d	148.0
6. VE (no attachments)	53b	3.1	27300cd	13.3	46.7	21.2ab	147.4
9. VS3BDR	56b	3.0	28800a	13.5	50.9	20.0abc	146.7
7. VE3BDR, aggressive disk	59b	2.9	28400ab	13.3	48.4	18.9 cd	146.5
2. No-till	92a	3.2	28600a	12.5	44.8	20.9ab	144.7
LSD (5%)	12	NS	1200	NS	NS	1.8	NS

† Average of 4 replications.
‡ Means with the same letter are not significantly different.

Considering the two-year averages found in Table 25, some trends are noticeable:

- Single pass cultivation systems are successful in continuous corn. There appears to be no advantage for primary tillage before 4400.
- More surface residue cover retained with Vibra®Chisel than other shanks. Vibra®Edge generally resulted in less residue cover.
- There was a 5-10 bushel/acre advantage with 4400 relative to no-till in continuous corn, but need more years/sites to get statistical significance.

Table 25. Feasibility of One Pass Tillage in Northern Indiana Study, Continuous Corn, Sebewa loam, Pinney Purdue Agr Center, Wanatah, IN, 1999-2000.†

Treatment	Residue cover after planting	Plant spacing S.Dev.	Week 4 stand	Week 4 height	Week 8 height	Grain moisture at harvest	Grain yield at 15.5%
	%	Inches	Plants/a.	Inches	Inches	%	Bu/a.
10. VC5BSR	56b‡	3.0	28200a	13.3ab	53.6abc	19.6a	148.0
5. VE5B	47c	3.3	26800c	12.9abc	51.2bc	17.5bcd	146.3
8. VE3BDR, minimal disk	47c	3.0	27300abc	12.5bc	51.5bc	17.7bc	144.9
4. VE5BSR	49bc	3.1	26900bc	13.6a	51.4bc	18.1bc	143.4
1. Conv. chisel, VE3BDR	31d	3.1	26900c	13.0abc	53.4abc	17.8bc	142.6
6. VE (no attachments)	47c	3.1	26800c	12.5bc	51.7bc	18.6ab	142.4
9. VS3BDR	53bc	2.9	28200a	13.2abc	55.3a	18.1bc	142.2
7. VE3BDR, aggressive disk	52bc	2.9	27800ab	13.0abc	53.4abc	17.0cd	142.0
3. VE3BDR	49bc	2.9	27300abc	13.3ab	53.9ab	16.4d	140.1
2. No-till	83a	3.2	28100a	12.1a	50.7c	18.3b	137.0
LSD (5%)	8	NS	1000	1.1	3.1	1.2	NS

† Average of 4 replications.
‡ Means with the same letter are not significantly different.

Soybean following Corn

CULTURAL PRACTICES USED 2000		
Feasibility of One Pass Tillage in Northern Indiana, Soybeans following Corn		
Item	Date	Application
Phosphorous	4/11	0-46-0 250 LB/a.
Tillage	11/4/1999	Fall chisel with ridge leveling sweeps
	4/13	VibraChisel + 5 bar + single roller
	5/6	One pass treatments as required
Variety planted	5/6	Pioneer 93B01 Roundup Ready (109 day)
Seeding rate		180,000 seeds/ac. Case-IH no-till drill equipped with coulter caddy.
Weed control	5/7	Pre-emerge:
		Bicep II Magnum .2 pt/a.
		Extrazine II 1.5 LB/a.
		Roundup 1.5 pt/a.
	6/?	Post-emerge:
		Accent Sp 2/3 oz/a.
		Atrazine 4L 2 pt/a.
		Broadcast with 8008 flat fan nozzles on 20-inch centers at 5.5 mph, 20 gallons water/a.
Nitrogen fertilizer	6/12	NH_3 @ 180 lb. N/a., sidedressed, no covering disks
Cultivation	6/19	All treatments except no-till
Harvest	10/2	Center 6 of 12 rows
P and K fertilizer	10/13	350 LB/a. of 0-15-40
Tillage	10/17	Fall chisel with ridge leveling sweeps

All tillage systems left adequate residue cover for soil erosion protection (Table 26). The single pass system left up to double the residue cover left after the conventional tillage option, but about one-third less than that left with no-till alone. No significant differences were found in plant stands, indicating the coulter caddy equipped drill did a good job in all systems. Plant height differences at 4 weeks after planting was minimal. Plant height differences at 8 weeks after planting showed a trend for no-till's slower plant growth. There were no significant differences in grain yield even though soybean yields averaged 10% higher with single pass cultivation than with no-till. If tillage is warranted for soybeans after corn, there is no apparent advantage for chisel plowing prior to a cultivation pass with the 4400.

