EFFECT OF A SOIL CONDITIONER ON PHYSICAL PROPERTIES IN GOLF COURSE PUTTING GREENS

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INTRODUCTION

Infiltration, water holding capacity, aeration, and compaction are important factors affecting the establishment and maintenance of high quality putting greens in golf courses. This study was designed to test the effect of a soil conditioner, Open All®, on the aforementioned soil physical properties.

MATERIALS AND METHODS

The test was conducted at the Industry Hills Golf Course, City of Industry, CA. Four plots (practice putting greens) were chosen to perform the test. Each plot was divided into two subplots. The test plots were mowed, irrigated, and fertilized according to typical putting green management procedures as follows:

Mowing height	3/16"
Mowing frequency	Five times/week
Irrigation amount	1/2"-1" actual applications
Irrigation frequency	one or two nights/week
Fertilization	1/2 N per month; 1# potash, 1/2# phosphorus foliar
Core cultivation	
Verti-cutting	Deep tine, in July
Verti-drilling	1/2" tines, 10" deep

Infiltration Rate

Infiltration rate was measured by double-ring infiltrometers. The inner and outer rings of the infiltrometer were 20 cm and 30 cm diameter, respectively. Water levels in the two rings were controlled by two separate Meriot bottles with a ponding depth of 5 cm. Infiltration rate

was measured only for the inner ring. Infiltrometer readings were taken until it reached approximately constant rate. Infiltration rate for each site was calculated from the average of the last three readings. Two infiltration tests were made for each subplot before and after Open All® was applied.

OpenAll® Application

OpenAll® was applied to one of the two subplots in each of the four putting greens by Mr. Bert Spivey, the golf course superintendent. The application rate for OpenAll® was 1 gallon/l000 ft^2.

Core Samples

Two 5 by 5 cm undisturbed cores were pulled from each of the 8 subplots (4 greens, each green was divided into 2 subplots) before OpenAll® was applied on August 18 and one month after OpenAll® was applied (September 22). These cores were taken approximately 1 cm below the surface. The core samples were brought to the lab for measuring water contents at saturation, 0.1, 0.3 and 1 bar. Since the putting greens are always maintained in a relatively wet soil condition, 1 bar was used as the low range of water content.

Samples for dry weight of roots for each treated and non-treated subplots were composited of 3 subsamples. Each subsample was 2.375 in diam. and 6 in deep.

Total porosity (f_{total}) was calculated from particle density (PD, 2.65 g cm^{-3}) and bulk density (BD) measured from the core samples:

$$f_{total} = 1 - (BD/PD)$$

Air-filled porosity (f_{air}) was calculated from the difference between total porosity and volumetric water content at 0.1 bar.

$$f_{air} = f_{total} - \theta_{0.1\,bar}$$

Field Capacity (FC, volumetric water content) is the water content measured at 0.1 bar

$$FC = \theta_{0.1\,bar}$$

Plant-available water content (θ_{av}) was calculated from water contents at 0.1 and 1 bar by assuming that water content lower $\theta_{1.0\,bar}$ would not be available for the green:

$$\theta_{av} = \theta_{0.1\,bar} - \theta_{1.0\,bar}$$

Rooting Analysis

        On September 22 three cores (6.03 cm diameter × 15.24 cm deep) were taken from each treated and non-treated subplot. The three cores per subplot were pooled into one bag. The crown was cut from each core, and the soil was washed from the roots. Root was dried for 48 hr at 60 ºC. Data was presented as root mass per 1300 cm^3.

Statistics

        Paired t-test was performed for each of the measured soil properties to determine if there are significant differences between treatments and measuring/sampling dates. Although the infiltration rates is more likely to have a log-normal distribution, but the statistical conclusion obtained by assuming log-normal and normal distribution was the same. Thus this report used the same t-test for infiltration rates. Statistical analysis was conducted to test whether or not treatment of Open All$^®$ and dates of measurement have significant effect on soil properties. For the differences to be significant, p-value should be less than or equal to 0.05 for the t two-tail test.

FINDINGS

Infiltration Rate

        The mean infiltration rates for treated and non-treated putting greens were 1.77 and 1.83 in/hr. (Table 1a), respectively. The slight difference, however, is not statistically different ($P < 0.90$).

