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AGRONOMY RESEARCH CENTER

Long Term Tillage Study

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 four replications; individual plots are 30' wide and 150' long.

Soil and Crop Management

Cultural practices have been relatively consistent since the study began. Plowing and chiseling were done in the fall with one disking and one 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" for soybeans from 1975 to 1994. Starting in 1995, soybeans were drilled in 7.5" rows for plow, chisel and no-till treatments. All 30" 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" 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 eight soybean varieties have been used during the 25 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, Chalmers silty clay loam, 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				

1999

Equipment used:

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 Glenco 10-foot field cultivator with rear mounted rolling baskets.

Nitrogen was applied preplant at a depth of 6 to 7 inches with a 5-knife 30-inch anhydrous ammonia applicator equipped with one coulter and, one sealing wing, and two 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 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 row-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 4-row 30-inch planter.

All rowed plots, except no-till, were cultivated with a 4-row 30-inch 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 30-inch 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 2000. *Dr. Scott Abney*

- Cindy H. Nakatsu and Sylvie M. Brouder, Agronomy: Diversity of the Rhizosphere Bacterial Community of Corn and Soybean
  This was the third 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. Soil treatments also resulted in distinct shoot and root growth patterns with significant differences observed in morphological and architectural aspects of the rooting systems. We do not know, however, whether the same communities will be observed yearly or whether yearly variables such as weather will be a greater influence than soil treatment on community structure. Very little is known about the diversity, composition and dynamics of this component of the terrestrial ecosystem therefore it is vital to conduct such studies. 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. This study will continue in 2000. *Dr. Cindy H Nakatsu*
- Terry D. West, Tony Vyn, and Dr. 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. Soil fertility and physical property investigations will be expanded in 2000.

Table 2. Soil test results based on composite samples, Long-term Tillage Study, ARC, Fall 1999.

Tillage	**Crop**	**Depth**	**OM**	**Phos.**	**K**	**Mg**	**Ca**	**Soil pH**	**Buffer pH**	**CEC**	**Percent Base Saturation**			
		Inches	%	ppm	ppm	ppm	ppm			meq/100g	% K	% Mg	% Ca	% H
Plow	B/C	0-8	4.1	31 H	125 M	575 VH	2200 M	6.5		17.4	1.8	27.5	63.1	7.5
Chisel	B/C	0-8	4.3	38 H	124 M	660 VH	2400 M	6.5		19.3	1.7	28.6	62.3	7.5
Ridge	B/C	0-8	4.6	53 VH	142 M	655 VH	2300 M	7.4		17.3	2.1	31.5	66.4	
No-till	B/C	0-8	4.3	61 VH	154 M	600 VH	2150 M	6.5		17.5	2.3	28.6	61.6	7.5
Plow	B/B	0-8	3.6	26 M	104 M	615 VH	2350 M	6.8	6.8	17.7	1.5	29.0	66.5	3.0
Chisel	B/B	0-8	3.7	51 VH	120 M	670 VH	2400 M	7.0	6.8	17.9	1.7	31.2	67.1	
Ridge	B/B	0-8	3.5	52 VH	129 M	615 VH	2250 M	7.0		16.7	2.0	30.7	67.3	
No-till	B/B	0-8	4.4	55 VH	140 M	615 VH	2300 M	7.0	6.8	17.0	2.1	30.2	67.7	

CULTURAL PRACTICES USED 1999
Long Term Tillage Study, ARC, Purdue Univ.

Item	Corn		Soybean	
	Date	Application	Date	Application
Nitrogen fertilizer	4/8	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	5/11 5/12	Disk once on plow and chisel treatments. Field cultivate once on plow and chisel treatments.	5/20 5/21	Disk once on plow and chisel treatments. Field cultivate once on plow and chisel treatments.
Hybrid/Variety planted	5/12	Beck's 5405 (110-Day) Row cleaners on c/b and c/c no-till. Shifted no-till c/c to west. (Shift to east in 2000).	5/21	Asgrow 3244 (2750 seeds/lb.).
Seeding rate		30000 seeds/a., Drum A, 24 pockets (variable rate controller).		Plow, chisel, no-till drilled: 210,000 seeds/a. Ridge 30" 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	5/3 5/12	<u>3 point hitch sprayer:</u> Burn-down on no-till and ridge: Gramoxone Extra 3 pt/a. Surfactant 1.5 pt/100 gallons water Pre-emergence: Bladex 4L 3 pt/a. Atrazine 4L 3 pt/a. Dual II 3 pt/a. *All broadcast with flat fan 8006 nozzles at 30 psi and 30 gallons water/a., 5 mph.*	5/3 5/21	<u>3 point hitch sprayer:</u> Burn-down on no-till and ridge: Gramoxone Extra 3 pt/a. Surfactant 1.5 pt/100 gallons water Pre-emergence: Dual II 2.5 pt/a. Lorox Plus 18 oz/a. *All broadcast with flat fan 8006 nozzles at 30 psi and 30 gallons water/a., 5 mph.*
Cultivation	6/9 6/9	Plow and chisel treatments. Ridge treatment (reridge).	7/7 10/15	Ridge treatment only. Ridge treatment (reridge).
Harvest	9/28	Center 4 of 12 rows, 150 ft.	10/14	Center pass, 150 ft.
Primary tillage	10/21 10/21	Fall plow on plow treatment. Fall chisel on chisel treatment.	10/21 10/21	Fall plow on plow treatment. Fall chisel on chisel treatment.
Bulk Potassium	12/9	200 LB/a. 0-0-60	12/9	200 LB/a. 0-0-60

Stand, growth, and yield -- Corn.

