DEVELOPMENT OF CULTIVATION PROGRAMS ON TURFGRASS TO REDUCE WATER USE AND IMPROVE TURF QUALITY

UNIVERSITY OF GEORGIA
Griffin, GA

Dr. Robert N. Carrow
Principal Investigator

1990 Research Grant: $18,000
(second year of support)

Adverse soil physical conditions interfere with turfgrass management by limiting water movement, reducing soil aeration, and decreasing root/shoot growth. Compaction of the soil surface and excessively fine-textured (i.e. high in clay and silt content) soil profiles are two of the most common adverse soil physical properties. Cultivation is a primary means of alleviating these problems; however, comparative research studies to evaluate different techniques have not been conducted.

Five cultivation techniques were compared for their effectiveness in improving soil physical properties and growth of common bermudagrass (Cynodon dactylon). The site was a Cecil clay loam, typical of the Piedmont region of the southeast. A non-compacted control and compacted control were included and all cultivation techniques were evaluated under compacted conditions. Severe compaction was applied with a smooth power roller on 5 April, 9 May, and 21 July 1989 and 6 March and 19 July 1990. The cultivation treatments were hollow tine core aeration (3 inch depth of penetration), Verti-drain (12 in.), Verti-slicer (4.5 in.), Aera-vator (3 in.), and Hydro-Jet (6-8 in.). Cultivation treatments were applied 24 May and 27 July 1989 and 13 April and 3 August 1990.

Soil Physical Properties. Within the surface 3 inches, only hollow time core aeration significantly reduced soil bulk density and increased total porosity relative to the compacted control. Soil strength, a measure of soil hardness, was determined in March, May and August 1990. Verti-drain application reduced soil strength by 23% to a depth of 8 inches in March and May measurements and 27% in August at the 4 inch depth. The Aera-vator treatment resulted in a 27% decline in soil strength in the May period to a depth of 2 inches. Hydraulic conductivity, a measure of water infiltration, increased 7.5 fold in May 1990 after Verti-drain treatment and 4.5 fold in August 1990 after Aera-vator application. Oxygen diffusion measurements were made ar four period in 1989 and 1990. No cultivation treatment improved oxygen diffusion over the compacted control.

Root and Water Relations. Root weights and root length density data were obtained in 29 June and 9 September 1989 and 18 July and 18 September 1990. Only the 1989 data are available. No root responses to treatment were observed in June 1989. On the September 1989 sample date, root weights in the 12 to 24 inch zone were decreased by Aera-vator and Verti-slice procedures, while root length densities increased 79% by Verti-drain treatment in the 12-24 inch zone relative to the compacted control. Water extraction data obtained during eight periods over 1989 and 1990 revealed higher water extraction than the compacted control on two dates for the Verti-slicer and one date for all other cultivation methods.

Shoot Growth. Turfgrass quality declined for 1-2 weeks after cultivation for all procedures except the Hydro-Jet in 1989. Some loss of shoot density occurred in August 1989 after Verti-slicer and hollow tine core aeration. In May 1990 improved visual quality and shoot density were apparent for Verti-drain and hollow tine core aeration plots. Also, Aera-vator application increased visual quality. Higher visual quality versus the compacted control was observed in June and October for the Verti-drain and Hydro-Jet treatments, respectively. At 1 week after cultivation in early August, some decline in shoot density occurred in the Aera-vator, Verti-slicer, and hollow tine coring plots.

Summary. A summary of results is:

(a) Verti-drain reduced soil strength to a depth of 8 inches and improved infiltration. These effects on soil physical properties enhanced deep rooting in late summer.

(b) Aera-vator reduced soil strength in the 2-4 inch soil zone on one date and enhanced infiltration. These improvements in the physical properties of the surface few inches did not result in better rooting since deep root growth in late summer was less than the control.

(c) Hollow tine core aeration improved soil surface conditions as shown by low bulk density and higher aeration porosity; however, rooting was not affected.

(d) Verti-slicer and Hydro-Jet treatments did not influence measured soil physical properties nor rooting.

