EFFICACY OF DEEP TILLAGE IN WISCONSIN [1/]

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Soil compaction is recognized as a yield limiting factor in crop production. Compaction problems continue to exist for several reasons, including; 1) the large size (mass) of agricultural vehicles; 2) increased operations on wet soils because of larger farm acreage and multi-axle driven equipment; and, 3) the lack of controlled traffic patterns in fields. Where compaction is identified as a problem, ameliorating its effects is difficult. Natural freeze/thaw and wet/dry cycles may take several years to correct the problem. Seeding tap-rooted forages is also often suggested, but is not practical because of rotational considerations. Many producers routinely subsoil (deep till) fields even if restricting layers have not been identified. Subsoiling is a relatively expensive and time consuming operation for which little research has been conducted to evaluate its impact on crop production.

Compaction affects the strength of the soil which has a direct impact on the ability of the root system to develop in the soil. Assessing the existence of soil compaction is a challenge because there is no absolute value of any measurement that indicates compaction levels that will negatively affect growth and yield. Penetrometer measurements give a relative reading of compaction because they are affected by factors such as water content and soil texture. Measurements should be made in areas where compaction is suspected and where it is not a problem.

Researchers have demonstrated the yield limiting effects of soil compaction. In Ontario it is estimated that compaction costs farmers $70 million/yr (Lammers-Helps, 1997). They estimate that yield losses may range between 16 and 25 % on the clay loam soils of that region. They also suggest that other soil management problems; e. g. erosion, runoff, and P losses are exacerbated by compaction. Subsoiling is an energy expensive practice. The University of Nebraska found that about 30-40 tractor HP/shank were required depending upon soil type (Jones et al., 1996). The expense and time requirement of subsoiling should be factored into any cost:benefit assessment of the practice.

Research in Wisconsin found a relationship between compaction and K fertility (Wolkowski, 1989; Wolkowski and Bundy, 1996). Yield responses were often seen at higher soil test levels on compacted soils. This response was thought to be related to the reduced aeration in the compacted soil that impacted plant K uptake. While the effect of compaction has been studied on other nutrients, no consistent relationships have been found. Regardless, if subsoiling permitted a crop to explore more of the soil volume, nutrient use efficiency should increase.

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Several researchers have examined the response of crops to subsoiling with mixed results. A Minnesota study found that subsoiling did have short term effects on soil bulk density and other physical properties, but no effect on yield (Evans et al., 1996). They cautioned that some indication of soil compaction must be evident before subsoiling would become worthwhile. Al-Adawi and Reeder (1996) found that subsoiling increased yield in compacted plots on a silty clay loam soil, but the observed yields were lower than the non-compacted control. Perhaps the most interesting finding of this study was that subsoiling increased yield in plots where there had been no intentional compaction. Soane et al. (1987) in a study of 16 sites in Great Britain found: 1) the most potential for a response on soils with higher bulk densities; 2) that sites re-compacted with time; 3) controlled or reduced traffic increased subsoiling longevity; 4) reducing moisture stress in dry periods was the greatest benefit; and, 5) silty soils may be degraded by subsoiling from structural breakdown.

These findings suggest that a response to subsoiling may be a site- or grower-specific phenomena which is dependent on the soil type and farmer practice. This paper will discuss the effect of deep tillage in Wisconsin as measured from a number of studies conducted on a wide range of soil types.

Procedure

Studies were conducted in 1997-1999 at six locations in a total of nine experiments to evaluate the response of crops to subsoiling and usually a soil fertility parameter. A variety of subsoilers, soil types, and crops were used in the evaluations. A description of the sites, crop grown, and equipment used is presented in Table 1.

Table 1. Site, soil type, crop, and machinery used in Wisconsin subsoiling studies, 1998-1999.

Site	Soil type	Crop	Subsoiler
Arlington	Plano silt loam	Corn/Soybean	Landoll 2" straight point
Columbus	Atterberry silt loam	Corn	DMI-Minimum Residue Disturbance 2.5" point
Hancock	Plainfield loamy sand	Sweet corn/ Soybean/Potato	Para-till paraplow
Manitowoc, Site 1	Kewaunee loam	Corn/Soybean	DMI Ecolo-tiger Rawson Zone-Builder
Manitowoc, Site 2	Hortonville silt loam	Corn/Soybean	Rawson Zone-Builder
Ripon	Plano silt loam	Sweet corn	Blue Jet 2.5" straight pt.

