HOLLOW AND SOLID TINE CULTIVATION EFFECTS ON SOIL STRUCTURE AND TURFGRASS ROOT GROWTH

A REPORT

Submitted to the
United States Golf Association

By

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1986

EXECUTIVE SUMMARY

HOLLOW AND SOLID TINE CULTIVATION EFFECTS ON SOIL STRUCTURE AND TURFGRASS ROOT GROWTH

Hollow and solid tine cultivation effects as influenced by soil compaction and moisture content during cultivation were evaluated on the basis of soil structural qualities and root growth. As expected compaction resulted in pronounced detrimental effects on soil structure and root growth. Both cultivation methods resulted in positive and negative effects on soil structure. Cultivation increased the amount of large soil pores with hollow tine coring being the most effective in producing this response. Regardless of compaction level, solid tine cultivation increased the amount of intermediate sized pores when compared to hollow tine cultivation. Therefore, hollow tine cultivation produced the most benefical changes in soil porosity. Soil strength within the zone of cultivation (surface 2-3 inches) was reduced after cultivation. Initially, solid tine cultivation was more effective in loosening the surface soil than hollow tine cultivation, however this effect was reversed by the end of this study. Water conductivity rate dropped dramatically after cultivation indicating compaction at the bottom of the cultivation zone restricted water flow. Compaction stress decreased root growth while cultivation had a limited effect on root growth. Cultivation decreased surface rooting in noncompacted soil but had no influence on rooting in compacted soil in November, 1985. Cultivation in noncompacted soil tended to increase rooting in June of 1986 but again had no effect on rooting in compacted soil. Throughout the study hollow tine cultivation ranked equal to or higher than soild tine cultivation in visual quality.

INTRODUCTION

Soil compaction is a common problem faced by turf managers. Soil compaction decreases soil porosity, particularly macroporosity, which can result in reduced soil water movement, aeration, and turfgrass shoot and root growth. Reductions in turfgrass growth result in lower functional qualtiy turf. Few alternatives are available for alleviating the problems associated with compacted soils because significant loosening of the soil cannot be accomplished without major disruption of the turf.

Core cultivation is the most extensively used practice to improve compacted soil conditions under turf. Recently, cultivation with solid tines has received attention as a possible practice to alleviate soil compaction. Solid tine cultivation eliminates soil core processing time and labor costs associated with hollow tine cultivation. However, little is known about the direct effects of solid tine cultivation on soil structural qualities and turfgrass root growth.

The objective of this investigation was to determine the effect of vertical operating hollow and solid tine coring on soil structural qualities and turgrass root growth as influenced by soil compaction and soil moisture at the time of cultivation. This report is a summary of the results found in this study. A more detailed description can be found in the thesis "HOLLOW AND SOLID TINE CULTIVATION EFFECTS ON SOIL STRUCTURE AND TURFGRASS ROOT GROWTH" by James Arthur Murphy, submitted to the USGA in September, 1986.

METHODS

A cultivation study was initiated in May, 1984 at the Michigan State University Robert Hancock Turfgrass Research Center on a 3 year old Penneagle creeping bentgrass turf maintained under greens conditions. The soil under this turf was a modified loamy sand.

A 2 x 2 x 2 factorially arranged randomized complete block design was utilized. One check at each compaction level was included for comparison to the average cultivation effect. Factors included compaction, tine type and soil moisture during cultivation operations. Compaction levels were noncompacted and compacted, performed with Ryan's Rollaire vibrating power roller. The two tine types were 1.3 cm diameter hollow and solid tines. Cultivation was performed at two soil moisture levels of 0.5 (moist) and 0.03 (wet) bar moisture potential.

Undisturbed soil cores were taken for laboratory analysis of bulk density, moisture retention, soil porosity, saturated hydraulic conductivity and oxygen diffusion (ODR) determinations in October 1984, 1985 and 1986.

A depth monitoring penetrometer was used throughout the study to determine soil strength changes with cultivation. Field infiltration rates were determined in August, 1986 using a constant head double ring infiltrometer technique.

Root sampling was performed in November, 1985 and June, 1986. Samples were washed, dried and weighed.

SOIL RESPONSES

As one might expect, compaction resulted in pronounced detrimental effects on soil structure (Tables 1 and 2). While cultivation yielded positive effects on some soil structural properties, some undesirable responses to cultivation were found as well.

