EFFECT OF SUBSOIL TILLAGE ON CROPS GROWN IN NO-TILL AND REDUCED TILL MANAGEMENTS[1]

E.C. Varsa, C.L. Hooks, D.A. Farquhar, and S.K. Chong[2]

ABSTRACT

Three different subsoil tillage experiments were conducted in southern Illinois on soils with root-limiting claypans that restrict crop growth. In the first experiment conducted at the SIU Belleville Research Center, subsoiling to 16 inches depth was compared to no subsoiling in a field that had been in long term, continuous no-till corn production. After 4 years of study, only small corn and soybean yield increases have observed with the tillage (2.0 bu/ac for corn and 1.0 bu/ac for soybeans). Large economic returns are unlikely from this practice.

In the other two experiments, deep subsurface tillage was done to fracture and disrupt the naturally-occurring claypan of two different Stoy silt loam soils. In one experiment conducted in Perry County, a moldboard plow that penetrated and inverted the soil to a depth of 32 inches was used. After 3 years of crop evaluation it was found that the deep plowing resulted in corn yields that averaged 10 bu/ac greater than a comparison soil that was not plowed. On another Stoy silt loam soil at the SIU Carbondale Agronomy Research Center, subsoil fracturing was accomplished with static and vibrating shank tillers to depths 0, 16, 24, and 36 inches. After 6 years of study only the 36 inch depth of tillage consistently resulted in yield increases that were significantly greater than the control treatment. Averaged over the 6 years of study, the yield increase has been about 19 bu/ac. Fracturing the subsoil to a 24-inch depth gave a significant yield increase over the control treatment in only one of the six years of study.

INTRODUCTION

Compaction resulting from man-induced tillage practices or from natural pan formation in soil development can be a serious limitation to crop growth and yield. Some producers feel that periodic soil loosening is necessary under long term no-tillage because of the compaction from fertilization, planting, spraying, and harvesting operations. Tillage implements that loosen the soil to depths of 12 to 16 inches without burying crop residues are commercially available. The objective of the first study reported here was to determine in a long term no-till managed field the

[1]Presented at the 26th North Central Extension-Industry Soil Fertility Conference, November 20-21, 1996. St. Louis, MO.

[2]Associate Professor, Assistant Scientist, former Graduate Assistant, and Professor, Plant and Soil Science Dept., Southern Illinois University, Carbondale, IL 62901-4415

benefit of soil loosening to a depth of 16 inches (without significant residue disturbance) yet continuing and maintaining a mostly "no-till" environment.

Another problem of many soils across the Southern Corn Belt is the occurrence of fragipans and claypans. These naturally formed horizons, usually occurring in the B horizon of soils, effectively impedes root development for water and nutrient uptake. Consequently, during droughty periods crops usually experience moisture stress and fail to yield up to their potential. The objective of the second and third studies reported here was to evaluate deep soil modification, beyond that usually done in Midwestern USA agriculture, in terms of soil property improvement and crop yield benefit.

METHODS

Experiment One: Belleville Research Center

An experiment was initiated in October 1992 to evaluate the effect of subsoil loosening to a depth of 16 inches on subsequent corn and soybean yields using no-tillage practices. The soil (an Iva silt loam with a slope of 1-2%, an organic matter content of 1.7%, and classified as a fine-silty, mixed, mesic Aeric Ochraqualfs) had been in continuous no-till corn production for the preceding 10 years. Compaction of the surface soil was thought to be a problem for early root development and a cause for reduced yield potential.

The implement used was the Blu-Jet Sub-Tiller II manufactured by Thurston Manufacturing Company, Thurston, Nebraska. The unit used consisted of five static shanks (30-inch spaced) that had 3-inch wide points for lifting and shattering the soil. A rolling coulter was mounted ahead of each shank to cut through heavy crop residues. Soil moisture was favorable for ideal soil fracturing on the date the tillage was done.

A corn and soybean rotation has been in place at this site and yields of both crops (using no-tillage practices) have been obtained from 1993 to 1996.

Experiment Two: Perry County, IL

This tillage experiment was initiated in October 1991 by Mr. Charles Hooks, who at the time was an Agronomist for the University of Illinois Prime Farmland Reclamation Center at Percy, Illinois. The study site was a 5 acre demonstration field that was dominantly a Stoy silt loam soil, a fine-silty, mixed, mesic Aquic Hapludalfs, with a very dense Bt horizon. Tillage to disrupt the claypan was accomplished by a large Canadian manufactured single-bottom moldboard plow that can reach a depth of penetration up to 32 inches. The plow was loaned from Mr. Ross Lay, a Montgomery County, Illinois farmer who used the plow on his farm.