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 fifth year of shifting the new rows. In four of the five years, we achieved these goals.

Continuous corn. Plant stands were equal for all tillages when measured at 4 weeks after planting (Table 3). Plant emergence was satisfactory for all treatments. With near normal rainfall and temperatures, plant growth was equal for all treatments through week 4 after planting. By week 8, chisel and plow were significantly ($P = 0.05$) taller than ridge and no-till. Ridge and no-till were not statistically different from each other. The plow treatment yielded significantly higher ($P = 0.05$) than the other treatments. Chisel and ridge were not statistically different from each other. No-till yielded more than 22 bushels/acre less than the other treatments (significant at $P = 0.05$).

Corn following soybeans. Plant stands in the ridge treatment were significantly ($P = 0.05$) lower than plow or no-till. This may have been due to planting the seed too deep, resulting in some seeds germinating but not emerging. Ridge and no-till seedbed moisture and tilth were ideal at planting. The plow and chisel soil was dry in the top 1-2 inches, but was wet below 2 inches. As is often the case with this soil, drying at depths below 2 inches was very slow. Although secondary tillage left the seedbed cloddy, subsequent rainfall helped germination and emergence. Plant growth through 8 weeks after planting was satisfactory.

All treatments yielded surprisingly well considering that July and August were much drier than normal (Fig 1). Chisel yields were the highest for chiseling in the 25 years of this study. Plow and no-till yields were second highest for each treatment in the 25 years of this study, while ridge yielded fourth best.

With the late planting date (May 12) in the warmer than normal spring of 1999, soil conditions for no-till were not as cold as we have experienced with earlier planting in most years of this study. The average yield for no-till continuous corn and no-till rotation corn ranked 7th and 2nd highest, respectively, out of the 25 years of this study. It suggests that when planting is delayed by wet soil conditions it could be more profitable to no-till plant the corn than take the time and expense to perform secondary tillage before planting. This would save on fuel, labor and machinery costs while planting the corn more timely. A date of planting/tillage study needs to be done to investigate the relative merits of delaying planting of no-till corn until soil conditions are favorable for uniform germination and early growth.

Table 3. Agronomic performance of corn as affected by tillage and rotation, Chalmers silty clay loam, Long Term Tillage Study, ARC, Purdue Univ., 1999. †

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	5d	28800	21.8	75.7a	19.0ab	200.5a
	Chisel	38c	28900	22.3	77.2a	18.4b	190.1b
	Ridge	58b	27800	21.9	70.9b	19.9a	188.1b
	No-till	88a	28700	21.2	72.0b	20.0a	166.2c
Soybean	Plow	2d	29500a	21.2	75.2b	19.2	212.5ab
	Chisel	21c	28800ab	23.7	81.0a	19.0	218.3a
	Ridge	58b	27900b	21.5	78.5ab	19.6	204.6b
	No-till	77a	29400a	23.4	81.8a	19.3	204.0b

†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 fifth 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.

Rotation soybean/corn: Ridge plant populations were significantly lower due to the reduced seeding rate at planting for 30" rows (Table 4). All treatments exhibited good plant growth through the year. There were no significant insect or disease problems noted. There were no significant yield differences among the treatments. The 30” row ridge plots were equal to the 7.5" drilled treatments. This year's dry July and August seemed to reduce soybean yields more so than corn yields (which is surprising). Many soybean pods did not fill completely and soybean seed size was variable with many small soybeans.

Continuous soybean: Plant emergence was uniform in all treatments. Plant populations in the ridge treatment were significantly lower due to the reduced seeding rate at planting for 30" rows. Plant height was shorter at the 8-week measurement than for soybeans in rotation. The ridge treatment continues to suffer from soybean cyst nematodes in some plots. We suspect that yields in all continuous soybean plots are affected by nematodes. Sampling for nematodes confirmed the presence of nematodes in many of the plots. A soybean cyst nematode resistant variety will be used starting in 2000. The 30” row ridge plots yielded 14.4% less than the 7.5” drilled treatments.