(e) Improved soil water extraction during dry-down periods was observed 1 out of 8 times for all procedures (2 out of 8 for the Verti-slicer).

(f) All methods except the Hydro-Jet caused some decline in visual quality and/or shoot density within a week of treatment on at least one occasion. The Verti-slicer and hollow tine core aeration exhibited this trend most often (i.e. 5 out of 4 treatments).

(g) All cultivation procedures resulted in some improvement in visual quality and/or shoot density during some period of the study, except the Verti-slicer treatment.

Future Direction. The results from this study and a previous one (funded by the USGA to evaluate 5 other procedures) will be used to formulate several cultivation programs. Cultivation programs will include 2-3 different procedures applied at appropriate times of year. New procedures may also be included. This phase will be conducted in 1991 and 1992.

November 1990

Annual Progress Report

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The objectives of this project were (a) to evaluate different cultivation techniques for their relative effectiveness in alleviating soil compaction, improving water use efficiency, and improving shoot/root growth, and (b) to develop "cultivation" programs for fairway/tee conditions based on using two or more different cultivation techniques.

The first phase (1989-1990) of this project focused on objective (a); however, new cultivation techniques will still be evaluated over the last two years (1991-1992). The primary focus in 1991 through 1992 will be to evaluate cultivation programs (i.e., objective b).

In 1989-1990, five different cultivation methods were evaluated (Table 1). The study is now complete except for 1990 rooting and one set of soil physical property evaluations. The data already analyzed are attached in Tables 2-18. A research paper will be prepared in 1991 based on this data. Also, another research paper will be developed based on the 1986-1988 study funded by the USGA to evaluate five (deep-drill aerofier, Aerway slicer, solid tine coring, hollow tine coring, and slicer unit) cultivation methods. Using the information from these two studies, various cultivation programs will be formulated for objective (b).

A summary of results to date is:

Adverse soil physical conditions interfere with turfgrass management by limiting water movement, reducing soil aeration, and decreasing root/shoot growth. Compaction of the soil surface and excessively fine-textured (i.e. high in clay and silt content) soil profiles are two of the most common adverse soil physical properties. Cultivation is a primary means of alleviating these problems; however, comparative research studies to evaluate different techniques have not been conducted.

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Soil Physical Properties (Tables 2-9). Within the surface 3 inches, only hollow time core aeration significantly reduced soil bulk density and increased total porosity relative to the compacted control. Soil strength, a measure of soil hardness, was determined in March, May and August 1990. Verti-drain application reduced soil strength by 23% to a depth of 8 inches in March and May measurements and 27% in August at the 4 inch depth. The Aera-vator treatment resulted in a 27% decline in soil strength in the May period to a depth of 2 inches. Hydraulic conductivity, a measure of water infiltration, increased 7.5 fold in May 1990 after Verti-drain treatment and 4.5 fold in August 1990 after Aera-vator application. Oxygen diffusion measurements were made ar four period in 1989 and 1990. No cultivation treatment improved oxygen diffusion over the compacted control.

Root and Water Relations (Tables 10-13). Root weights and root length density data were obtained in 29 June and 9 September 1989 and 18 July and 18 September 1990. Only the 1989 data are available. No root responses to treatment were observed in June 1989. On the September 1989 sample date, root weights in the 12 to 24 inch zone were decreased by Aera-vator and Verti-slice procedures, while root length densities increased 79% by Verti-drain treatment in the 12-24 inch zone relative to the compacted control. Water extraction data obtained during eight periods over 1989 and 1990 revealed higher water extraction than the compacted control on two dates for the Verti-slicer and one date for all other cultivation methods.

Shoot Growth (Tables 14-18). Turfgrass quality declined for 1-2 weeks after cultivation for all procedures except the Hydro-Jet in 1989. Some loss of shoot density occurred in August 1989 after Verti-slicer and hollow tine core aeration. In May 1990 improved visual quality and shoot density were apparent for Verti-drain and hollow tine core aeration plots. Also, Aera-vator application increased visual quality. Higher visual quality versus the compacted control was observed in June and October for the Verti-drain and Hydro-Jet treatments, respectively. At 1 week after cultivation in early August, some decline in shoot density occurred in the Aera-vator, Verti-slicer, and hollow tine coring plots.