Table 26. Feasibility of One Pass Tillage in Northern Indiana Study, Soybeans Following Corn, Sebewa loam, Pinney Purdue Agr Center, Wanatah, IN, 2000.†

Treatment	Residue cover after planting	Week 4 stand	Week 4 height	Week 8 height	Grain moisture at harvest	Grain yield at 15.5%
	%	Plants/a.	Inches	Inches	%	Bu/a.
10. VC5BSR	61b‡	191000	3.7	11.9	11.2	59.6
1. Conv. chisel, VE3BDR	30c	172000	3.8	11.9	11.3	57.7
3. VE3BDR	55b	187000	3.8	12.2	11.2	57.2
7. VE3BDR, aggressive disk	52b	185000	3.5	11.4	11.3	56.1
6. VE (no attachments)	51b	179000	3.5	11.6	11.2	55.7
8. VE3BDR, minimal disk	47bc	181000	3.8	11.7	11.3	55.5
9. VS3BDR	56b	170000	3.6	11.3	11.3	54.8
5. VE + 5 bar	50b	181000	3.8	11.4	11.3	53.7
4. VE5BSR	52b	174000	3.5	10.7	11.4	52.1
2. No-till	83a	181000	3.6	10.0	11.3	50.0
LSD (5%)	7	NS	NS	NS	NS	NS

† Average of 4 replications.
‡ Means with the same letter are not significantly different.

Corn following Soybean

CULTURAL PRACTICES USED 2000 Feasibility of One Pass Tillage in Northern Indiana, Corn Following Soybeans		
Item	Date	Application
Fall tillage	11/4/1999	Chisel plow
	11/11/2000	Strip-prep with Remlinger 6-row set at 8-inches deep.
Spring tillage	5/4	As required by treatment
Hybrid planted	5/4	Pioneer 34F80Bt (109 day)
Seeding rate		30,000 seeds/ac. Case-IH 950 Cyclo equipped with row cleaners
Starter fertilizer/planter		34-0-0 @ 96 LB/a., 2-inches to the side and 2-inches below the seed
Insecticide/planter		Force 3G, 5 oz/1000 row feet.
Weed control	5/5	Pre-emerge:
		Bicep II Magnum 4.2 pt/a.
		Extrazine II 1.5 LB/a.
		Roundup 1.5 pt/a.
	6/?	Post-emerge:
		Accent Sp 2/3 oz/a.
		Atrazine 4L 2 pt/a.
		Broadcast with 8008 flat fan nozzles on 20-inch centers at 5.5 mph, 20 gallons water/a.
Nitrogen fertilizer	6/12	NH_3 @ 180 lb. N/a., sidedressed
Cultivation		None
Harvest	10/3	Center 6 of 12 rows, 150 feet
Fall tillage	10/19	All fall tillage treatments

Only no-till and strip-till left enough residue cover to adequately protect the soil from erosion (Table 27). Although there were significant differences in plant stands at 4 weeks, all stands were sufficient. With no significant differences in 8-week plant height, grain moisture at harvest or in yields, all treatments qualify for satisfactory plant growth and yield. If the objective is to reduce soil erosion and yet maintain satisfactory yields, then the no-till or strip till treatments qualify.