Table 4. Agronomic performance of soybean as affected by tillage and rotation, Chalmers silty clay loam, Long Term Tillage Study, ARC, Purdue Univ., 1999. †

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	7d	184000a	4.8	22.2a	13.4bc	48.1
	Chisel	49c	165000a	4.7	20.3b	13.5ab	47.9
	Ridge	70b	127000b	4.6	19.1b	13.3c	49.0
	No-till	96a	191000a	4.3	17.4c	13.6a	48.8
Soybean	Plow	2d	191000a	4.8	20.2a	13.5	44.4a
	Chisel	13c	178000a	4.7	18.8ab	13.4	43.1a
	Ridge	36b	131000b	4.6	17.3bc	13.4	36.8b
	No-till	83a	177000a	4.0	16.5c	13.5	41.6ab

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

Table 5. Analysis of variance summary, tillage data, Long Term Tillage Study, ARC, Purdue Univ., 1999.

Variable	Residue cover after planting	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield Bu/a.
	------------Significance Level------------					
				Corn		
Tillage	.01	.03	NS	.01	.04	.01
Previous crop	.07	NS	NS	.01	NS	.01
Tillage x previous crop	.03	NS	NS	.01	NS	.01
				Soybean		
Tillage	.01	.01	.04	.01	.01	NS
Previous crop	.01	NS	NS	NS	NS	.04
Tillage x previous crop	.01	NS	NS	NS	NS	.10

Grain Composition Analysis

Grain samples were taken from all treatments for grain composition analysis. No explanations for results are offered here. The Grain Composition Analysis Service tested samples. The following quote is from the Service's Internet homepage found at http://pasture.ecn.purdue.edu/~grainlab/comp.html.

"The significance of end-user oriented quality factors is growing. Differentiating grains based on quality traits and testing for composition of corn and soybeans should be of importance to:

- Crop producers interested in taking advantage of premiums for quality grains
- Livestock feeders aiming at optimizing ration formulations, and utilizing higher protein and oil
- hybrids for their feeds
- Elevators merchandising grain based on desired quality traits
- Processors in need of grain qualities that optimize milling and end product yield
- Plant breeders striving to develop value-added corn and soybean varieties

Economically, maximizing end-user oriented intrinsic quality traits such as protein, oil, starch, and fiber content can increase value by 10-40 cents per bushel. If during the 1994-1995 marketing year only 10 percent of Indiana's corn and soybean crops had been sold based on such premiums, an additional $10.8-43.1 million could have been generated in income for Indiana producers."

Table 6. Corn grain content as affected by tillage and rotation, Chalmers si.c.l., Long Term Tillage Study, ARC, Purdue Univ., 1999.†

Previous Crop	Tillage	Grain Moisture	Protein	Oil	Starch	Density
		%	%	%	%	g/ml
Corn	Plow	15.5	7.0	3.6	61.6a‡	1.289
	Chisel	15.9	7.0	3.5	61.4ab	1.284
	Ridge	16.7	7.1	3.6	60.8ab	1.287
	No-till	16.5	7.5	3.6	60.6b	1.287
Soybean	Plow	15.3	7.2	3.6	61.4	1.288
	Chisel	15.5	7.1	3.7	61.4	1.287
	Ridge	15.9	7.1	3.5	61.4	1.292
	No-till	16.2	7.0	3.5	61.2	1.290

†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 7. Soybean grain content as affected by tillage and rotation, Chalmers si.c.l., Long Term Tillage Study, ARC, Purdue Univ., 1999.†

Previous Crop	Tillage	Grain Moisture	Protein	Oil	Fiber
		%	%	%	%
Corn	Plow	12.9	37.1a‡	17.1b	4.7b
	Chisel	13.0	36.6b	17.1b	4.7b
	Ridge	13.0	36.1c	17.4a	4.7b
	No-till	13.0	36.3bc	17.2b	4.8a
Soybean	Plow	13.2	37.8a	16.9b	4.8
	Chisel	13.1	37.4ab	17.0b	4.7
	Ridge	12.9	37.2b	17.2a	4.7
	No-till	13.2	37.4ab	16.9b	4.8

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

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 25 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, 1975-99.

Tillage	Corn/Soybean		Continuous Corn		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	176.0	- - -	167.2	- - -	5
Chisel	176.6	100	162.3	97	9
Ridge*	181.3	103	165.5	99	10
No-till	171.3	97	143.6	86	19

*1980-1998

Table 9. Soybean Yield Response to Tillage and Rotation, Long Term Tillage Study, ARC, 1975-99.

Tillage	Corn/Soybean		Continuous Soybean		Yield Gain for Rotation
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	%
Plow	52.1	- - -	47.8	- - -	9
Chisel	50.9	98	45.4	95	12
Ridge*	50.1	96	44.5	93	13
No-till	49.4	95	45.5	95	9

*1980-1998

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.

DMI Strip Tillage/Fertilizer Placement Demonstration

Tony J. Vyn and Terry D. West

CULTURAL PRACTICES USED 1999
DMI Strip Tillage/Fertilizer Placement Demonstration, Rotation Corn Following Soybeans, ARC.