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(g) All cultivation procedures resulted in some improvement in visual quality and/or shoot density during some period of the study, except the Verti-slicer treatment.

Educational Efforts

Educational activities that I was involved in that included data from this project or the previous (1986-1988) project were as follows. In each instance the USGA was credited for their support.

Publications

1. Wiecko, Greg. 1990. Effects of cultivation and wetting agents on turfgrass growth and on alleviation of soil compaction. Ph.D. thesis. University of Georgia.

2. Carrow, R. N. 1990. Developing turfgrass cultivation programs. Golf Course Management Vol. 58(8):14-22.

Presentations

1. Deep Tine Aerification. Inter. Golf Course Super. Assn. Amer. Meeting. Orlando, FL. Feb. 20-24, 1990. 1800 attendance.

2. Cultivation/Topdressing Seminar. Presented by P. Rieke and R. Carrow. Inter. Golf Course Super. Assn. Amer. Meeting. Orlando, FL. Feb. 20-24, 1990. 800 attendance.

3. Developing Cultivation Programs for Golf Courses. Univ. of Mass. Turf Conf. and Show. Springfield, MA. March 14-16, 1990. 1800 attendance.

Personnel

In additions to technicians involved in this project, this project has provided partial support to:

1. Greg Wiecko. Ph.D. assistantship
2. Dr. Sang Ryul Shim. Visiting scientist from South Korea who has been working on this project from Feb. 1990 - Feb. 1991.

Table 1. Treatment descriptions.

Treatment[z]			Cultivation Pattern			
Technique	Compaction	Type	Depth	Spacing	Size	Source
			- - - - - inch - - - - -			
Control	No	---	---	---	---	---
Control	Yes	---	---	---	---	---
Verti-drain	Yes	solid tine	12	5-6	0.50 dia	Redexium BV
Aera-vator[y]	Yes	solid tine	3	2x3	0.50 dia	First Prod.
Verti-slice	Yes	slice	4.5	4	0.25 width	Ransomes
Coring[x]	Yes	hollow tine	3	2	0.63 dia	Ryan
Hydro-Jet	Yes	water pressure	6-8	3	0.13 dia	Toro

[x]Cores were broken up and dragnetted into the sod.

[y]The solid tine has a burrowing and rotary pattern in the soil.

[z]Cultivation applied in 1989 on 24 May and 27 July and in 1990 on 13 April and 3 August.

Table 2. Bulk density, total pore space, and porosity at -10kPa from samples obtained 24 May 1990.

Treatment[z]		Bulk Density	Total Pore Space	Pore Space at -10kPa
Technique	Compaction	24 May	24 May	24 May
		---gm cm^{-3}--	----------%----------	
Control	No	1.39a[y]	37.7b	7.70a
Control	Yes	1.39a	37.2b	7.22a
Verti-drain	Yes	1.35ab	38.9ab	8.48a
Aera-vator	Yes	1.32ab	39.3ab	7.39a
Verti-slicer	Yes	1.34ab	39.5ab	8.24a
Hollow-tine coring	Yes	1.29b	42.6a	9.23a
Hydro Jet	Yes	1.34ab	39.7ab	7.81a
Treatment PR>F =		.28	.38	.53
CV(%) =		4.8	8	18

[y]LSD (.05) treatment separation is unprotected by significant F-test.

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 3. Hydraulic conductivity data in 1990.

Treatment[z]		Hydraulic Conductivity	
Technique	Compaction	14 May 90	28 Aug 90
		- - - - mm H_2O hr^{-1} - - - -	
Control	No	21.8ab	37.3b
Control	Yes	3.9c	36.6b
Verti-drain	Yes	29.3a	23.2b
Aera-vator	Yes	15.7abc	164.3a
Verti-slice	Yes	11.1bc	28.0b
Hollow-tine coring	Yes	8.6bc	35.5b
Hydro-Jet	Yes	8.2bc	25.0b
Treatment PR>F =		.072	.0001
CV (%) =		82	45

[z]Cultivation treatments applied 24 May and 27 July 1989.