When operated at full depth, the plow inverts a portion of the topsoil (Figure 1). The upper B horizon is fractured and laid-over at an angle, approximately 60 degrees from complete inversion. In this study the furrow slice was to a maximum depth of 32 inches and spacing of each pass was about 48 inches. A 335 hp tractor was used to maintain an operating speed of about 3.5 mph. A comparison tillage treatment using a traditional chisel plow that achieved a penetration depth of 12 inches was used as a control.

Corn yield data was obtained for 3 years, 1993 to 1995, and penetrometer resistance measurements were taken in May, 1992. No soybean yield data was taken because of deer grazing problems.

<u>Experiment Three</u>: Carbondale Agronomy Research Center

A deep tillage experiment was initiated in August 1989 at the SIUC Agronomy Research Center to evaluate the effect of subsoil loosening at depths of 0 (control), 16, 24, and 36 inches. The soil at the study site was a Stoy silt loam that had a dense claypan in the B horizon. Three different implements were used to loosen and fracture the soil to the indicated depths. The Blu-Jet Sub-Tiller II was used for the 16 inch depth of tillage. The 24 inch tillage depth was achieved with the TLG-430 and the 36 inch tillage depth was obtained with the TLG-12B vibrating shank tillers, both manufactured by the Kaelble-Gmeinder Company of Mosbach, Germany. Each implement, the TLG-430 and TLG-12B, utilizes hydraulically driven vibrating shanks with 6-inch wide pointed shoes that lift and shatter the soil as the implement is pulled through the soil. The Blu-Jet unit was a 5 shank implement with 30-inch spaced shanks. The TLG-460 implement had 4 shanks with 30-inch spacings and the TLG-12B implement had 3 shanks with 32-inch spacings.

Following tillage treatment employment the entire area was disked and seeded to a cover crop of wheat. Beginning in 1990 a corn-soybean rotation was established with both crops grown simultaneously using no-till and reduced till annual management practices as subplots. Only the corn yield results will be presented for the years of 1990 to 1995. Soybean yields were not included because of deer grazing problems affecting certain plots but not others.

RESULTS AND DISCUSSION

<u>Experiment One</u>: Effect of Subsoiling a Long Term No-Till Managed Soil. Belleville Research Center.

Subsoil tillage of a long term no-till managed field had a negligible effect on subsequent corn and soybean yields. As shown in Table 1 only during the 1996 season did soil loosening to 16 inches (performed in 1992) significantly increase no-till corn and soybean yields. Of the 4 years following tillage treatment, the 1996 season was the most favorable for crop growth and apparently residual benefits of the soil loosening had a positive impact on yield. It was also apparent that compaction, perceived to be a problem from long term no-tillage management, was not a real problem at this site. Organic matter presence at the soil surface and freezing and thawing action served to alleviate any serious compaction problems. When summarized over the 4 years of study, corn yields were increased an average of 2.0 bu/ac and soybeans were increased by 1.0 bu/ac as a result the 16-inch subsoil tillage.

Table 1. Effect of Subsoiling a Long Term No-Till Managed Soil on Subsequent No-Till Corn and Soybean Yields, Belleville Research Center, SIUC.

	Corn Yields (Bu/ac)[1]				
	1993	1994	1995	1996	Mean
Non-Tilled	136 a	155 a	133 a	171 b	149
Tilled to 16 inches with Blu-Jet Subtiller II	137 a	157 a	135 a	175 a	151

	Soybean Yields(Bu/ac)[1]				
	1993	1994	1995	1996	Mean
Non-Tilled	48.0 a	56.5 a	44.0 a	60.7 b	52.3
Tilled to 16 inches with Blu-Jet Subtiller II	47.8 a	58.0 a	45.1 a	62.1 a	53.3

[1]Grain yield means for each year followed by letters in common are not significantly different at the 10 percent level of significance by the Duncan's Multiple Range Test.

Experiment Two: Effect of Soil Modification by Deep Moldboard Plowing on Soil Properties and Corn Yield, Perry Co., Illinois.

Deep plowing to 32 inches depth disrupted the upper profile of the Stoy (claypan) soil and inverted a portion of the A horizon to the depth of tillage (Figure 1). Likewise, portions of the B horizon became exposed and were mixed with the surface soil upon disking and leveling operations. Previous experience of Mr. Ross Lay, a farmer from Montgomery County, Illinois who loaned the use of the plow, suggested that a pronounced yield advantage resulted from similar deep tillage of certain soils on his farm.

Soil strength, which is a property that can affect impedance to rooting, was significantly modified by the deep plowing. As shown in Figure 2 penetrometer resistance values were significantly reduced and were only 50 to 75 percent as high in the 0 to 24 inch soil depth compared to the soil tilled with the chisel plow. This ease of mechanical penetration probably created greater macroporosity that allowed more water to enter the soil and become stored for plant use. Likewise, the reduced resistance likely allowed for more non-impeded root development for nutrient and water extraction. Penetrometer resistance values below about 24 inches depth were essentially no different than those of the chiseled control treatment. Only limited root proliferation is usually found in soils when the penetrometer resistance becomes much greater than 300 psi. Consequently, root exploration in this soil beyond 30 inches depth was likely to be limited.