Item	Date	Application
Fall strip tillage	12/16/98	DMI with mole knife. With and without fertilizer. Depth set at 9 inches. Fertilizer applied at 7.5 inches.
Spring strip tillage	5/7	DMI with mole knife. With and without fertilizer. Depth set at 9 inches. Fertilizer applied at 7.5 inches.
Hybrid planted	5/7	Pioneer 33A14 (113 day)
Seeding rate		30,000 seeds/ac. Case-IH 950 Cyclo planter.
Starter fertilizer/planter		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	?	Pre-emergence:
Nitrogen fertilizer	6/15	NH_3 @ 160 lb. N/a., sidedressed, no covering disks
Cultivation		None
Harvest	11/8	2 rows x 16.25 feet

Table 10. Agronomic performance of corn as affected by strip tillage and fertilizer placement, rotation corn/soybean, DMI Strip Tillage/Fertilizer Placement Demonstration, 1999.†

Tillage	Stand 4 weeks	Height 4 weeks	Harvest moisture	Yield @15.5%
	ppa	in	%	Bu/a.
No-till	29300	11	13.9	131.3
Fall strip till	29600	12	13.9	121.5
Deep band 0-0-60 @ 150 LB/a.	27100	11	14.3	141.4
No-till with banded starter 0-0-60 @ 75 LB/a. at planting	28300	11	14.1	138.7
Deep band 0-0-60 with banded starter 0-0-60 @ 75 LB/a. at planting	29500	11	14.2	141.6
Fall strip till with banded starter 0-0-60 @75 LB/a. at planting	29400	11	14.1	138.5

†Average of 2 replications.

This demonstration trial was established at the Diagnostic Training Center to demonstrate the relative advantages of various potassium (K) fertilizer placements after long-term no-till. The results are inconclusive, but visual K deficiency symptoms were evident in both no-till and fall strip-till plots where no K fertilizer had been applied.

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

Recently, Indiana farmers have begun to use no-till less frequently for corn production. On the other hand, no-till soybean acres have increased. In 1998, no-till was used on 54% of the soybean acreage but only 16% of the corn acreage in Indiana (CTIC, 1998). Indiana corn acreage in no-till has declined from 25% in 1994 to the current 16%. The most common reasons for reduced no-till corn acres have been concerns with lower yields than conventionally tilled corn and the planting difficulties associated with cold, wet soil conditions in the spring.

To overcome these problems, corn farmers have been using chisel, disk, or field-cultivator based tillage systems following no-till soybeans prior to corn. This has been referred to as rotational tillage. This tillage is often deep, intensive, and incorporates most surface residue. Rotational tillage may be helping to overcome the farmer's cold, wet soil conditions in the spring; however, the no-till benefits are being lost. There is a drastic increase in the potential for soil erosion. Modifications to the current systems are needed to maintain more surface residue and improve spring planting conditions while retaining more of the economic and soil quality benefits typically associated with no-till.

Fall zone tillage can be considered as an alternative to intensive tillage systems when pure no-till is no longer effective. 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 will 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.

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" rows.

Treatments

1) Fall Plow
2) Fall Disk Only
3) Fall Zone-Till 14" Depth (John Deere 510 Deep Ripper)
4) Fall Zone-Till 8" Depth (DMI 2500 w/mole knife and berming disks)
5) No-till with 3 Coulters
6) No-till with Trash Whippers

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 1999 Feasibility of Fall Zone Tillage for Corn Production in Indiana, ARC, Purdue Univ.		
Item	Date	Application
Fall Tillage	Dec. 1998	
Secondary tillage	5/5	Glencoe Soil Finisher or Phillips Rotary Harrow
Hybrid planted	5/5	Pioneer 33A14 (113 day)
Seeding rate		30,000 seeds/ac.
Starter fertilizer/planter		200 LB/a. 11.5-11.5-30, 2 inches to the side and 2 inches below the seed
Insecticide/planter		Force 3.0G, 5 oz/1000 row feet.
Weed control	5/10	3 point hitch sprayer Pre-emergence Harness Extra 2.5 qt/ac. Roundup Ultra 1.5 pt/ac. *All broadcast with flat fan 8006 nozzles at 30 psi and 30 gallons water/ac., 5.0 mph.*
Nitrogen fertilizer	6/7	NH_3 @ 160 lb. N/ac., sidedressed, no covering disks
Harvest	9/28	Hand harvest 15 meter of row per plot

Preliminary Results

Preliminary results for accumulated soil growing degree days, percent volumetric soil moisture, days from planting to 50% emergence, plant height at 4 weeks after planting, days from planting to 50% silk, and harvest grain moisture are summarized in Table 11. For the purpose of this report, data from only six of the ten 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. †

Treatment	Accumulated Soil GDD (4/29 to 5/4/99)	Soil Moisture (5/4/99)	Days to 50% Emergence	Plant Height At 4wks	Days to 50% Silk	Harvest Grain Moisture
	GDD	% (v/v)	days	inches	days	%
Fall Plow	43.8	22.9	8.25	16.3	68.8	17.3
Fall Disk Only	39.3	27.6	9	16.5	67.5	17.9
Fall Zone-till 14"	41.7	24.8	9.5	15.4	71.3	18.7
Fall Zone-till 8"	37.3	24.7	9.75	15.0	71.5	18.9
No-till w/ 3 Coulters	25.2	27.2	10.75	13.1	74	19.6
No-till w/ trash whippers	26.3	28.1	11	14.4	73	19.3

† Average of 4 Replications.