        The mean infiltration rates measured on August 18 and September 22 were 1.19 and 1.80 in/hr. (Table 1b), respectively. Again, the means are not statistically different ($P < 0.26$) since the variance was much greater for infiltration rates measured on September 22 than on August 18.

Bulk Density

        The mean bulk density measurements on August 18 and September 22 were 1.457 and 1.450 g cm^{-3} (Table 2a), respectively. They were not significantly different ($P < 0.50$).

        The mean bulk densities for treated and non-treated putting greens were 1.449 and 1.451 g cm^{-3} (Table 3a), respectively. Again, they were not significantly different ($P < 0.90$).

Total Porosity

The mean total porosity values on August 18 and September 22 were 44.99% and 45.28% (Table 2b), respectively. They were not significantly different (P < 0.47).

The mean total porosity values for treated and non-treated putting greens were 45.36% and 45.21% (Table 3b), respectively. Again, they were not significantly different (P < 0.86).

Air-filled Porosity

The mean air-filled porosity measurements on August 18 and September 22 were 25.26% and 23.25% (Table 2c), respectively. They were different at the 90% level (P < 0.09).

The mean bulk densities for treated and non-treated putting greens were 22.97% and 23.52% (Table 3c), respectively. However, they were not significantly different (P < 0.61).

Water Holding Capacity

The mean field water holding capacity (volumetric water content) measurements on August 18 and September 22 were 0.197 and 0.220 cm^3 cm^{-3} (Table 2d), respectively. The field capacity was increased by 2% from August 18 to September 22 at a significant level of 0.06 (P < 0.06). The slight difference is well within the experimental error.

The mean field water holding capacity measurements between treated and non-treated putting greens were 0.224 and 0.217 (Table 3d), respectively. They were not significantly different (P < 0.64).

Plant-Available Water

The mean plant-available water (volumetric water content) measurements on August 18 and September 22 were 0.052 and 0.058 cm^3 cm^{-3} (Table 2e), respectively, for the treated and non-treated subplots. They were not different at the 90% significant level (P < 0.28).

There is a slight increase in the mean plant-available water (volumetric water content). The mean plant-available water measurements on treated and non-treated putting greens were 0.056 and 0.061 cm^3 cm^{-3} (Table 3e), respectively. They were not statistically different (P < 0.61).

Dry weight of roots

The mean dry weight of roots measured on September 22 were 0.102 and 0.110 gram per 1300 cm^3, respectively, for the treated and non-treated subplots. They were not statistically different at the significant level of 90% (P < 0.72).

CONCLUSIONS

From the limited test conducted at the Industry Hills Golf Course putting greens, we did not find significant differences between treated and non-treated putting greens regarding infiltration rate, bulk density, total porosity, air-filled porosity, water holding capacity, plant-available water content, and dry weight of roots.

Table 1a. Infiltration rate (in/hr.) of treated and non-treated by Open All

Location	Treated	Non-treated
Z	1.50	0.10
Z	0.65	0.67
S	0.15	2.72
S	0.32	0.56
E	3.36	0.91
E	0.54	0.14
D	6.45	5.72
D	1.18	3.81

t-Test: Paired Two Sample for Means

	Treated	Non-treated
Mean	1.77	1.83
Variance	4.62	4.21
Observations	8	8
Pearson Correlation	0.64	
Hypothesized Mean Difference	0.00	
df	7	
t Stat	-0.10	
P(T<=t) one-tail	0.46	
t Critical one-tail	1.89	
P(T<=t) two-tail	0.93	
t Critical two-tail	2.36	

Table 1b. Infiltration rate (in/hr.) on 8/18 and 9/22/95

Location	Pre Treatment	Post Treatment
Z1	0.73	0.10
Z2	0.37	0.67
Z3	0.65	1.50
Z4	1.53	0.65
S1	3.78	2.72
S2	0.65	0.56
S3	0.43	0.15
S4	0.11	0.32
E1	0.05	3.36
E2	0.02	0.54
E3	0.70	0.91
E4	0.51	0.14
D1	3.84	5.72
D2	1.31	3.81
D3	0.32	6.45
D4	4.06	1.18

t-Test: Paired Two Sample for Means

	Inf. 8/18/95	Infl. 9/22/95
Mean	1.19	1.80
Variance	1.96	4.12
Observations	16	16
Pearson Correlation	0.31	
Hypothesized Mean Difference	0	
df	15	
t Stat	-1.17	
P(T<=t) one-tail	0.13	
t Critical one-tail	1.75	
P(T<=t) two-tail	0.26	
t Critical two-tail	2.13	