Equipment and manufacturer names are given for educational purposes only and do not represent an endorsement of the author or the University of Wisconsin.

Studies at Arlington and Hancock were conducted on UW Agricultural Research Stations, whereas the Columbus, Manitowoc, and Ripon sites were on private farms. Some of the studies were established in typical small plot configurations, while the others were set up in replicated field length strip trials. Usually the cooperator at each location supplied the subsoiler because of the logistics associated with locating the equipment needed to transport and pull the subsoiler. The soil was not intentionally compacted prior to tillage at any site. Soil bulk density measurements taken prior to study establishment did not suggest root restricting limitations with the exception of Hancock where a definite plow pan was found at about 8" (data not shown). Research will be summarized by location.

Arlington

Small plots were established in the fall of 1997 in two adjacent fields located on the Arlington Agricultural Research Station. Fields are rotated between corn and soybean each year. This site has a very low initial soil test K level of about 60 ppm K. Treatments were set up in a split plot design containing four replications. The main plot was subsoiling (none; subsoiling annually, fall 1997, and fall 1998; and fall chisel plowing). This tillage was conducted in the fall using the subsoiler described in Table 1. Chiseling was done with a twisted shank coulter chisel. The subplot was annual K fertilization (0, 100 lb K_2O/a, and 200 lb K_2O/a). This fertilizer was broadcast prior to secondary tillage in the spring. Other than the tillage performed by subsoiling, the only subsequent tillage was a single pass with a field cultivator just prior to planting.

The yield results for 1998 and 1999 are shown in Table 2. Yield of either corn or soybean was not affected by any of the tillage treatments including subsoiling. It is noteworthy to point out that a simple field cultivation just prior to planting produced yields that were equal to those obtained with any of the tillage treatments. Because of the unusually low soil test K an excellent response to K fertilization was observed. Unfertilized plots demonstrated K deficiency throughout the season.

Hancock

Small plots were established in a single field located on the Hancock Agricultural Research Station to assess the response of potato, sweet corn, and soybean to deep tillage on a sandy soil. This site also had a low soil test K level of about 70 ppm K. Treatments were set up in a split plot design containing four replications. The main plot was subsoiling (none; subsoiling annually in the fall, subsoiling annually in the spring). In 1998 tillage was conducted only in the spring. The subplot was K fertilization (half rate or full rate). In the potato study the full rate was 300 lb K_2O/a. Half of this was applied with the starter so that all plots would have sufficient systemic insecticide. The full treatments received an additional 150 lb K_2O/a broadcast. The full K rate in the corn and soybean was a broadcast of 65 lb K_2O/a. Broadcast treatments were made prior to secondary tillage in the spring. No starter fertilizer was used in the corn or soybean studies. Nitrogen fertilizer was applied to the sweet corn and potato at a rate consistent with UWEX recommendations. Secondary tillage consisted of a single pass with a “dyna drive” rotary tiller just prior to planting. All crops were irrigated to meet evapo-transpiration demand.

Table 2. Effect of subsoiling and K fertilization on corn and soybean yield at Arlington, Wis., 1998 and 1999.

Subsoil K Treatment	Treatment	Grain Yield 1998	1999	1998	1999
		----------------------------	bu/a	----------------------------	
		Corn Study		Soybean Study	
None	None	106	117	41	35
	Half	215	193	53	42
	Full	223	204	53	45
Annual	None	--	141	--	32
	Half	--	198	--	45
	Full	--	186	--	47
Subsoil-97	None	137	105	41	35
	Half	209	193	50	44
	Full	217	189	54	42
Subsoil-98	None	--	133	–	39
	Half	--	203	–	46
	Full	--	201	–	51
Chisel	None	126	100	38	37
	Half	215	202	56	41
	Full	223	206	57	47
Pr>F					
Subsoil		0.52	0.39	0.89	0.65
K		0.01	0.01	0.01	0.01
S*K		0.36	0.37	0.30	0.45

Sweet corn was hand harvested, whereas the soybean and potato were both harvested with small plot harvesters. The harvested potatoes were then graded into US1A, US1B, and cull with a stationary potato grader.