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 the corn emergence and developmental 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 more optimum conditions allowed for improved emergence and corn growth in comparison to no-till. The first 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, earlier silking, 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. No significant benefits were observed to zone tillage at the 14” versus 8” depth in the variables reported in Table 11.

This study will be repeated for the 2000 and 2001 growing seasons. In the fall of 1999, the tillage treatments were conducted on an adjacent field following soybeans with a similar no-till and crop rotation history. The first year data supports 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 (Springfield, 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

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. The study will continue for at least 4 years.

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 1999.

Tillage	Crop	Depth	OM	Phos.	K	Mg	Ca	Soil pH	Buffer pH	CEC	Percent Base Saturation			
		Inches	%	ppm	ppm	ppm	ppm			meq/100g	% K	% Mg	% Ca	% H
Chisel	C/C	0-8	3.1	27 M	87 M	360 VH	1200 M	6.1	6.8	10.7	2.1	28.0	55.9	14.0
	C/B	0-8	3.6	27 M	94 M	425 VH	1400 M	6.4	6.9	11.8	2.0	29.9	59.1	9.0
No-till	C/C	0-2	3.7	36 H	169 H	400 VH	1300 M	6.5	6.9	11.1	3.9	30.0	58.6	7.5
		2-4	3.1	20 M	83 M	325 VH	1150 M	6.0	6.8	10.2	2.1	26.6	56.4	15.0
		4-8	2.7	11 L	64 L	375 VH	1350 M	6.2	6.8	11.4	1.4	27.4	59.2	12.0
No-till	C/B	0-2	3.4	46 H	206 H	455 VH	1450 M	6.7	7.0	12.1	4.4	31.3	59.8	4.5
		2-4	3.3	34 H	99 M	370 H	1350 L	5.8	6.7	12.5	2.0	24.8	54.2	19.0
		4-8	3.3	30 H	83 M	385 H	1400 L	5.8	6.7	12.9	1.7	24.9	54.4	19.0

CULTURAL PRACTICES USED 1999

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

Item	Corn		Soybean	
	Date	Application	Date	Application
Spring tillage	4/14	1 pass with aerator: Case-IH 8940 tractor w/duals, 8 mph, and 2.5-degree angle on aerator gangs.	4/24	1 pass with aerator: Case-IH 8940 tractor w/duals, 8 mph, and 2.5-degree angle on aerator gangs.
Nitrogen fertilizer	4/7	NH_3 @ 150 LB/a. N, N-serve, 5-knife applicator w/double rate on outside knives, 3.8 mph.		None.
Secondary tillage	5/3 5/4	Disk. Field cultivate.	5/3 5/4	Disk. Field cultivate.
Hybrid/Variety planted	5/4	Pioneer 3489 (108 day).	5/15	Pioneer 93B01 Roundup Ready.
Seeding rate		29,900 seeds/a.		200,000 seeds/a.
Starter fertilizer/planter		19-17-0 @ 125 LB/a., 2 inches to the side and 2 inches below the seed.		None.
Insecticide/planter		Force 1.5G, 10 oz/1000 row feet.		None
Weed control	5/1	<u>Pre-emergence:</u> Atrazine 0.5 LB/a. Extrazine 1.5 LB/a. Dual 2 pt/a. Roundup 1.5 pt/a. *Broadcast with 8008 flat fan nozzles on 20" centers at 5.5 mph, 20 gallons water/a.*	6/14	<u>Post-emergence with trailer sprayer:</u> Roundup 1 qt/a. *Broadcast with 8008 flat fan nozzles on 20" centers at 5.5 mph, 20 gallons water/a.*
Cultivation	6/8	Once as required by treatment.		None
Harvest	10/1	All 6 rows, 130 ft.	9/17	Whole plot, 130 ft.
P and K fertilizer	10/26	350 LB/ac of 0-15-40	10/26	350 LB/ac of 0-15-40
Fall tillage	10/27	Fall chisel with leveling bar. Fall disk, no harrow. Fall soil-aerator at 8 mph, 2.5-degree angle on gang, no weights.	10/27	Fall chisel with leveling bar. Fall disk, no harrow. Fall soil-aerator at 8 mph, 2.5-degree angle on gang, no weights.