By the fall of 1985, solid tine cultivation resulted in higher soil density and lower aeration porosity when compared to hollow tine cultivation (Table 1). Soil porosity measurements within various moisture potential ranges indicated cultivation increased the amount of very large pores drained between 0 and -0.01 bar in the soil (Table 1). Hollow tine cultivation was more effective than solid tine cultivation in producing this response. Along with the increase in large voids, cultivation in noncompacted soil reduced the amount of remaining macropores drained between -0.01 and -0.10 bar. Solid tine cultivation resulted in a greater amount of micropores drained between -0.10 and -1.00 bar compared to hollow tine cultivation regardless of soil compaction and moisture levels. Based on the earlier findings of Petrovic (1979) it is suggested that the increase in macroporosity occurs in the upper region of the cultivation zone, i.e. tine holes, while the decrease in remaining macroporosity in noncompacted soil and the increase in the amount of finer pores with solid tine usage resides at the lower end of the cultivation zone. The results of hydraulic conductivity and ODR measurements in this study support this conclusion.

Conductivity rates dropped 37.7% as a result of cultivation in noncompacted soil (Table 2). This effect was not as consistent in compacted soil and supports the idea of the compactive effect of cultivation having less influence in compacted soil.

Table 1. The influence of compaction, cultivation and soil moisture at the time of cultivation on bulk density, aeration porosity, and percent porosity drained between various moisture potentials in October, 1985.

Treatments	Bulk Density	Aeration Porosity	Moisture Potentials (-bar) 0 - .01	.01 - .10	.10 - 1.0	> 1.0
	g/cc	%	Percent Porosity			
Noncompacted (NC)						
Check (Ck)	1.74	15.5	2.6	12.9	4.9	14.0
Hollow Moist	1.72	15.7	4.4	11.4	4.8	14.7
Hollow Wet	1.71	15.4	4.1	11.3	4.8	15.0
Solid Moist	1.78	14.1	3.1	11.0	5.1	14.6
Solid Wet	1.76	15.0	3.4	11.5	4.8	14.9
Compacted (Cd)						
Check (Ck)	1.80	12.1	2.3	9.7	5.0	14.8
Hollow Moist	1.76	14.0	3.6	10.4	4.4	14.6
Hollow Wet	1.80	13.2	3.5	9.7	4.7	15.2
Solid Moist	1.81	11.9	2.9	9.0	4.9	15.1
Solid Wet	1.81	11.4	3.0	8.4	5.3	15.5
Comparisons	Mean Squares[a]					
Compaction (C)	19.76 **	50.96 **	1.41 **	34.99 **	0.00	1.08
Tine Type (T)	10.00 **	13.65 **	3.92 **	3.01	0.84 **	0.14
Moisture (M)	0.10	0.15	0.10	0.30	0.12	1.04
C x T	0.70	1.35	0.22	2.60	0.26	0.38
C x M	2.20	1.26	0.00	1.17	0.35	0.04
T x M	0.70	0.84	0.26	0.22	0.01	0.00
C x T x M	0.50	0.22	0.05	0.09	0.05	0.00
NC-Ck vs Cultivation	0.00	0.42	3.36 **	6.21 *	0.00	1.47
CD-Ck vs Cultivation	0.03	0.79	2.28 **	0.29	0.10	0.22
Error	7.92	1.52	0.16	1.36	0.10	0.45

a-Bulk Density mean squares are adjusted x 10^{-3}
** and * denote significance at 0.01 and 0.05, respectively.