Table 4. Oxygen diffusion rate data taken on 30 June 1989 and 28 March 1990.

Treatment[z]		Oxygen Diffusion Rate[y]				
		30 Jun 89		28 Mar 90		
Technique	Compaction	2 hr	7 hr	1 hr	4 hr	7 hr
		- - - - - - - - - - $\mu g\ O_2\ cm^{-2}\ m^{-1}$ - - - - - - - - - -				
Control	No	.08	.12	.07ab	.12	.11
Control	Yes	.07	.11	.09a	.07	.10
Verti-drain	Yes	.08	.10	.03b	.08	.12
Aera-vator	Yes	.07	.08	.04b	.10	.12
Verti-slicer	Yes	.06	.07	.06ab	.08	.10
Hollow-tine coring	Yes	.07	.08	.08ab	.10	.14
Hydro-Jet	Yes	.07	.07	.05ab	.11	.14
Treatment PR> F =		.39	.40	.15	.49	.72
CV (%)		21	41	53	40	35

[y]Hours are hours after soil saturation when ODR readings were obtained.

[z]Cultivation treatments applied 24 May and 27 July 1989 and 13 April and 3 August 1990.

Table 5. Oxygen diffusion rate data taken on 7 to 8 May 1990.

Treatment[z]		Oxygen Diffusion Rate[y] (7-8 May 1990)				
Technique	Compaction	1 hr	3 hr	5 hr	24 hr	30 hr
		- - - - - - - - - - - $\mu g\ O_2\ cm^{-2}\ m^{-1}$ - - - - - - - - - - -				
Control	No	.14	.12	.15	.23	.25
Control	Yes	.06	.07	.08	.10	.45
Verti-drain	Yes	.06	.06	.08	.11	.17
Aera-vator	Yes	.07	.06	.07	.09	.21
Verti-slicer	Yes	.14	.13	.18	.19	.35
Hollow-tine coring	Yes	.15	.10	.17	.19	.29
Hydro-Jet	Yes	.12	.17	.14	.17	.22
Treatment PR> F =		.60	.53	.56	.44	.73
CV (%)		84	87	84	65	88

[y]Hours are hours after soil saturation when ODR readings were obtained.

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 6. Oxygen diffusion rate data taken on 10 August and 25 to 26 October 1990.

Treatment[z]		Oxygen Diffusion Rate[y]					
		10 Aug 90			25-26 Oct 90		
Technique	Compaction	1 hr	3 hr	7 hr	1 hr	2 hr	21 hr
		- - - - - - - - - $\mu g\ O_2\ cm^{-2}\ min^{-1}$ - - - - - - - - -					
Control	No	.34a	.20bc	.25	.14	.14	.19
Control	Yes	.20bc	.30a	.34	.11	.11	.27
Verti-drain	Yes	.13c	.15c	.19	.10	.14	.29
Aera-vator	Yes	.18bc	.20bc	.20	.14	.12	.26
Verti-slicer	Yes	.25ab	.27ab	.33	.10	.12	.28
Hollow-tine coring	Yes	.21bc	.14c	.20	.10	.11	.26
Hydro-Jet	Yes	.20bc	.14c	.25	.14	.16	.33
Treatment PR> F =		.026	.002	.19	.61	.67	.31
CV (%) =		33	26	39	37	33	28

[y]Hours are hours after soil saturation when ODR readings were obtained.

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 7. Penetration resistance by soil depth from the 21 March 1990 sample date.

Treatment[z]		Penetration Resistance				
Technique	Compaction	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm
		- - - - - - - - - - - - N cm^{-2} - - - - - - - - - - - -				
Control	No	201ab	236a	195a	218a	214
Control	Yes	207a	227a	190a	207ab	206
Verti-drain	Yes	161b	178b	148b	164b	162
Aera-vator	Yes	198ab	229a	201c	223a	202
Verti-slicer	Yes	180ab	220ab	185ab	201ab	199
Hollow-tine coring	Yes	214a	240a	213a	243a	206
Hyrdo-Jet	Yes	212a	258a	186a	224a	194
Treatment PR> F =		.19	.06	.10	.04	.59
CV (%) =		15	14	15	14	19

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 8. Penetration resistance by soil depth from the 3 May 1990 sample date.