Table 27. Feasibility of One Pass Tillage in Northern Indiana Study, Corn Following Soybeans, Sebewa loam, Pinney Purdue Agr Center, Wanatah, IN, 2000.†

Treatment	Residue cover after planting	Week 4 stand	Week 4 height	Week 8 height	Grain moisture at harvest	Grain yield at 15.5%
	%	Plants/a.	Inches	Inches	%	Bu/a.
3. Fall VC5BSR, spring SS*	25c‡	29200ab	12.7a	59.4	17.8	161.2
6. Fall disk, spring VE5BSR	16def	29300ab	11.8cb	56.7	18.2	157.6
1. Fall Conv. chisel, spring VE5BSR	11f	28300c	10.7e	53.8	18.9	156.8
4. Fall VC5BSR, spring VE5BSR	14ef	29000abc	10.7bc	57.7	18.1	156.6
7. Spring VE5BSR (raised disk)	21cd	28700cb	11.9abc	59.0	17.7	155.9
2. No-till with row cleaners	56a	29300ab	12.2abc	56.7	18.3	155.8
9. Fall strip-till	43b	29300ab	11.5cd	56.3	18.1	155.7
8. Spring VE5BSR	25c	29500a	12.5ab	59.2	17.6	154.1
5. Fall disk, spring SS	19cde	28300c	12.2abc	56.8	18.3	153.7
LSD (5%)	7	700	0.8	NS	NS	NS

† Average of 4 replications.
‡ Means with the same letter are not significantly different.
*SS = Stale seedbed.

Summary

- Of the shank alternatives investigated, the Vibra®Chisel resulted in consistently higher levels of surface residue cover, and a tendency to higher yields of both corn and soybeans than other shanks.

- Single pass cultivation was as good as or slightly better than a 2-pass system (where chisel plowing preceded cultivation) in terms of yield, and superior in terms of residue cover.
- Single pass with 4400 in fall followed by spring no-till may be as good as conventional tillage for corn, and leave more residue cover. Also may prove to be superior to fall disk plus stale seedbed.
- Few significant differences in residue cover or crop response were observed among harrow attachments (whether 5BSR or 3BDR) or in disk settings on the 4400.
- If resources permit, seedbed quality parameters should be investigated in more detail in 2001.

Studies for 2001

- Continuous Corn: Field D.
- Corn following Soybeans: Field D. This study will include two strip till treatments.
- Soybeans following corn. Field F.

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Effect of Acrylic Polymer Seed Coatings on the Feasibility of Relay Intercropping in Indiana

Scott M. McCoy, Tony J. Vyn, and Terry D. West

Introduction

Relay intercropping of soybeans is a system in which a second crop (soybeans) is planted into a field before the first crop (winter wheat) is harvested. This system may have the potential to increase profitability by harvesting 2 crops per growing season. Double cropping of soybeans after wheat is common in the southern one-third of Indiana. However, double cropping is seldom successful in northern Indiana because later wheat harvest and earlier frosts don't usually leave enough time for soybeans to mature. Relay intercropping extends the growing season for soybeans and increases the probability of success if moisture is adequate. Seed coatings may further improve the feasibility of this system by delaying soybean emergence. Delayed emergence may reduce the damage to wheat by enabling earlier planting of interseeded soybeans. Delayed emergence should also increase soybean yields by limiting stem elongation (etoliation) in the reduced light environments under the wheat canopy.

The most common crops used in relay intercropping are winter wheat and soybeans. Wheat is planted in wide rows (usually 10-15-inch) to accommodate interplanting of soybeans in the spring. Soybeans are planted between the wheat rows before head emergence (Feekes stages 9-10). Modified equipment such as row dividers and narrow tires help to limit damage to the standing wheat crop. The wheat is harvested as early as possible to reduce stress on the soybeans. The wheat is cut high enough to avoid cutting off any soybean nodes. Soybeans should reach maturity before a killing frost occurs, and well before double cropped soybeans would. Although neither the soybeans nor the wheat will yield as much grain as either crop would individually, their combined yield may increase net income since fixed costs can be spread over two crops.