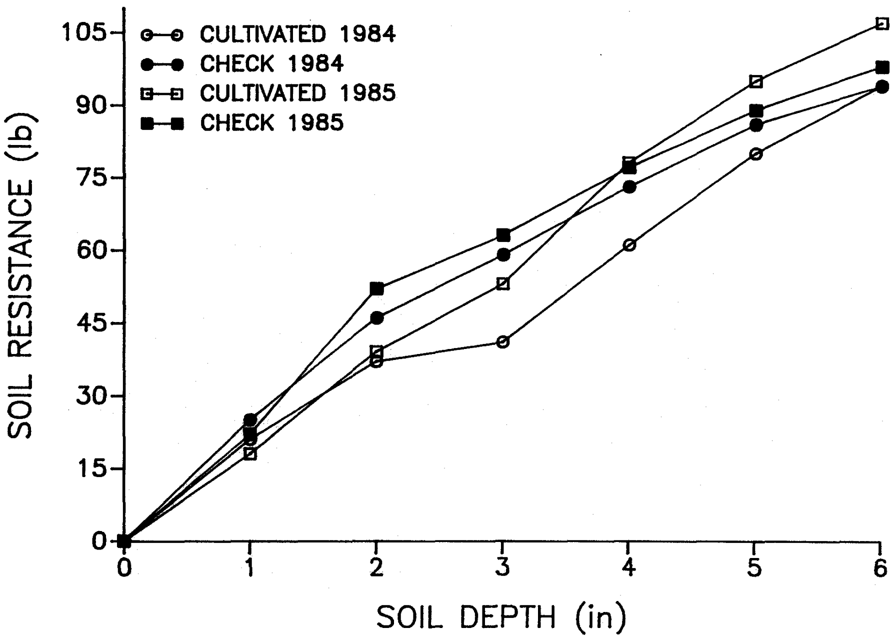
Table 2. The influence of compaction, cultivation and soil moisture at the time of cultivation on saturated hydraulic conductivity and field water infiltration in October, 1985 and August, 1986, respectively.

Treatments	Hydraulic Conductivity	Field Infiltration
	cm/hr	cm/hr
Noncompacted (NC)		
Check (Ck)	5.1	8.4
Hollow Moist	3.6	7.4
Hollow Wet	3.3	5.5
Solid Moist	2.9	8.8
Solid Wet	2.9	4.3
Compacted (Cd)		
Check (Ck)	3.0	4.5
Hollow Moist	2.1	4.9
Hollow Wet	1.9	2.3
Solid Moist	2.1	5.7
Solid Wet	1.1	2.9
Comparisons	**Mean Squares**	
Compaction (C)	16.73 **	60.21 **
Tine Type (T)	1.40	0.88
Moisture (M)	0.81	51.63 **
C x T	0.06	0.43
C x M	0.38	0.38
T x M	0.11	3.23
C x T x M	0.38	2.28
NC-Ck vs Cultivation	9.36 **	8.59
CD-Ck vs Cultivation	3.31 +	0.75
Error	0.99	5.30

** and + denote significance at 0.01 and 0.10, respectively.

Soil moisture content during cultivation influenced field water infiltration (Table 2). Coring under wet soil conditions reduced water infiltration 44.0% when compared to cultivation during moist soil conditions regardless of the type of tine utilized.

Cultivation with either tine resulted in loosening the soil. However, penetrometer data for 1985 suggest cultivation in noncompacted soil developed greater soil strength in the region below the cultivation zone when compared to 1984 data (Figure 1), a phenomena not found in compacted soil. Initially, solid tine cultivation was more effective in loosening the surface soil than hollow tine cultivation (Figure 2), however this effect was reversed by the end of the study (Figure 3).



Figrue 1. Comparison of check vs. cultivation in noncompacted soil for 1984 and 1985.

