COMPARING HOLLOW AND SOLID TINE CULTIVATION

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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 accomoplished 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 turfgrass root growth as influenced by soil compaction and soil moisture at the time of cultivation.

Financial support for this research, from the United States Golf Association and the Michigan Turfgrass Foundation, is gratefully acknowledged.

METHODS

A cultivation study was initiated in May, 1984 at 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 3 factor experiment was utilized to examine the effects of compaction, tine type and soil moisture content during cultivation operations. One check at each compaction level was included for comparison to the average cultivation effect. Compaction levels were noncompacted and compacted, performed with Ryan's Rollaire vibrating power roller. The two tine types were 1/2 inch 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.

A depth monitoring penetrometer was used at the end of each season to determine soil strength changes due to cultivation. Field infiltration rates were determined in September, 1984 using a constant head double ring infiltrometer technique.

RESULTS

As expected, compaction increased soil density while cultivation lowered soil density. However, compaction and cultivation had little influence on aeration porosity. Aeration porosity refers to the larger soil pores which allow for the mass flow of water and air and unrestricted growth of roots through the soil. Although aeration porosity was not significantly altered total porosity was reduced under compaction stress while cultivation increased total porosity by 3.7% over the uncultivated treatment. Total porosity was divided into 4 pore size ranges as measured by the percentage of pores drained between various moisture potentials. As soil moisture potentials become more negative the average soil pore size is smaller. This allows for measuring the distribution and amount of various pore size ranges. Soil porosity measurements indicated that hollow tine coring was slightly more effective than solid tine cultivation in increasing the amount of very large soil pores drained between 0 and -0.01 bar (Table 1). Cultivation in general resulted in greater amounts of intermediate sized pores (-0.1 to -1.0 bar range) when compared to the uncultivated treatment. The amount of very fine pores drained between -1.0 bar and oven dry was increased by solid tine cultivation during wet soil conditions. An increase in the amount of intermediate sized and very fine pores would suggest that cultivation is creating very large pores (tine holes) at the expense of compressing other pores in the soil to a smaller size.

Based on the work of Petrovic (1979) it is likely the increase in the amount of finer pores with coring resides at the bottom of the cultivation zone. The results of ODR measurements in this study support his conclusion. Oxygen diffusion rate at -0.03 bar moisture potential was reduced at the 2 inch depth after cultivation when compared to the uncultivated treatment.

Soil moisture content during cultivation influenced field water infiltration rate. Cultivation performed during wet soil conditions reduced water infiltration 38% when compared to cultivation during drier (moist) soil conditions (Table 2), regardless of the type of tine used.

Compaction increased soil strength while cultivation with either tine loosened the surface 2-3 inches of 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. This suggests that development of a cultivation pan may be less of a concern in compacted soil. In 1984, 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 1985 seaon (Figure 3).

Table 2. The influence of compaction, cultivation and soil moisture at the time of cultivation on field water infiltration rate and oxygen diffusion rate at -0.02, -0.03 and -0.04 bar in September and October, 1984, respectively.

Treatments	Field Infiltration	Moisture Potentials (bar)		
		-0.02	-0.03	-0.04
	in/hr	gm x $10^{-8}/cm^2/min$		
Noncompacted (NC)				
Check (Ck)	7.6	8.8	42.9	75.8
Compacted (Cd)				
Check (Ck)	5.8	4.5	47.5	83.1
Hollow Moist	5.8	3.2	30.6	80.2
Hollow Wet	4.6	3.6	32.5	77.9
Solid Moist	6.4	4.4	36.3	83.4
Solid Wet	3.0	3.5	23.0	73.9
Comparisons	Mean Squares			
CD Ck vs NC Ck	0.60	27.74	29.5	80.7+
Tine Type (T)	0.08	0.85	11.2	0.3
Moisture (M)	2.16 *	0.27	98.6	104.4
T x M	0.56	1.33	171.8	38.9
CD-Ck vs Cultivation	0.38	1.73	670.7 **	43.4
Error	0.39	9.15	67.4	61.8

**, * and + denote significance at 0.01, 0.05 and 0.10, respectively.

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 and total porosity in October, 1984.

Treatments	Bulk Density	Aeration Porosity	Moisture Potentials (-bar)				Total Porosity
			0 - .01	.01 - .10	.10 - 1.0	> 1.0	
	g/cc	%	Percent Porosity				
Noncompacted (NC)							
Check (Ck)	1.74	13.9	3.2	10.7	5.0	14.5	33.4
Compacted (Cd)							
Check (Ck)	1.78	12.5	2.9	9.6	4.8	14.8	32.1
Hollow Moist	1.74	12.6	3.4	9.2	6.2	15.3	34.1
Hollow Wet	1.74	12.7	3.2	9.5	5.7	14.9	33.3
Solid Moist	1.76	12.3	2.8	9.5	6.2	14.4	32.9
Solid Wet	1.75	10.3	2.7	7.7	6.6	16.2	33.1
Comparisons	Mean Squares[a]						
CD Ck vs NC Ck	24.00 *	2.94	0.135	1.93	0.04	0.14	2.54 +
Tine Type (T)	8.33	5.20	0.963 +	1.76	0.80	0.07	1.33
Moisture (M)	0.00	2.52	0.083	1.76	0.01	1.54	0.21
T x M	1.33	3.31	0.013	3.63	0.61	3.52 *	0.75
CD-Ck vs Cultivation	24.07 *	0.66	0.043	1.01	4.32 *	0.37	3.55 *
Error	4.46	2.06	0.211	2.41	0.58	0.63	0.59

a-Bulk Density mean squares are adjusted x 10^{-4}

* and + denote significance at 0.05 and 0.10, respectively.