Treatment[z]		Penetration Resistance				
Technique	Compaction	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm
		- - - - - - - - - - - - - N cm^{-2} - - - - - - - - - - - - -				
Control	No	201cb	210ab	249ab	219bc	237b
Control	Yes	244a	220a	251a	254ab	288ab
Verti-drain	Yes	180c	185b	194b	182c	246b
Aera-vator	Yes	179c	220a	225ab	256ab	293ab
Verti-slicer	Yes	209abc	205ab	224ab	220bc	247b
Hollow-tine coring	Yes	216abc	233a	268a	268a	288ab
Hydro-Jet	Yes	220ab	217ab	259a	279a	313a
Treatment PR> F =		.03	.15	.14	.0007	.10
CV (%) =		13	10	16	11	15

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 9. Penetration resistance by soil depth from the 30 August 1990 sample date.

Treatment[z]		Penetration Resistance				
Technique	Compaction	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm
		- - - - - - - - - - - - - - - - N cm^{-2} - - - - - - - - - - - - - - - -				
Control	No	237	227a	234	231	257
Control	Yes	240	234a	230	234	234
Verti-drain	Yes	183	170b	204	224	249
Aera-vator	Yes	199	229a	230	247	278
Verti-slicer	Yes	220	235a	224	213	255
Hollow-tine coring	Yes	196	225a	228	219	258
Hydro-Jet	Yes	214	230a	225	211	234
Treatment PR> F =		.41	.15	.95	.84	.86
CV (%) =		19	15	18	17	19

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 10. Root weight and root length density data from the 29 June 1989 sample date by soil depth.

Treatment[z]		Root Weight			Root Length Density	
Technique	Compaction	0-30 cm	30-60 cm	0-60 cm	0-30 cm	30-60 cm
		- - - - - mg cm^{-2} - - - - -			- - - - - cm cm^{-3} - - - - -	
Control	No	6.62	1.73	8.35	.372	.078
Control	Yes	5.70	1.61	7.31	.319	.077
Verti-drain	Yes	5.19	1.85	7.03	.332	.067
Aera-vator	Yes	9.75	1.59	11.34	.511	.078
Verti-slicer	Yes	6.44	2.13	8.57	.359	.109
Hollow-tine coring	Yes	5.44	1.70	7.14	.343	.049
Hydro-Jet	Yes	8.22	1.36	9.58	.462	.057
Treatment PR> F =		.70	.95	.78	.76	.57
CV (%) =		47	54	42	50	45

[z]Cultivation treatments applied 24 May and 27 July 1989.

Table 11. Root weight and root length density data from the 9 September 1989 sample date by soil depth.

Treatment[z]		Root Weight			Root Length Density	
Technique	Compaction	0-30 cm	30-60 cm	0-60 cm	0-30 cm	30-60 cm
		- - - - - mg cm^{-2} - - - - -			- - - - - $cm\ cm^{-3}$ - - - - -	
Control	No	7.90	1.53ab	9.43	.479	.063ab
Control	Yes	7.25	1.25ab	8.50	.486	.043b
Verti-drain	Yes	6.56	2.12a	8.68	.424	.077a
Aera-vator	Yes	3.75	0.91b	4.66	.289	.036b
Verti-slicer	Yes	7.01	1.10b	8.11	.449	.053ab
Hollow-tine coring	Yes	7.67	1.44ab	9.11	.476	.052ab
Hydro-Jet	Yes	6.57	1.34ab	7.91	.421	.048ab
Treatment PR> F =		.61	.25	.43	.86	.14
CV (%) =		47	45	39	50	37

[z]Cultivation treatments applied 24 May and 27 July 1989.