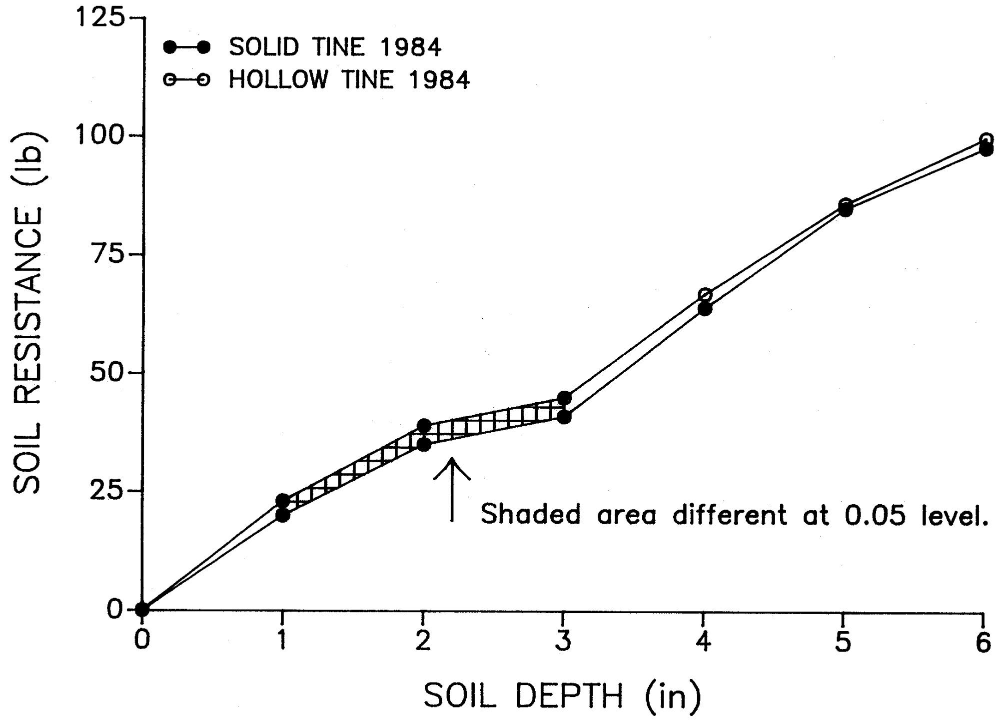


Figure 2. Tine effect on soil strength in 1984.

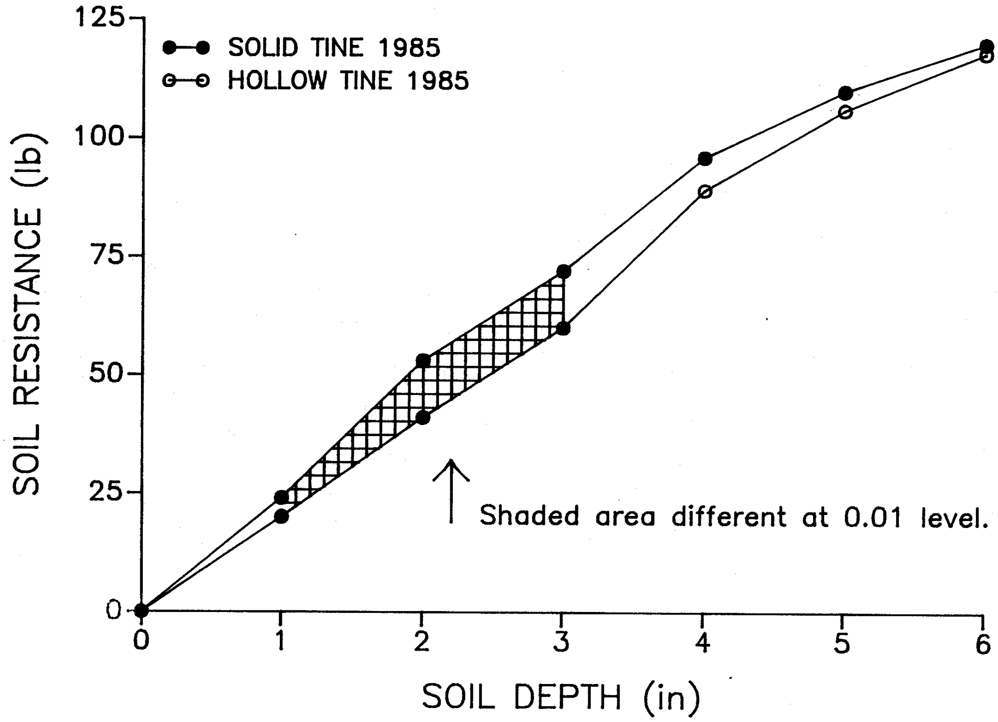


Figure 3. Tine effect on soil strength in 1985.

ROOT RESPONSES

Root sampling in November, 1985 and June, 1986 found total root weight declined 12.6 and 11.2%, respectively, with compaction stress (Table 3). Interestingly, sampling in the fall of 1985 demonstrated that total root weight declined with cultivation in noncompacted soil while cultivation in compacted soil had no effect on total root weight. Sampling in June, 1986 found a tendency for rooting to increase with cultivation in noncompacted soil. Cultivation in compacted soil resulted in no effect on total root weight.