Corn yield in the deep plowed treatment was greater in all years of the study, 1993 to 1995 (Figure 3). Only in 1994 was the yield difference statistically non-significant. The high grain yield obtained in 1993 reflected an overall favorable growing season. In 1995 yields were poor because of droughty conditions late in the growing season but deep plowing resulted in a 19 bu/ac increase in yield over the chiseled control plots. This suggests that the greatest benefit from deep soil modification will likely occur when soil moisture is a limiting factor. For the 3 years of this study, deep tillage resulted in a statistically significant average yield increase of 10 bu/ac.

Experiment Three: Effect of Depth of Soil Subsoil Tillage and No-Till vs. Reduced Till Annual Management on Soil Strength Changes and Corn Yield. Agronomy Research Center, SIU-Carbondale.

Soil strength, as evaluated by penetrometer resistance measurements, was incrementally reduced to each depth that tillage took place. In 1993, 4 years following experiment initiation, the effect of each successively deeper tillage remained apparent in terms of reduced penetrometer resistance (Figure 4). The largest resistance reduction occurred with the 36 inch tillage depth such that values of less than 300 psi were detected well below 30 inches into the soil. When penetrometer resistance exceeds 300 psi, there is an increased likelihood that root impedance will become a serious factor limiting plant growth. The high penetrometer resistance (~ 400 psi) observed at the 8-inch depth for the non-tilled treatment was probably a result of a plowplan that developed over the many years of tillage that preceded this experiment.

By 1996, 7 years following experiment initiation, the effects of deep tillage remained somewhat similar to those observed in 1993 (Figure 5). Penetrometer resistance differences between the 24 inch and 16 inch tillage depths, however, largely disappeared between 1993 and 1996 such that the values were nearly identical throughout the soil profile. It appeared that shallow loosening into the B horizon (24 inches) was not sufficient for long-term reductions in soil strength. Penetrometer resistance values were clearly reduced with the 36-inch depth of tillage to values less than 200 psi well into the B horizon (below 30 inches depth in the soil). This should allow for greater root development and proliferation compared to the other tillage treatments.

Corn yield response to the different increments of tillage varied widely from year to year between 1990 and 1995 (Table 2). In all years, the 36-inch tillage depth treatment gave the highest grain yield. Except for 1995, the yield difference between the 36 inch tillage treatment and the non-tilled control was always significant. Only in 1991 (a very hot and dry year) did the 16-inch or 24-inch tillage treatment significantly increase yield over the non-tilled control. When averaged over the 6 years of study the 16, 24, and 36 inch tillage treatments resulted in grain yields that were 0, 5, and 19 bu/ac greater than the non-tilled treatment (Table 3).

The split plot evaluation of no-till vs reduced till annual managements imposed over each depth of subsoil tillage for the 1990 to 1995 growing seasons is given in Table 2. In the first two years of the study, corn yields were significantly greater with reduced till management compared to no-till. However, beginning in 1992 no-till yields were significantly greater than those obtained with reduced tillage. Apparently, the benefits of organic matter residues building up on the soil surface in no-till translated into increased yields later in the experiment. The yield benefits from no-till compared to reduced till management were especially evident for the 0 and 16 inch tillage depths compared to 24 or 36 inch depth of tillage (Table 4). The soil moisture conserving properties of the mulch in no-till was most beneficial when the claypan was not disrupted.

SUMMARY AND CONCLUSIONS

1. Shallow subsoiling to 16 inches depth in a long term no-tilled field increased corn and soybean yields negligibly (2.0 bu/ac for corn and 1.0 bu/ac for soybeans) during the 4-year study.

2. Deep tillage to disrupt the claypan in southern Illinois soils requires a tillage depth of at least 36 inches to effectively improve the yield of corn and to maintain a favorable rooting environment (i.e. maintain a reduced soil strength in the B horizon).

3. The yield advantage of no-tillage management was most apparent when the claypan was not disrupted. When the subsoil was modified by tillage (24 to 36 inch depth), no-till and reduced till managements resulted in similar but higher corn yields.

4. Yield increases from deeper tillage depths of the claypan (greater than 24 inches) appear to be long term in nature.

5. Tillage to deeper depths tends to maintain a more favorable soil strength environment for root development throughout the soil profile.

Figure 1. Cross-Section and Horizon Redistribution of Inverted Soil by Deep Moldboard Plowing of a Stoy Silt Loam Soil, Perry County, Illinois.