Yield for the sweet corn and soybean are shown in Table 3. The yield of corn or soybean was not affected by subsoiling in either year. Sweet corn yield was significantly increased by K fertilization in 1998, but interestingly showed a reverse trend in 1999. Soybean appeared to be unaffected by K fertilization in this study.

Table 3. Effect of subsoiling and K fertilization on sweet corn and soybean yield, plant height, and tissue nutrient concentration at Hancock, Wis., 1998-1999.

Subsoil Treatment	K Treatment	Yield 1998	Yield 1999	Yield 1998	Yield 1999
		--------- T/a ---------		---------- bu/a ---------	
		Sweet Corn		Soybean	
None	Half	5.7	6.4	34	40
	Full	7.9	6.3	37	38
Spring	Half	6.1	6.5	37	38
	Full	7.7	6.2	37	37
Fall	Half	–	7.5	–	33
	Full	–	6.4	–	34
Pr>F					
Subsoil		0.78	0.32	0.73	0.41
K		0.01	0.13	0.73	0.83
S*K		0.35	0.48	0.50	0.92

The effect of subsoiling and K treatment on potato yield and grade-out is shown in Table 4. Total yield in 1998 was significantly affected by subsoiling such that yields were approximately 30 cwt/a higher where subsoiled. A similar response was observed in 1999, however differences were not statistically different. There was no effect on the grade-out of the potato crop by subsoiling. The potato yield was not influenced by K fertilization in 1998, but was significantly higher in 1999 where recommended K was applied. Grade-out was not affected by K fertilization in either year.

Ripon

A small plot study was established in the fall of 1997 in a farmer's field located near the city of Ripon. The cooperator was interested in refining his N rate, as well as examining subsoiling. Treatments were set up in a split plot design containing four replications. The main plot was subsoiling (none; subsoiling annually in the fall, subsoiled in the fall of 1997, and subsoiled in the fall of 1998). The subsoiler used is described in Table 1. The only additional tillage was a single pass with a rolling harrow just prior to planting. The subplot was sidedress N fertilization (none, 25 lb N/a, or 50 lb N/a). These rates were in addition to 90 lb N/a that was applied preplant by the farmer as anhydrous ammonia. Yield measurements were taken by hand harvesting.

Neither subsoiling or N fertilization had an effect on yield of the crop in either year (Table 5). These findings confirmed the farmer's beliefs regarding the benefits of subsoiling. He indicated that he would subsoil headlands and truck lanes that may have been compacted by harvesting operation, but would avoid subsoiling entire fields.

Table 4. Effect of subsoiling and K fertilization on potato yield and grade-out at Hancock, Wis., 1998-1999.

Subsoil Treatment	K Treatment	1998 Yield	1998 Grade-out US1A	1998 Grade-out US1B	1998 Grade-out Cull	1999 Yield	1999 Grade-out US1A	1999 Grade-out US1B	1999 Grade-out Cull
		cwt/a	-------------- %	--------------		cwt/a	-------------- %	-------------	
None	Half	341	72	15	12	379	51	11	38
	Full	348	67	17	16	420	53	10	37
Spring	Half	374	66	17	16	409	51	8	42
	Full	376	72	16	12	430	58	8	34
Fall	Half	–	–	–	–	407	50	10	40
	Full	–	–	–	–	429	50	10	40
Pr>F									
Subsoil		0.05	0.78	0.48	0.75	0.34	0.71	0.19	0.85
K		0.78	0.86	0.68	0.99	0.01	0.19	0.59	0.23
S*K		0.87	0.05	0.05	0.07	0.84	0.11	0.61	0.04

Table 5. Effect of subsoiling and N fertilization on sweet corn yield, at Ripon, Wis., 1998-1999.