Table 12. Water extraction from the 0 to 60 cm soil depth over four time periods in 1989.

Treatment[z]		Water Extraction Per Day (0 to 60 cm depth)			
Technique	Compaction	17 to 19 Jul	11 to 13 Sep	19 to 21 Sep	04 to 09 Oct
		mm d^{-1}			
Control	No	3.59	4.00	3.90	2.07
Control	Yes	5.49	4.42	2.29	2.26
Verti-drain	Yes	4.27	3.00	2.44	2.53
Aera-vator	Yes	5.70	3.05	2.36	1.92
Verti-slicer	Yes	4.65	2.82	3.36	1.86
Hollow-tine coring	Yes	6.94	3.97	3.97	1.85
Hydro-Jet	Yes	4.35	4.04	2.52	2.38
Treatment PR> F =		.49	.39	.35	.84
CV (%) =		60	99	75	37

[z]Cultivation treatments applied 24 May and 27 July 1989.

Table 13. Water extraction from the 0 to 60 cm soil depth over four time periods in 1990.

Treatment[z]		Water Extraction Per Day (0 to 60 cm depth)			
Technique	Compaction	07 to 14 Jun	18 to 21 Jun	13 to 20 Aug	17 to 28 Sep
		mm d^{-1}			
Control	No	3.89	4.40ab[y]	3.02	3.72a
Control	Yes	3.82	3.60ab	3.13	2.60b
Verti-drain	Yes	5.07	3.60ab	2.61	3.83a
Aera-vator	Yes	4.08	4.20ab	2.64	3.69a
Verti-slicer	Yes	5.20	5.45a	2.51	3.66a
Hollow-tine coring	Yes	3.00	2.85b	2.51	3.33a
Hydro-Jet	Yes	3.42	3.10b	3.30	3.48a
Treatment PR> F =		.73	.24	.73	.036
CV (%) =		52	38	30	14

[y]LSD (.05) comparisons are based on unprotected F-test.

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 14. Visual quality in 1989.

Treatment[z]		Visual Quality					
Technique	Compaction	06 Jun	22 Jun	21 Jul	08 Aug	12 Sep	24 Oct
		--9 = ideal density, color uniformity; 1 = no live turf--					
Control	No	7.5a	7.0	7.6	7.4a	7.7	7.6
Control	Yes	7.4ab	7.0	7.5	7.5a	7.6	7.5
Verti-drain	Yes	7.2b	7.1	7.5	7.3a	7.6	7.8
Aera-vator	Yes	7.3ab	6.8	7.4	6.8b	7.3	7.6
Verti-slicer	Yes	6.7c	6.7	7.3	6.4c	7.6	7.5
Hollow-tine coring	Yes	6.2d	6.7	7.5	7.0ab	7.7	7.6
Hydro-Jet	Yes	7.5a	6.9	7.5	7.5a	7.6	7.5
Treatment PR> F =		.0001	.22	.79	.0002	.19	.38
CV (%) =		2.9	3.5	3.4	3.9	2.8	2.2

[z]Cultivation treatments applied 24 May and 27 July 1989.

Table 15. Visual quality and shoot density in 1990.

Treatment[z]		Visual Quality[y]					Shoot Density[x]	
Technique	Compaction	10 May	21 Jun	09 Aug	29 Sep	17 Oct	10 May	09 Aug
Control	No	6.3bc	7.2b	7.3ab	7.5a	7.6a	7.1a	8.4a
Control	Yes	6.0c	7.1bc	7.2ab	7.1ab	7.3b	6.9b	8.1b
Verti-drain	Yes	6.6a	7.5a	7.5a	7.0b	7.4ab	7.5a	8.0bc
Aera-vator	Yes	6.4ab	7.2b	7.2ab	6.9b	7.3b	7.3ab	7.7de
Verti-slicer	Yes	6.0c	6.9c	7.0b	6.4c	7.3b	6.8b	7.5e
Hollow-tine coring	Yes	6.4ab	7.2b	7.1ab	6.7bc	7.4ab	7.5c	7.9cd
Hydro-Jet	Yes	6.1bc	7.3ab	7.4ab	7.0b	7.6a	6.9b	8.2b
Treatment PR> F =		.007	.003	.34	.002	.018	.051	.0011
CV (%) =		3.5	2.4	4.2	3.9	1.8	5.0	1.8

[x]Shoot density: 9 = ideal; 1 = no live turf.