Soil temperatures:

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

Stand, growth, and yield -- Corn.

Continuous corn. The planter was shifted six inches to the side of last year's old row in no-till. There were significant differences for stand and plant height at 4 weeks after planting 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 either crushed by the planter units or shoved aside and did not reduce stands. The aerator reduced residue cover compared to no-till by 21 percentage points. Plant height at 4 weeks was tallest for treatments with the least residue. By 8 weeks after planting, plant height again correlates closely to residue cover. The aerator and no-till treatments yielded significantly less (.01 level) than the tilled treatments. It appeared that the corn in aerator and no-till treatments was slower developing through the year and this was reflected in the yields.

Rotation corn/soybeans. As in continuous corn the aerator reduced residue cover compared to no-till by 21 percentage points (Table 13). The aerator and no-till plant stands at 4 weeks after planting were significantly greater than the tilled treatments (.02 level). Plant growth through the growing season was significantly slower (.02 level) for the aerator and no-till treatments. There were no significant differences among treatments in yields. This fact illustrates that no-till corn can yield competitively with tillage when planted in rotation if soil conditions are favorable.

Table 13. Agronomic performance of corn as affected by tillage and rotation, Sebewa loam, Long Term Tillage Study, Pinney Purdue Agricultural Center, 1999.†

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	14c	27400ab	14.7a	63.2a	14.6	141.5a
	Chisel/field cultivator	20c	26300b	15.6a	63.8a	14.5	146.8a
	Fall aerator, spring aerator	74ab	28300a	13.2b	53.3c	14.5	123.9c
	Disk/field cultivator	64b	26300b	13.0b	58.3b	14.6	133.5b
	No-till	95a	27100ab	13.5b	51.2c	14.9	124.4c
Soybean	Chisel/disk/field cultivator	4b	26700b	16.0a	66.6a	14.9	166.7
	Chisel/field cultivator	8b	26600b	15.5a	67.8a	14.9	171.2
	Fall aerator, spring aerator	59a	28200a	14.0b	62.0b	15.1	160.0
	Disk/field cultivator	16b	26800b	15.6a	67.1a	15.1	169.0
	No-till	81a	28800a	14.5ab	62.8b	15.3	166.8

†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 14. Analysis of variance summary, tillage data, corn, Long Term Tillage Study, PPAC, 1999.

Variable	Residue cover after planting	Stand 4 weeks	Height 4 weeks	Height 8 weeks	Harvest moisture	Yield Bu/a.
	--Significance Level---------------------------------					
Tillage	.01	.02	.01	.01	.08	.01
Previous crop	.01	.02	.05	.01	NS	.01
Tillage x previous crop	NS	.06	.05	.01	NS	.01

Stand, growth, and yield -- Soybeans

There were no significant differences in stands or plant height at 4 weeks after planting (Table 15). By 8 weeks after planting the aerator and no-till treatments appeared to be growing slower that the tilled treatments. Final grain yields were at least 3 Bu/a lower with these treatments than with the tilled treatments.

Table 15. Agronomic performance of soybean as affected by tillage, Sebewa loam, rotation soybean/corn, Long Term Tillage Study, Pinney Purdue Agr Center, 1999.†

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	28c	181000	4.0	13.6a	10.8	46.8ab
Chisel/field cultivator	33c	181000	4.1	14.3a	10.9	49.5a
Fall aerator, spring aerator	86a	174000	3.8	11.9ab	11.1	43.5bc
Disk/field cultivator	69b	180000	3.9	13.7a	10.6	46.0ab
No-till	91a	174000	3.8	10.8b	11.1	41.6c
ANOV sig. level	.01	NS	NS	.01	NS	.01

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

Grain Composition Analysis

Grain samples were taken from all treatments for grain composition analysis. No explanations for results are offered here. The Grain Composition Analysis Service tested samples. See quote on page 8 of this report.

Table 16. Corn grain content as affected by tillage and rotation, Sebewa loam, Long Term Tillage Study, Pinney Purdue Agricultural Center, 1999.†

Previous Crop	Tillage	Grain Moisture	Protein	Oil	Starch	Density
		%		%	%	g/ml
Corn	Chisel/disk/field cultivator	12.5	6.9	3.3	63.5	1.301
	Chisel/field cultivator	12.8	6.9	3.3	63.5	1.307
	Fall aerator, spring aerator	12.7	6.8	3.2	63.6	1.310
	Disk/field cultivator	12.5	6.8	3.3	63.4	1.308
	No-till	12.3	7.0	3.3	63.3	1.312
Soybean	Chisel/disk/field cultivator	12.7	7.5	3.5	62.7	1.315
	Chisel/field cultivator	12.7	7.4	3.5	62.8	1.312
	Fall aerator, spring aerator	12.9	7.1	3.5	63.1	1.311
	Disk/field cultivator	12.8	7.4	3.5	62.7	1.314
	No-till	12.9	7.1	3.4	62.9	1.311
		No statistical differences among treatments.				