Root density data show compaction influenced rooting at all depths, while cultivation effects on rooting were limited to the 0 to 7.5 cm depth zone. It should be noted that compaction effects on rooting could be attributed to soil compaction and/or wear. These two factors are difficult to separate when dealing with a traffic requiring treatment such as compaction.

Table 3. The influence of compaction, cultivation and soil moisture at the time of cultivation on total root growth and root density in November, 1985 and June, 1986.

Treatments	Total Root Weight (mg dm^{-2})		Root Density (mg dm^{-3}) 0 - 7.5 cm		7.5 - 15 cm		15 - 23 cm
	1985	1986	1985	1986	1985	1986	1986
Noncompacted (NC)							
Check (Ck)	8100	8370	930	890	130	170	50
Hollow Moist	6990	9860	810	1070	110	190	40
Hollow Wet	6610	9430	750	1030	120	180	30
Solid Moist	6600	9020	750	960	120	180	40
Solid Wet	7140	9070	800	990	140	160	40
Compacted (Cd)							
Check (Ck)	6240	8600	740	960	80	130	40
Hollow Moist	5890	8230	680	900	90	140	40
Hollow Wet	6940	7900	800	880	110	140	20
Solid Moist	5550	8030	630	890	100	140	20
Solid Wet	6340	7860	740	890	100	120	30
Comparisons	x(10^5)		(x10^3)		(x10^3)		
Compaction (C)	60.43 **	79.10 **	61.02 *	50.43 *	5.28 **	14.08 **	853 **
Tine Type (T)	2.37	7.67	5.05	6.67	0.05	0.94	4
Moisture (M)	15.05	2.93	18.70	0.60	0.58	0.70	38
C x T	4.38	3.43	3.95	8.82	0.58	0.00	104
C x M	10.64	0.05	18.93	0.02	0.01	0.00	4
T x M	1.64	1.62	3.75	2.82	0.07	0.20	338
C x T x M	5.11	0.38	5.89	0.60	0.28	0.04	38
NC-Ck vs Cultivation	38.24 *	23.05 +	57.66 *	33.14 +	0.30	0.24	135
CD-Ck vs Cultivation	0.10	8.61	1.29	12.62	0.52	0.08	167
Error	6.93	6.52	11.26	10.01	0.17	0.66	90

**, * and + denote significance at .01, .05 and .10, respectively.

VISUAL QUALITY

Visual quality for June and July 1985 show a lower quality existed on noncompacted plots (Table 4). Reduced quality on noncompacted turf was due to mower scalp, whereas, compacted plots resisted scalp because of the compressed nature of the thatch resulting from compaction treatment. However, by August compaction resulted in reduced quality.

Compaction again resulted in higher quality plots in 1986 until August when quality declined with compaction (Table 5). However, improved quality with compaction was a result of earlier green-up on compacted plots in the spring of 1986. Throughout the study hollow tine cultivation ranked equal to or higher than solid tine cultivation in visual quality. It should be noted that although hollow tine coring ranked higher than solid tine coring in its effect on visual quality solid tine coring did provide some improvement compared to the uncultivated treatment.

Cultivation in general resulted in earlier green-up when compared to noncultivated plots in the spring of 1986. Cultivation also yielded improved quality under compaction as compaction stress increased during the 1986 season. By the fall this response to cultivation diminished when compaction treatments were stopped.

Soil moisture content during cultivation influenced quality at the end of the 1986 season (Table 5). Cultivation under wet soil conditions resulted higher quality turf when compared the moist cultivation treatments. Moist soil conditions resulted in rather dry surface conditions which could have stressed the turf resulting in injury to the turf during cultivation.

Table 4. The influence of compaction, cultivation and soil moisture at the time of cultivation on visual quality during 1985.