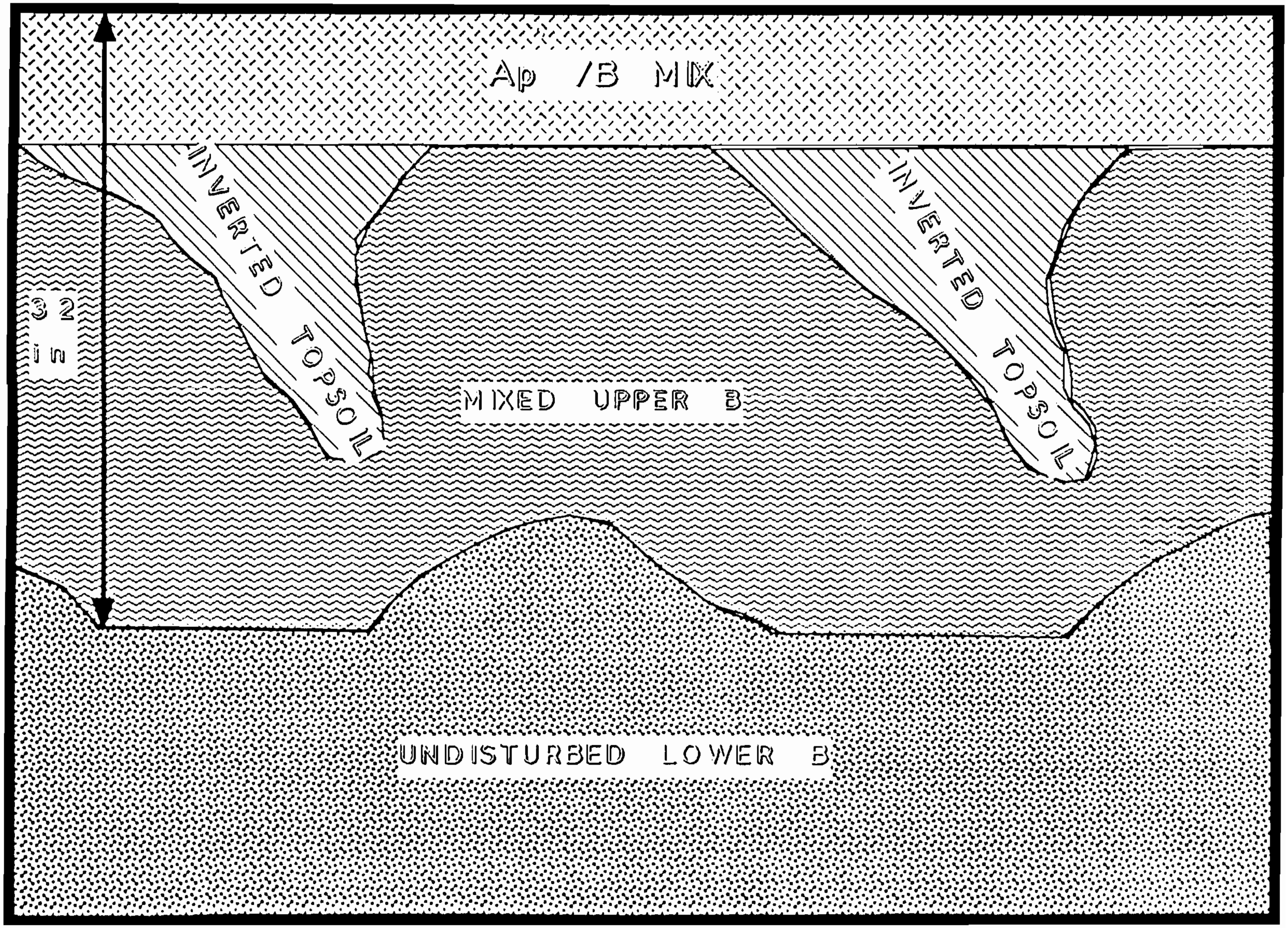

Figure 2. Penetrometer Resistance in a Stoy Silt Loam as Effected by Chiseling and Deep Moldboard Plowing (32 inch depth) Perry County Illinois, May 1992.