†Average of 4 replications.

Table 17. Analysis of variance summary, grain composition data, corn, Long Term Tillage Study, PPAC, 1999.

Variable	Grain moisture	Protein	Oil	Starch	Density
	----------------------------Significance Level----------------------------				
Tillage	NS	.10	NS	NS	NS
Previous crop	NS	.05	.03	.02	NS
Tillage x previous crop	NS	.06	NS	NS	NS

Table 18. Soybean grain content as affected by tillage and rotation, Sebewa loam., Long Term Tillage Study, Pinney Purdue Agricultural Center, 1999.†

Tillage	Grain Moisture	Protein	Oil	Fiber
	%	%	%	%
Chisel/disk/field cultivator	9.4	35.4	18.5	5.2
Chisel/field cultivator	9.5	35.3	18.6	5.1
Fall aerator, spring aerator	9.5	35.2	18.5	5.1
Disk/field cultivator	9.5	35.3	18.7	5.1
No-till	9.3	35.2	18.4	5.2
		No statistical differences.		

†Average of 4 replications.

Long Term Yields

Table 19. Yield summary, Bu/ac, Sebewa loam, Long Term Tillage Study, PPAC.†

Previous Crop	Tillage	1997	1998	1999	2000	2001	2002	97-99 Avg.
				Corn				
Corn	Fall chisel, disk, field cultivate	187.2	188.4	141.5				172.4
	Fall chisel, field cultivate	194.5	187.1	146.8				176.1
	Fall aerate, spring aerate	181.4	157.2	123.9				154.2
	Fall disk, field cultivate	184.3	180.4	133.5				166.1
	No-Till	184.9	156.0	124.4				155.1
	CC Average	186.5	173.8	134.0				164.8
Soybeans	Fall chisel, disk, field cultivate	206.9	195.6	166.7				189.7
	Fall chisel, field cultivate	211.3	186.6	171.2				189.7
	Fall aerate, spring aerate	207.8	170.7	160.0				179.5
	Fall disk, field cultivate	205.6	196.1	169.0				190.2
	No-Till	204.6	169.9	166.8				180.4
	CB Average	207.2	183.8	166.7				185.9
	Average	196.9	178.8	150.4				175.3
				Soybean				
Corn	Fall chisel, disk, field cultivate	60.4	48.6	46.8				51.9
	Fall chisel, field cultivate	61.9	48.3	49.5				53.2
	Fall aerate, spring aerate	61.2	49.9	43.5				51.5
	Fall disk, field cultivate	60.5	45.1	46.0				50.5
	No-Till	60.8	51.0	41.2				51.0
	BC Average	61.0	48.6	45.4				51.6

†Average of 4 replications.

Feasibility of One Pass Tillage in Northern Indiana

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

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 problem however in cooler climates with the perception that no-till leads to delayed planting, reduced plant stands and 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 16% of the corn acreage was planted with no-till in 1998 and that the no-till corn acreage has been declining for the past 5 years.

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 2 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 (1975-99) at the 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" 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. The previous crop was corn.

CULTURAL PRACTICES USED 1999
Feasibility of One Pass Tillage in Northern Indiana, Continuous Corn

Item	Date	Application
Primary tillage	5/3	Spring chisel and one pass treatments as required
Secondary tillage	5/4	Combo-mulch-finisher once on chisel treatment
Hybrid planted	5/4	Pioneer 34F80Bt (109 day)
Seeding rate		29,900 seeds/ac. JD7000 planter.
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 oz/1000 row feet.
Weed control	5/7	Pre-emergence: Atrazine 0.5 LB/a. Extrazine 1.5 LB/a. Dual II Magnum 2.25 pt/a. Roundup 1.5 pt/a. *Broadcast with 8008 flat fan nozzles on 20" centers at 5.5 mph, 20 gallons water/a.*
Nitrogen fertilizer	6/15	NH_3 @ 150 lb. N/a., sidedressed, no covering disks
Cultivation	6/8	Chisel treatment, once
Harvest	10/12	Center 6 of 12 rows
Primary tillage	11/4	Fall chisel with ridge leveling sweeps
	11/11	Fall VC5BDR

Continuous Corn: Stand, growth, and yield.

All tillage systems left enough residue cover for adequate soil erosion protection (Table 20). No-till had significantly more residue cover than the other treatments. There were no significant differences among the other treatments. Plant spacing standard deviation did not vary among treatments significantly, nor did week 4 stand, week 4 and 8 plant height, grain moisture or grain yield.