[y]Visual quality: 9 = ideal shhot density, color, uniformity; 1 = no live turf.

[z]Cultivation treatments applied 13 April and 3 August 1990.

Table 16. Shoot density, relative clipping yield and canopy temperature data in 1989.

Treatment[z]		Shoot Density[y]			Relative Clipping Yield		Canopy Temperature
Technique	Compaction	21 Jul	08 Aug	24 Oct	31 Aug	13 Sep	12 Sep (1:30 pm)
					- - - % - - -		- - - oC - - -
Control	No	7.8	7.6a	7.7	100	100a	37.1a
Control	Yes	7.7	7.4ab	7.4	100	107a	35.3b
Verti-drain	Yes	7.7	7.4ab	7.7	106	107a	37.1a
Aera-vator	Yes	7.6	7.1bc	7.7	52	74b	37.8a
Verti-slicer	Yes	7.6	6.9c	7.7	81	67ab	36.4ab
Hollow-tine coring	Yes	7.6	7.0c	7.7	70	63ab	36.8a
Hydro-Jet	Yes	7.6	7.5ab	7.7	92	80ab	37.6a
Treatment PR> F =		.56	.004	.45	.36	.15	.014
CV (%) =		25.5	3.3	3.2	3.2	35	2.4

[y]Shoot density: 9 = ideal density; 1 = no live turf.

[z]Cultivation treatments applied 24 May and 27 July 1989.

Table 17. Turfgrass color in 1989.

Treatment[z]		Turf Color[y]				
Technique	Compaction	22 Jun	21 Jul	08 Aug	12 Sep	24 Oct
Control	No	7.5	7.8	7.4a	7.5	7.4
Control	Yes	7.6	7.9	7.5a	7.6	7.4
Verti-drain	Yes	7.6	7.8	7.5a	7.7	7.5
Aera-vator	Yes	7.4	7.6	7.3a	7.4	7.4
Verti-slicer	Yes	7.5	7.7	7.0b	7.6	7.5
Hollow-tine coring	Yes	7.6	7.7	7.4a	7.4	7.5
Hydro-Jet	Yes	7.5	7.7	7.5a	7.5	7.5
Treatment PR> F =		.35	.80	.014	.35	.57
CV (%) =		2.1	3.6	2.5	3.2	1.8

[y]Turf color: 9 = dark green; 1 = no green.

[z]Cultivation treatments applied 24 May and 27 July 1989.

Table 18. Turfgrass color and relative clipping yield data in 1990.

Treatment[z]		Turf Color[x]					Relative Clipping Yield	
Technique	Compaction	10 May	21 Jun	09 Aug	29 Sep	17 Oct	22 May	05 Jul
							- - - - % - - - -	
Control	No	6.9a	7.2bc	7.6a	7.3ab	7.6	100a	100
Control	Yes	6.5ab	7.0cd	7.5ab	7.3ab	7.5	62b	91
Verti-drain	Yes	6.9a	7.5a	7.5ab	7.2ab	7.5	81ab	78
Aera-vator	Yes	6.5ab	7.1bcd	7.3b	7.3ab	7.5	84ab	89
Verti-slicer	Yes	6.2b	6.9d	7.4ab	7.1b	7.5	64b	97
Hollow-tine coring	Yes	6.5ab	7.2bc	7.4ab	7.5a	7.5	57b	87
Hydro-Jet	Yes	6.3b	7.3ab	7.5ab	7.5a	7.6	62b	90
Treatment PR> F =		.104	.004	.205	.129	.90	.052	.95
CV (%) =		5.3	2.5	2.5	2.4	2.4	27	30

[y]Turf color: 9 = dark green; 1 = no green.

[z]Cultivation treatments were applied 13 April and 3 August 1990.