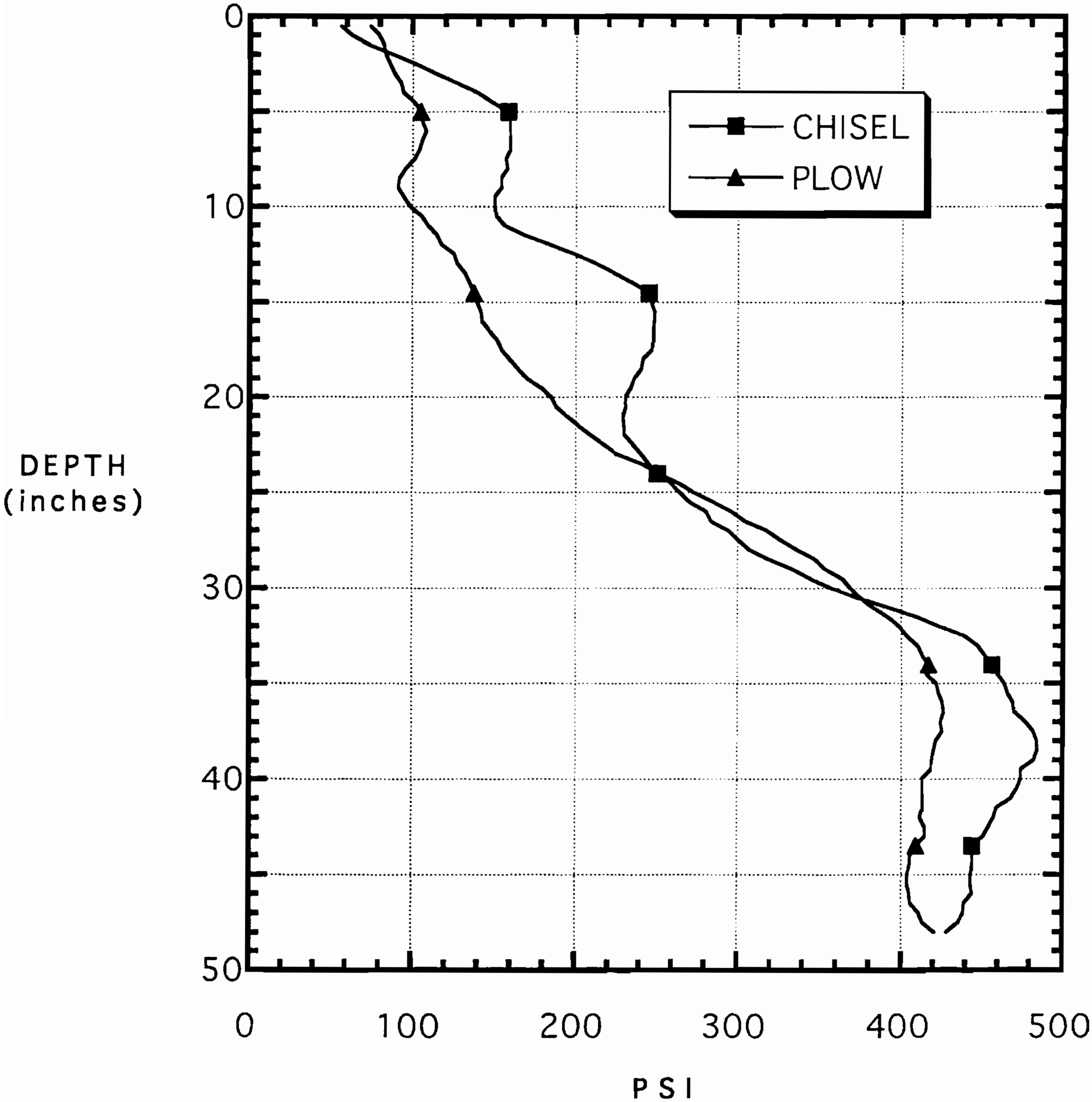

Figure 3. Corn Yield as Effected by Chiseling and Deep Moldboard Plowing (32 inch depth) Perry County, Illinois. 1993-1995.