Subsoil Treatment	N Treatment	1998 Yield	1999 Yield
	lb N/a	T/a	T/a
None	0	7.3	9.4
	25	7.7	9.7
	50	7.4	10.0
Annual	0	–	9.2
	25	–	8.8
	50	–	9.1
Subsoil-97	0	6.9	9.0
	25	7.3	9.0
	50	7.9	9.7
Subsoil-98	0	–	9.6
	25	–	9.5
	50	–	9.4
Pr>F			
Subsoil		0.78	0.26
N		0.27	0.43
S*N		0.29	0.77

Manitowoc County

Two separate studies were conducted on private farms in Manitowoc County in 1997-1999. Both evaluated subsoiling in a corn/soybean rotation. Studies at Site 1 were done using a small plot comparison, while Site 2 used field length strips. Subsoiling treatments used at Site 1 were none (zone-till planting), DMI Ecolo-tiger with 4" wings, and the Rawson Zone-builder which creates a slot with limited full width disturbance. The subsoiling treatments used at Site 2 were with and without the Zone-builder. Studies were placed on top of the same site each year.

Subsoiling significantly increased the yield of soybean in 1997 and corn in 1998 at Site 1 (Table 6). Yield of soybean at this site in 1999 was unaffected by treatment. The use of the Zone-builder appeared to be superior to the more aggressive subsoiler (DMI) at Site 1. The soybean yield at Site 2 was significantly reduced by subsoiling in 1998, however the difference was less than half a bu/a. Yields are usually not expressed by this researcher in fractional bushels, but in this case with the difference significant an exception was made. No advantage to subsoiling corn in 1999 was observed.

Table 6. Effect of subsoiling on corn and soybean yield at Manitowoc County, Wis., 1997-1999.

Subsoil Treatment	1997	1998	1999
	bu/a		
		Site 1	
No-till	30	213	57
DMI	40	188	58
Zone-Builder	51	226	59
Pr>F	0.01	0.01	0.75
$LSD_{(0.05)}$	7	15	N S
		Site 2	
None	--	57.9	218
Zone-Builder	--	57.5	220
Pr>F	--	0.03	0.28
$LSD_{(0.05)}$	--	0.3	NS

Columbus

This study consisted of the evaluation of the first year and residual effect of subsoiling conducted in the fall of 1996 on corn. This experiment was set up in field length strips containing four replications, with and without subsoiling. Yield was determined by harvesting each strip and measuring yield in a weigh wagon. No response to subsoiling was observed in 1997, and similarly no response was found in 1998 (Table 7).

Table 7. Response of corn to subsoiling, Columbus, Wis., 1997-1998.

Subsoiling	1997 Yield	1998 Yield
No	152	189
Yes	151	188
Pr>F	0.60	0.35

Subsoiled in the fall of 1996

References

Al-Adawi, S. S. and R. C. Reeder. 1996. Compaction and subsoiling effects on corn and soybean yields and soil physical properties. Trans. ASAE. 39:1641-1649.

Evans, S. D., Lindstrom, M. J., Voorhees, W. B., Moncrief, J. F., and G. A. Nelson. 1996. Effect of subsoiling and subsequent tillage on soil bulk density, soil moisture, and corn yield. Soil and Till. Res. 38:35-46.

Jones, A. J., Bashford, L. L., Grisso, R. D. 1996. Subsoiling in NebFact Bull. NF 96-258. Univ. of Nebraska-Lincoln.

Lammers-Helps, H. 1993. Soil compaction costs Ontario farmers. Http://sib.lrs.uoguelph.ca/d1\sccof\.

Soane, G. C., R. J. Godwin. M. J. Marks. And G. Spoor. 1987. Crop and soil response to subsoil loosening, deep incorporation of phosphorus and potassium fertilizer, and subsequent soil management on a range of soil types. Part 2. Soil structural conditions. Soil Use Manage. 3:123-130.

Wolkowski. R. P. 1989. Soil compaction and fertility interactions. Ph.D. Thesis. University of Wisconsin-Madison.

Wolkowski. R. P. and L. G. Bundy. 1996. Soil compaction and potassium fertility interactions on alfalfa production. Proc. of the Wis. Forage Council. pp. 93-100. UWEX.