Treatments	Date of Evaluation 6/4	6/24	7/19	8/14
Noncompacted (NC)		visual quality (9=ideal 1=dead)		
Check (Ck)	6.0	6.0	6.3	6.8
Hollow Moist	6.0	7.0	7.0	7.5
Hollow Wet	6.0	6.3	6.7	7.0
Solid Moist	6.0	6.3	5.7	6.5
Solid Wet	5.7	6.3	5.7	6.8
Compacted (Cd)				
Check (Ck)	8.0	7.3	8.3	5.5
Hollow Moist	8.0	7.3	7.7	5.7
Hollow Wet	8.0	7.7	8.3	5.7
Solid Moist	7.7	6.7	7.0	5.3
Solid Wet	7.7	7.2	7.3	6.2
Comparisons		Mean Squares		
Compaction (C)	28.03 **	5.21 **	16.13 **	12.03 **
Tine Type (T)	0.38	1.26 *	6.00 **	0.38
Moisture (M)	0.04	0.01	0.17	0.17
C x T	0.04	0.09	0.17	0.67
C x M	0.04	0.84 *	0.67	0.38
T x M	0.04	0.26	0.00	1.04
C x T x M	0.04	0.09	0.17	0.00
NC-Ck vs Cultivation	0.02	0.60	0.02	0.04
CD-Ck vs Cultivation	0.07	0.04	1.35	0.10
Error	0.37	0.18	0.45	0.36

** and * denote significance at .01 and .05, respectively.

Table 5. The influence of compaction, cultivation and soil moisture at the time of cultivation on visual quality during 1986.

Treatments	Date of Evaluation 4/8	5/10	7/8	8/7	8/30	9/17	10/14
			visual quality (9=ideal 1=dead)				
Noncompacted (NC)							
Check (Ck)	5.5	5.3	5.0	8.0	6.7	8.3	7.7
Hollow Moist	6.8	7.0	6.0	8.7	8.0	8.0	7.3
Hollow Wet	6.8	7.0	5.8	9.0	8.7	9.0	7.3
Solid Moist	6.2	6.3	5.3	8.0	7.0	7.7	7.3
Solid Wet	5.8	6.0	5.0	8.3	7.3	8.0	7.3
Compacted (C)							
Check (Ck)	6.0	6.3	6.7	4.7	5.5	7.3	5.0
Hollow Moist	7.0	7.7	7.5	6.0	7.0	7.0	5.7
Hollow Wet	7.5	7.8	7.7	6.0	6.7	8.3	6.0
Solid Moist	7.0	7.3	6.0	6.0	5.0	7.0	5.0
Solid Wet	6.8	7.7	6.3	5.3	6.3	6.7	6.0
Comparisons				Mean Squares			
Compaction (C)	3.01 **	8.01 **	14.70 **	58.80 **	15.41 **	6.53 **	30.00 **
Tine Type (T)	2.04 **	1.76	7.04 **	1.50 *	8.17 **	3.38 **	0.00
Moisture (M)	0.00	0.01	0.00	0.00	1.50 *	2.04 *	1.50
C x T	0.38 *	0.51	0.67	0.17	0.00	0.04	0.67
C x M	0.17	0.26	0.37	0.67	0.00	0.04	0.17
T x M	0.38 *	0.01	0.00	0.17	0.67 +	2.04 *	0.67
C x T x M	0.04	0.09	0.04	0.17	1.50 *	0.38 *	0.00
NC-Ck vs Cultivation	2.02 **	3.75 **	0.70	0.60	2.82 **	0.07	0.07
CD-Ck vs Cultivation	2.82 **	4.00 **	0.10	3.27 **	1.35 **	0.02	1.07
Error	0.05	0.15	0.16	0.34	0.19	0.32	0.39

**, * and + denote significance at .01, .05 and .10, respectively.

CONCLUSIONS

Based on the bulk density, soil porosity, soil strength and visual quality responses to solid tine cultivation this practice cannot be considered as effective as hollow tine cultivation in relieving the detrimental effects of compaction stress. However, solid tine cultivation can decrease surface soil strength, increase the amount of large pores within the zone of cultivation and improve visual quality. With this in mind, solid tine cultivation could be seen as an effective tool for short term relief of surface compaction when demands on time and labor resources are high. It is cautioned that the long term effects of solid tine use on a frequent basis is still to be determined.

It is evident that both compaction and cultivation effects have continued to develop throughout the course of this study. Interpretation of these results should take into account that the responses found in this short term study may be enhanced with long term treatment on a finer textured soil. The potential for development of a subsurface hardpan caused by core cultivation will most likely require several years to develop adverse effects, particularly on sandy soils. Since this study utilized a loamy sand soil it could be speculated that cultivation effects may be more pronounced on finer textured soils where soil compaction effects should be more severe. However, the beneficial effects of coring within the zone of cultivation outweigh any concerns for subsurface pan development in a severely compacted soil.