Studies for 2000:

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

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Table 20. Feasibility of One Pass Tillage in Northern Indiana Study, Sebewa loam, Pinney Purdue Agr Center, Wanatah, IN, 1999.†

Treatment	Soil Aggregate	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%
	%< 4.76mm	%	Inches	Plants/acre	Inches	Inches	%	Bushels/acre
1. Conv. chisel, 42x: VibraEdge + 3 bar + double roller	39.2a‡	37b	3.0	27100	13	57	16.1	136.5
2. No-till	19.4b	73a	3.3	27700	12	55	15.7	129.4
3. 42x: VibraEdge + 3 bar + double roller	27.9ab	39b	3.1	27300	12	59	15.4	132.1
4. 42x: VibraEdge + 5 bar + single roller	31.2ab	40b	3.1	26700	13	57	16.0	137.6
5. 42x: VibraEdge + 5 bar	31.4ab	40b	3.2	26700	12	58	15.3	139.7
6. 42x: VibraEdge (no attachments)	33.5ab	41b	3.1	26300	12	57	16.0	137.5
7. 42x: VibraEdge + 3 bar + double roller, aggressive disc	30.0ab	45b	2.8	27300	12	58	15.1	137.5
8. 42x: VibraEdge + 3 bar + double roller, minimal disc	34.4ab	40b	3.1	26700	12	56	15.6	138.3
9. 42x: VibraShank + 3 bar + double roller	29.5ab	50b	2.7	27700	13	60	16.1	137.6
10. 42x: VibraChisel + 5 bar + single roller	34.2ab	49b	3.1	27700	13	58	17.4	146.2
Significance level:	.02	.01	NS	NS	NS	NS	NS	NS

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

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") 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 spreaders 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 1998-99	
Name	**Location**
Ag Alumni Seeds	Romney
Agronomy Research Center	West Lafayette
Brodbeck Seeds	Wabash
Northeast Purdue Ag Center	Columbia City
Pinney Purdue Ag Center	Wanatah
Southeast Purdue Ag Center	Butlerville

CULTURAL PRACTICES USED AT 6 LOCATIONS IN 1998-99		
Item	Date	Application
Primary tillage	10/98	Fall disking at 3 locations; No-till at 3 locations
Wheat variety		Ag Alumni 9531 and 9811
Soybean variety		Hubner Seeds H317, H355, and H382 (group 3.1 to 3.8, depending on location)
Soybean seeding rate	5/8/99-5/17/99	175,000 seeds/ac in 15" rows (Sunflower 9412 grain drill).
Starter fertilizer	10/98	30-40 LB N/ac
Nitrogen fertilizer	3/99	70 LB N/ac
Weed control	4/99	Buctril in wheat
	8/99	Roundup in soybeans
Wheat harvest	6/22/99-7/7-99	Entire plot
Double crop planting	6/22/99-7/7/99	240,000 seeds/ac in 7.5" rows
Soybean harvest	10/99-11/99	Entire plot

Table 21. Growth of soybeans as affected by seed coatings and cropping system*, Purdue University, 1999.

Treatment	Days to 50% Emergence	Height at Wheat Harvest	Height at Wheat Harvest + 30 Days	Height at Harvest	Harvest Population
	days	in	in	in	ppa
15" Full Season Soybeans	11.8	17.3	30.2	30.7	129,000
Intercropped Coating A	29.8	9.5	16.8	19.9	93,000
Intercropped Coating B	37.3	8.5	15.7	19.8	83,000
Intercropped Coating C	34.5	8.9	16.7	20.1	95,000
Intercropped Uncoated	12.0	11.5	18.5	18.2	98,000

*6 Site Averages

Winter Wheat Yield

Wheat yields in 15" rows averaged 63 Bu/ac, just 10 Bu/ac less than wheat seeded in 7.5" rows. Wheat yield losses associated with soybean interseeding itself were negligible, since yields were just 2 Bu/ac lower when soybeans were interseeded, versus wheat in 15" rows that was not disturbed by the tractor/drill combination prior to heading.

Soybean stand, growth, and yield

Data in tables show that there were differences in emergence delay among the treatments. These delays did not have a large impact on final plant height. During 1999, heavy stand losses occurred in the intercropped soybeans. We attributed this to dry soil conditions during germination and emergence, and some insect pressure after emergence.

Due to shading from the wheat, the intercropped soybeans were shorter than full season soybeans throughout the entire growing season.

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 by approximately 20 days and that winter wheat yields were reduced by less than 15% in 15" row widths versus the standard 7.5" rows. At this time it is not clear how these delays translate into soybean yield gains versus uncoated soybeans. 1999 was a dry year in terms of precipitation during the growing season. Lack of rain caused pod abortion in intercropped soybeans and severely reduced soybean yields. Available moisture appears to be the factor that has the greatest influence on the success of relay intercropping. However, moisture limited double crop soybeans even more, since double cropped soybeans averaged less than 4 Bu/ac at the five sites north of Indianapolis.

This experiment will be repeated in 2000 with some changes. Some of the changes include higher soybean seeding rates, an evaluation of two different planting dates into wide row wheat, and examination of multiple wheat varieties. The planting date study is being conducted to find the optimum timing for soybean planting. The polymers used in this experiment have also been reformulated for 2000.

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