Table 2. Bulk density, porosity, and water retention data

8/18/95 BD g/cm^3	Porosity (%)	Air-Pore (%)	f-capacity (v/v, %)	PAva-WC (v/v, %)	9/22/95 BD g/cm^3	Porosity (%)	Air-Pore (%)	f-capacity (v/v, %)	PAva-WC (v/v, %)
1.400	47.106	27.974	0.191	0.052	1.410	46.612	25.575	0.210	0.073
1.490	43.627	27.597	0.160	0.057	1.420	46.521	24.859	0.217	0.049
1.440	45.835	20.762	0.251	0.070	1.380	47.908	28.599	0.193	0.032
1.450	45.147	27.581	0.176	0.049	1.450	45.294	22.765	0.225	0.067
1.480	43.993	23.743	0.203	0.068	1.510	43.002	19.135	0.239	0.060
1.500	43.313	20.887	0.224	0.053	1.520	42.536	23.308	0.192	0.040
1.530	42.411	24.485	0.179	0.046	1.510	42.997	20.254	0.227	0.056
1.480	44.118	26.912	0.172	0.065	1.450	45.128	20.642	0.245	0.088
1.420	46.532	26.407	0.201	0.057	1.450	45.333	21.370	0.240	0.050
1.450	45.244	23.957	0.213	0.070	1.400	47.192	22.824	0.244	0.056
1.450	45.314	24.718	0.206	0.034	1.410	46.940	23.153	0.238	0.058
1.410	46.859	26.543	0.203	0.007	1.420	46.568	23.406	0.232	0.060
1.440	45.541	23.923	0.216	0.047	1.500	43.418	27.610	0.158	0.057
1.460	44.861	28.119	0.167	0.046	1.470	44.498	21.954	0.225	0.072

The following two numbers were treated as missing values

8/18/95 BD g/cm^3	Porosity (%)	Air-Pore (%)	f-capacity (v/v, %)	PAva-WC (v/v, %)	9/22/95 BD g/cm^3	Porosity (%)	Air-Pore (%)	f-capacity (v/v, %)	PAva-WC (v/v, %)
1.420	46.360	24.139	0.222	0.070	1.430	45.893	11.908	0.340	0.055
1.440	45.713	24.353	0.214	0.056	1.300	51.032	27.010	0.240	0.060

Table 2a. t-Test: Paired Bulk density for Means - dates

	8/18/95	9/22/95
Mean	1.457	1.450
Variance	0.001	0.002
Observations	14	14
Pearson Correlation	0.581132	
Hypothesized Mean Difference	0	
df	13	
t Stat	0.693889	
P(T<=t) one-tail	0.249982	
t Critical one-tail	1.770932	
P(T<=t) two-tail	0.499964	
t Critical two-tail	2.160368	

Table 2b. t-Test: Paired total porosity for Means -dates

	8/18/95	9/22/95
Mean	44.993	45.282
Variance	1.896	3.102
Observations	14	14
Pearson Correlation	0.597222	
Hypothesized Mean Difference	0	
df	13	
t Stat	-0.74595	
P(T<=t) one-tail	0.234486	
t Critical one-tail	1.770932	
P(T<=t) two-tail	0.468973	
t Critical two-tail	2.160368	

Table 2c. Paired air-filled porosity for Means - Dates

	8/18/95	9/22/95
Mean	25.258	23.247
Variance	6.009	7.230
Observations	14	14
Pearson Correlation	-0.25668	
Hypothesized Mean Difference	0	
df	13	
t Stat	1.845459	
P(T<=t) one-tail	0.043932	
t Critical one-tail	1.770932	
P(T<=t) two-tail	0.087864	
t Critical two-tail	2.160368	

Table 2d. t-Test: Paired field capacity for Means - Dates

	8/18/95	9/22/95
Mean	0.197	0.220
Variance	0.001	0.001
Observations	14	14
Pearson Correlation	-0.42394	
Hypothesized Mean Difference	0	
df	13	
t Stat	-2.05452	
P(T<=t) one-tail	0.0303	
t Critical one-tail	1.770932	
P(T<=t) two-tail	0.060601	
t Critical two-tail	2.160368	