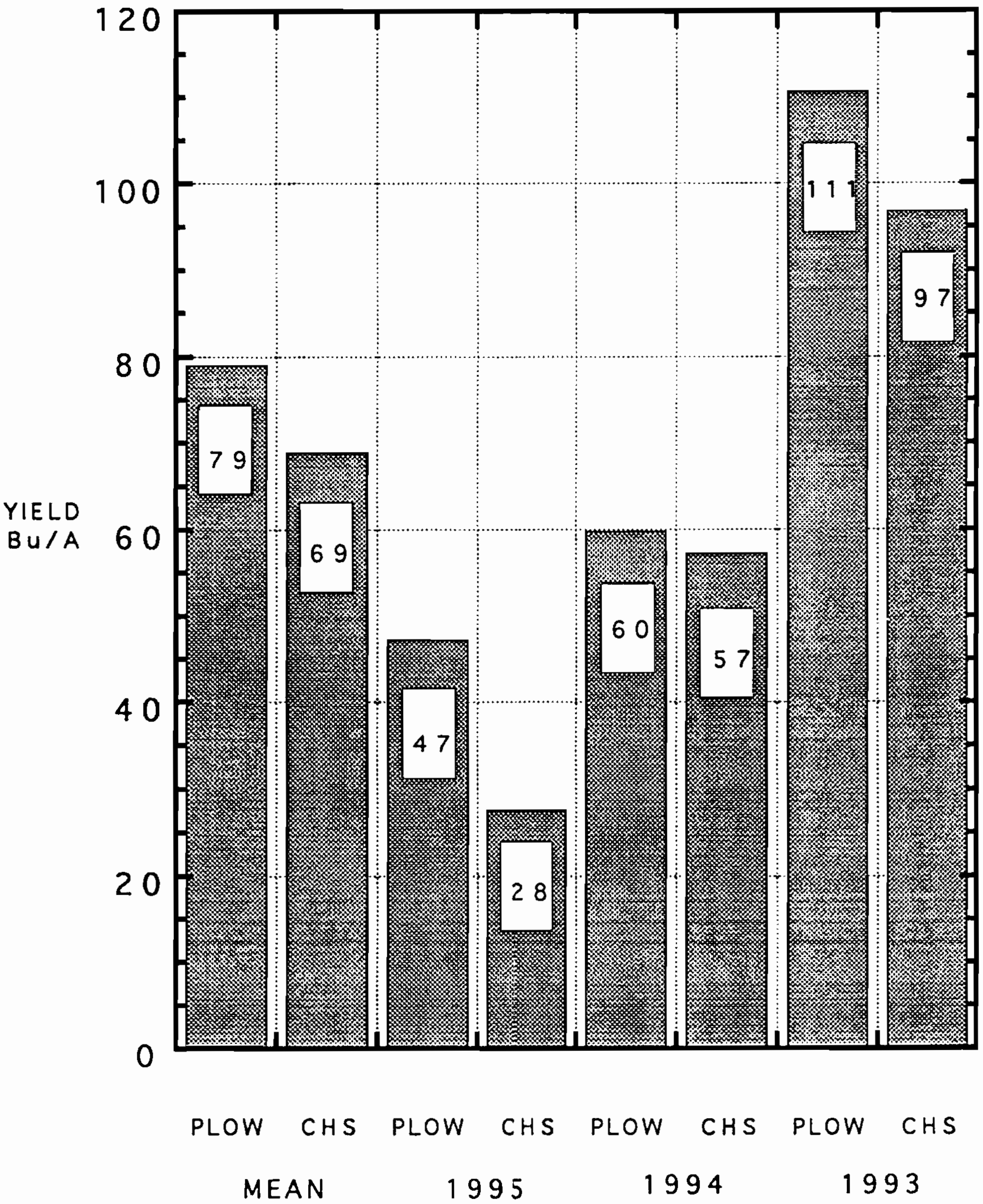

Figure 4. Penetrometer Resistance in a Stoy Silt Loam Soil as Affected by 0, 16, 24, and 36 inch Depths of Subsoil Tillage. Carbondale Agronomy Research Center, June 1993