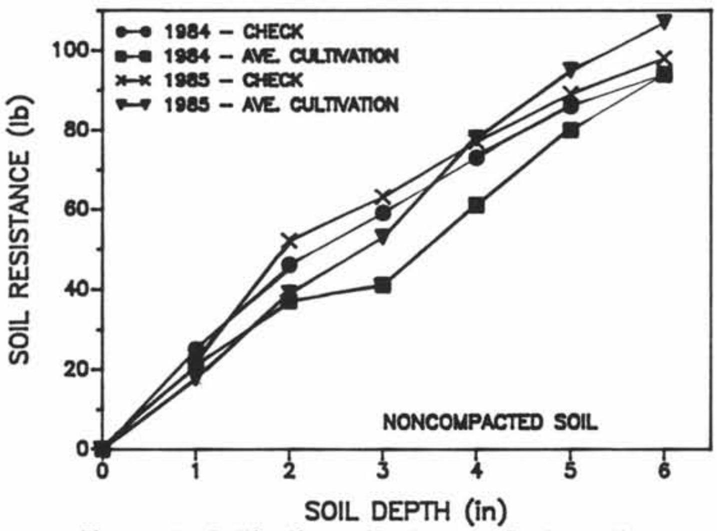

Figure 1. Cultivation effect on soil strength.

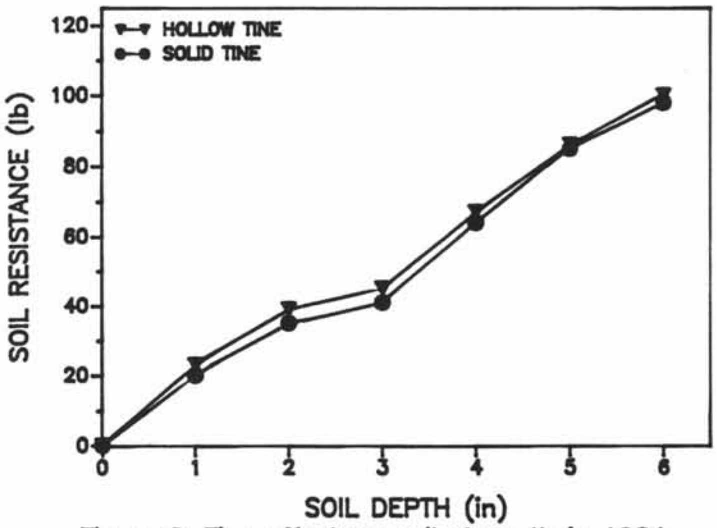

Figure 2. Tine effect on soil strength in 1984.

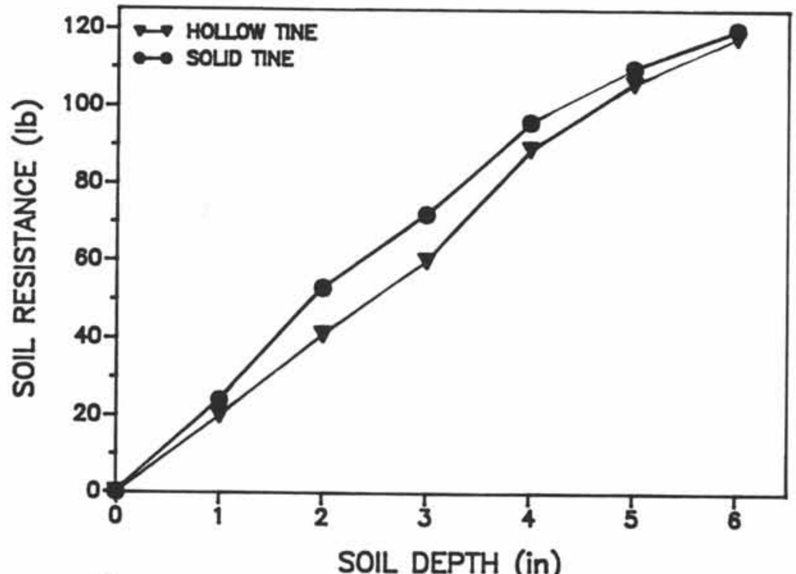

Figure 3. Tine effect on soil strength in 1985.

CONCLUSIONS

Solid and hollow tine cultivation have had small but consistent effects on soil density and soil porosity. Cultivation improved soil density by slightly increasing total porosity. However, cultivation, which creates large voids (tine holes), also increased the amount of finer soil pores. Cultivation can be seen as creating large voids in the soil at the expense of crushing other pores and therefore increasing the amount of finer pores. Reducing pore size can lower air and water movement within the soil and inhibit root growth. Earlier research has shown this compactive effect of cultivation occurs mainly at the bottom of the tine hole. Obviously, if hardpan formation is to occur it will require several years of treatment. The immediate benefit of loosening the soil surface with cultivation outweighs any immediate concerns about cultivation pan formation in a severely compacted soil. To inhibit the formation of a compacted layer below the cultivation zone aerification should be performed under "dry" soil conditions and the depth of tine penetration varied, if possible. 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 cultivation on a frequent basis are still to be determined.

LITERATURE CITED

Petrovic, A. M. 1979. The effects of vertical operating hollow tine (VOHT) cultivation on turfgrass soil structure. Ph.D. Dissertation. Michigan State University. 86pp.