Table 2e. t-Test: Paired plant-available water content for Means-dates

	8/18/95	9/22/95
Mean	0.052	0.058
Variance	0.000	0.000
Observations	14	14
Pearson Correlation	-0.12094	
Hypothesized Mean Difference	0	
df	13	
t Stat	-1.12781	
P(T<=t) one-tail	0.139893	
t Critical one-tail	1.770932	
P(T<=t) two-tail	0.279787	
t Critical two-tail	2.160368	

Table 3. Bulk density, porosity, and water retention of treated and non-treated

Pre-treatment

BD g/cm^3	Porosity (%)	Air-Pore (%)	f-capacity (v/v, %)	PAva-WC (v/v, %)
1.41	46.612	25.575	0.21	0.073
1.42	46.521	24.859	0.217	0.049
1.51	4.3002	19.135	0.239	0.06
1.52	42.536	23.308	0.192	0.04
1.45	45.333	21.370	0.24	0.05
1.41	46.940	23.153	0.238	0.058
1.42	46.568	23.406	0.232	0.06

Post-treatment

BD g/cm^3	Porosity (%)	Air-Pore (%)	f-capacity (v/v, %)	PAva-WC (v/v, %)
1.38	47.908	28.599	0.193	0.032
1.45	45.294	22.765	0.225	0.067
1.51	42.997	20.254	0.227	0.056
1.45	45.128	20.642	0.245	0.088
1.4	47.192	22.824	0.244	0.056
1.5	43.418	27.610	0.158	0.057
1.47	44.498	21.954	0.225	0.072

Table 3a. Paired t-test for bulk density for Means of treated and non-treated

	Non-treated	Treated
Mean	1.449	1.451
Variance	0.002	0.002
Observations	7	7
Pearson Correlation	0.278735	
Hypothesized Mean Difference	0	
df	6	
t Stat	-0.13178	
P(T<=t) one-tail	0.449733	
t Critical one-tail	1.943181	
P(T<=t) two-tail	0.899466	
t Critical two-tail	2.446914	

Table 3b. Paired t-test for total porosity for Means of treated and non-treated

	Non-treated	Treated
Mean	45.359	45.205
Variance	3.401	3.306
Observations	7	7
Pearson Correlation	0.257469	
Hypothesized Mean Difference	0	
df	6	
t Stat	0.182402	
P(T<=t) one-tail	0.430637	
t Critical one-tail	1.943181	
P(T<=t) two-tail	0.861274	
t Critical two-tail	2.446914	

Table 3c. Paired t-test for air-filled porosity for Means of treated and non-treated

	Non-treated	Treated
Mean	22.972	23.521
Variance	4.661	10.830
Observations	7	7
Pearson Correlation	0.57563	
Hypothesized Mean Difference	0	
df	6	
t Stat	-0.53712	
P(T<=t) one-tail	0.305253	
t Critical one-tail	1.943181	
P(T<=t) two-tail	0.610506	
t Critical two-tail	2.446914	

Table 3d. Paired t-test for field water holding capacity for Means of treated & untreated

	Non-treated	Treated
Mean	0.224	0.217
Variance	0.000	0.001
Observations	7	7
Pearson Correlation	-0.23318	
Hypothesized Mean Difference	0	
df	6	
t Stat	0.487019	
P(T<=t) one-tail	0.321762	
t Critical one-tail	1.943181	
P(T<=t) two-tail	0.643525	
t Critical two-tail	2.446914	

Table 3e. Paired t-test plant-available water for Means of treated and non-treated

	Non-treated	Treated
Mean	0.056	0.061
Variance	0.000	0.000
Observations	7	7
Pearson Correlation	-0.84295	
Hypothesized Mean Difference	0	
df	6	
t Stat	-0.53653	
P(T<=t) one-tail	0.305448	
t Critical one-tail	1. 943181	
P(T<=t) two-tail	0.610895	
t Critical two-tail	2.446914	

Table 3f: Paired t-test for means of dry root in treated and non-treated plots

	Treated	Non-treated
Mean	0.102	0.110
Variance	0.002	0.002
Observations	4	4
Pearson Correlation	0.628	
Hypothesized Mean Difference	0	
df	3	
t Stat	-0.394	
P(T<=t) one-tail	0.360	
t Critical one-tail	2.353	
P(T <=t) two-tail	0.720	
t Critical two-tail	3.182	