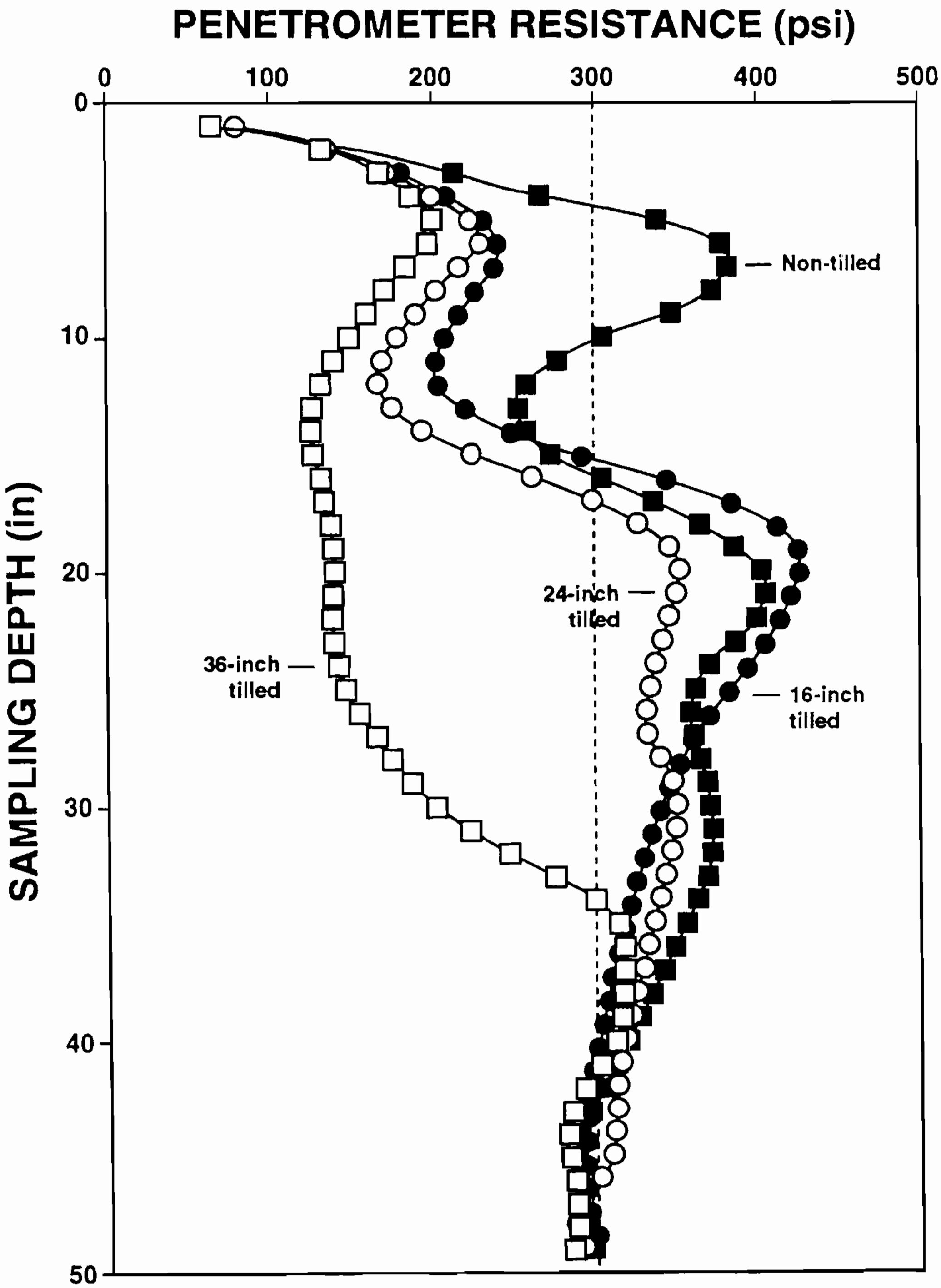

Figure 5. Penetrometer Resistance in a Stoy Silt Loam Soil as Affected by 0, 16, 24, and 36 inch Depths of Subsoil Tillage. Carbondale Agronomy Research Center, June 1996