RESEARCH LOCATIONS IN 2000	
Name	**Location**
Ag Alumni Seeds	Romney
Agronomy Research Center	West Lafayette
Northeast Purdue Ag Center	Columbia City
Pinney Purdue Ag Center	Wanatah
Southeast Purdue Ag Center	Butlerville

CULTURAL PRACTICES USED AT 5 LOCATIONS IN 1999-2000

Field Operation	Date	Application Details
Primary tillage	10/99	Fall field cultivation
Wheat planting	10/99	Ag Alumni 9811(1.7 million seeds/acre in 7.5-inch rows)
Soybean variety		Hubner Seeds H286(RR), H352(STS), and H403(RR) (group 2.8 to 4.0, depending on location)
Soybean seeding rate	4/28/00-6/1/00	225,000 seeds/ac in 15-inch rows (Sunflower 9412 grain drill). Two locations (Romney and West Lafayette) had tow planting dates of all coated seed treatments.
Starter fertilizer	10/99	30-40 LB N/ac
Nitrogen fertilizer	2/00	90 LB N/ac
Weed control	4/00	Buctril in wheat
	7/00-8/00	Roundup RR soybeans, Synchrony + Select on STS soybeans
Wheat harvest	6/23/00-7/12-00	Entire plot
Double crop planting	6/23/00-7/12/00	250,000 seeds/ac in 7.5-inch rows
Soybean harvest	10/00-11/00	Entire plot

Table 28. Soybean growth and crop yields as affected by seed coatings and cropping system, Purdue University, 2000.†

Treatment	Emergence Delay (Uncoated = 0)	Height at Wheat Harvest	Height at Wheat Harvest + 30 Days	Wheat Yield	Soybean Yield

	days	in	in	bu/a.	bu/a.
15-inch Full Season Soybeans	-0.9	17.6	31.2	N/A	52.7
Intercropped Coating A	14.3	14.7	20.8	69.8	21.8
Intercropped Coating B	20.0	12.9	18.9	69.8	18.5
Intercropped Uncoated	0.0	17.0	19.7	70.1	16.8
15-inch Wheat Only				70.5	N/A
7.5-inch Wheat Only				78.1	N/A

†Average of 4 Northern Indiana Sites; 2 sites had a second relay planting date and a third seed coating treatment, but these data are not presented.

Winter Wheat Yield

Wheat yields in 15-inch rows averaged 70 bu/ac, just 8 bu/ac less than wheat seeded in 7.5-inch rows. Wheat yield losses associated with soybean interseeding itself were negligible, since yields were less than 3 bu/ac different between the highest and lowest yielding 15-inch wheat treatments.

Soybean stand, growth, and yield

The data in table 28 show that there were differences in emergence delay among the treatments. These delays did not have a large impact on final plant height. During 2000, some stand loss occurred in the intercropped soybeans at certain locations. We attributed this to preferential rodent feeding of polymer coated seeds during emergence, and competition with the wheat. Average intercropped soybean populations were 135,000 plants/ac, compared to 155,000 plants/ac for full season soybeans.

Due to shading from the wheat, the intercropped soybeans were shorter than full season soybeans throughout the entire growing season. Intercropped soybeans natured several weeks before double-crop soybeans.

The uncoated soybeans were taller than the coated soybeans up to and just after wheat harvest. However, the uncoated soybeans lodged more extensively. Their early emergence made them subject to a longer period of shading by the wheat. As a result, they became etoliated (spindly) and the stems couldn't support the weight of the plants as the season progressed.

Preliminary Conclusions

The results of this experiment showed that the coatings tested delayed emergence of intercropped soybeans up to approximately 20 days and that winter wheat yields were reduced by less than 13% in 15-inch row widths versus the standard 7.5-inch rows. At this time it is not clear how these emergence delays translate into soybean yield gains versus uncoated soybeans. Theyear had above normal precipitation during the growing season. Moisture throughout the season was generally adequate and was above average until August. The highest yielding coated treatment averaged 22 bushel/acre with a conventional combine, but small plot combined yields (of untracked areas in intercropped soybean plots at 3 locations) averaged 35 bushel/acre in the highest yielding intercropped treatment. Available moisture appears to be the factor that has the greatest influence on the success of relay intercropping. However, moisture appears to be even more limiting for double crop soybeans, since double cropped soybeans averaged less than 7 bushel/acre at the 4 sites north of Indianapolis.

This experiment will be repeated for a third year of research in 2001 at 4 sites. Research will include continued evaluation of 2 different planting dates into wide row wheat and continued examination of multiple wheat varieties. A planting date study will be continued to determine the optimum timing for soybean planting with specific polymers. The polymers used in this experiment may be reformulated for 2001.

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