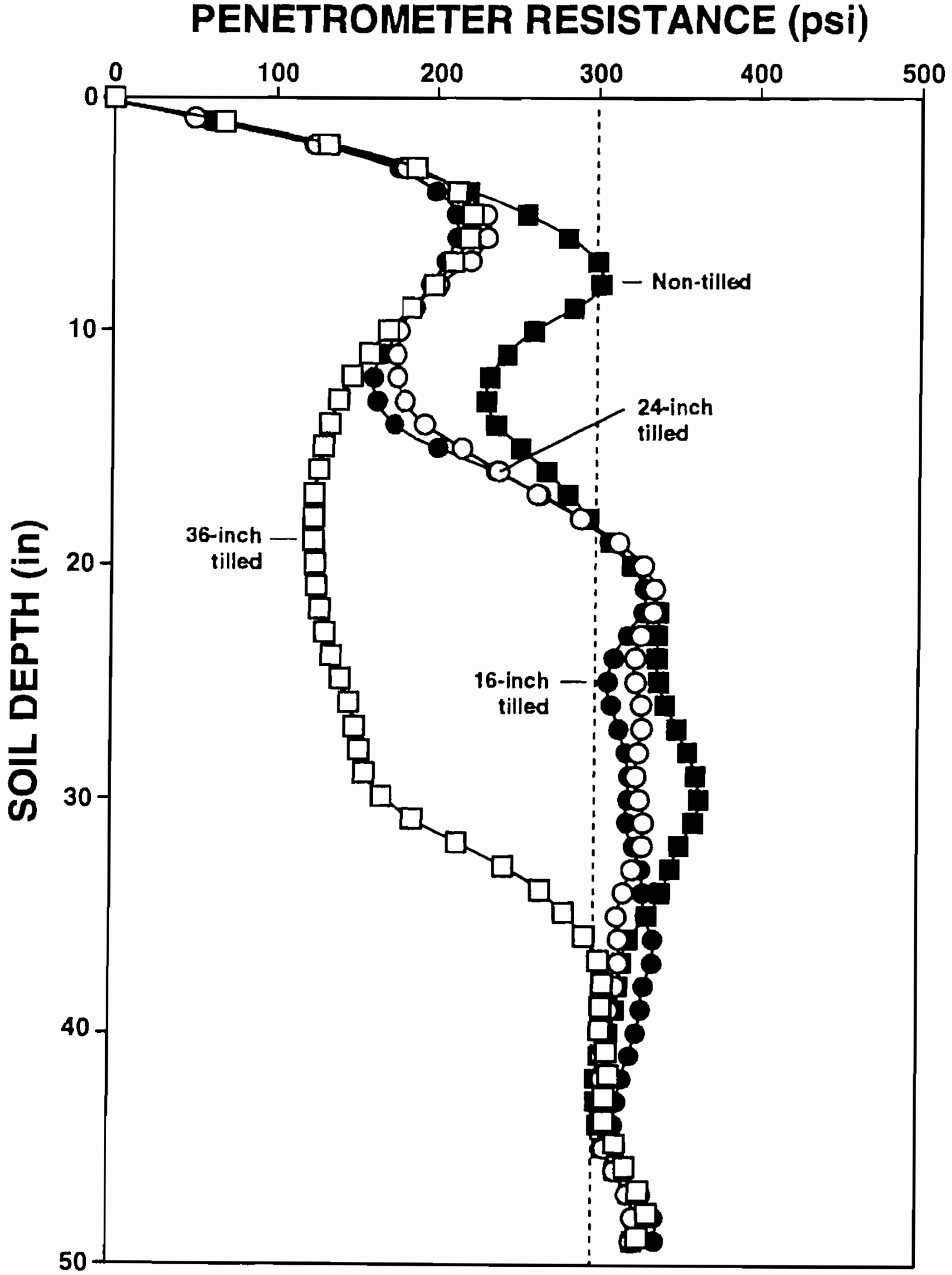

Table 2. Corn Grain Yields as Affected by Soil Tillage Depth and the Annual Tillage Management at the Agronomy Research Center, Southern Illinois University, Carbondale, IL, 1990-1995 *

Annual Tillage Management System	Tillage Depth (in) 0	16	24	36	Mean
	bu/ac				
			1990		
No-Till	116.6	118.7	118.0	124.4	119.4b
Reduced Till	117.7	120.7	121.7	129.5	122.4a
Mean	117.1b	119.7b	119.8b	127.0a	
			1991		
No-Till	68.1	84.8	100.8	115.3	92.3b
Reduced Till	76.8	87.5	112.0	128.4	101.2a
Mean	72.5d	86.1c	106.4b	121.9a	
			1992		
No-Till	127.9	111.2	122.5	138.9	125.1a
Reduced Till	114.8	113.2	117.2	127.2	118.1b
Mean	121.4b	112.2b	119.9b	133.1a	
			1993		
No-Till	138.6	142.3	135.1	142.6	139.9a
Reduced Till	122.1	116.7	129.6	150.6	129.8b
Mean	130.3b	129.5b	132.3b	146.7a	
			1994		
No-Till	141.9	144.7	141.8	166.1	148.6a
Reduced Till	131.8	128.3	135.2	149.1	136.1b
Mean	136.8b	136.5b	138.5b	157.6a	
			1995		
No-Till	140.1	130.0	118.9	140.5	132.4a
Reduced Till	128.4	123.0	129.8	139.3	130.1a
Mean	134.3a	126.5b	124.3b	139.9a	

* Means in rows or columns followed by letters in common are not significantly different at the 5 percent significance level by the Duncan's Multiple Range Test.

Table 3. Corn Grain Yields as Affected by Depth of Soil Tillage at the Agronomy Research Center, Southern Illinois University, Carbondale, IL. (Averaged over No-Till and Reduced Till Annual Managements) *

Tillage Depth	1990	1991	1992	1993	1994	1995	Mean
(in)	bu/ac						
0	117.1b*	72.5d	121.4b	130.3b	136.8b	134.3a	118.8
16	119.7b	86.1c	112.2b	129.5b	136.5b	126.5b	118.5
24	119.8b	106.4b	119.9b	132.3b	138.5b	124.3b	123.6
36	127.0a	121.9a	133.1a	146.7a	157.6a	139.9a	137.7

* Means in the same column followed by letters in common are not significantly different at the 5 percent significance level by the Duncan's Multiple Range Test.

Table 4. A Summary Table of Corn Grain Yields as Affected by Tillage Depth and Annual Management at the Agronomy Research Center, Southern Illinois University, Carbondale, IL. (Average of 6 years, 1990-1995)

	Tillage Depth (in)				
	0	16	24	36	Mean
	bu/ac				
No-Till	122.2	122.0	122.9	138.0	126.3
Reduced Till	115.3	114.9	124.3	137.4	123.0
Mean	118.8	118.5	123.6	137.7	

PROCEEDINGS OF THE TWENTY-SIXTH

NORTH CENTRAL EXTENSION-INDUSTRY

SOIL FERTILITY CONFERENCE

Published for
The North Central Extension-Industry Soil Fertility Conference
by
Potash & Phosphate Institute
700 - 22nd Avenue, South
Brookings, SD 57006
605-697-7149

November 20-21, 1996

St. Louis Westport Holiday Inn
St. Louis, Missouri

Volume 12

Program Chairman and Editor:

Dr. Peter Scharf
University of Missouri
Dept. of Agronomy
Columbia, MO 65211