EFFECTS OF SEVERAL WETTING AGENTS ON CREEPING BENTGRASS AND SOIL WATER REPELLENCY

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DECEMBER 19, 2007

INTRODUCTION

Water repellent soils have been observed for many years in grasslands (1) forests (2) and citrus groves (3). They have become an increasing problem on golf greens since 1960, when the United States Golf Association recommended that golf green topsoil mix should contain at least 90% sand (23). Symptoms of these water repellent soils begin as small irregular shaped areas of drought-stressed turfgrass known as localized dry spots (4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 20,21,22,25). If left untreated these areas can increase in size and become excessively dry. Large areas of turfgrass can be severely damaged. Research has shown that the sand particles in the localized dry spots are covered with an organic coating, which renders them water repellent (5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,22,25). The problem is most evident during late spring, summer and early fall.

Currently, hand-watering, syringing, coring and the use of wetting agents are the best methods for controlling localized dry spots (4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21, 22,25) caused by water repellent soils. However, wetting agents are potentially phytotoxic to turfgrasses if improperly used. The objectives of this research were:

1. To determine the effects of several wetting agents on creeping bentgrass color and quality.
2. To determine the effects of several wetting agents on soil water repellency.

MATERIALS AND METHODS

The field experiment was initiated June 14, 2007 on the University of Georgia Experimental Golf Green that was built in 1996 to USGA specifications with a topsoil mix consisting of 85% sand and 15% peat (23). The green consists of 325.2 square meters (3500 $ft.^2$) of 'Penncross' creeping bentgrass (*Agrostis stoloniferous* var. *palustris*). The green was mowed at 0.64 cm (0.25 inch) and irrigated as needed with 0.95 cm (0.375 inch) of water when sufficient rainfall did not occur. Regular maintenance practices (fertilizer and pesticide applications) were performed as needed. Daily temperature and rainfall were recorded for the duration of the experiment (Appendix).

Treatments were applied to 0.61 X 0.61 meter (2 X 2 ft.) plots with a CO_2 backpack sprayer. Immediately after application, treatments were irrigated into the soil with 0.64 cm (0.375 inch) of water. The following treatments were applied:

1. SMS-700: 22.3 l/ha (7 oz./1000 $ft.^2$) in 814.9 liters of water/ha (2.0 gallons of water /1000 $ft.^2$) applied on 6/14/07 and 6/21/07.
2. EXP-255: 22.3 l/ha (7 oz./1000 $ft.^2$) in 814.9 liters of water/ha (2.0 gallons of water /1000 $ft.^2$) applied on 6/14/07 and 6/21/07.
3. EXP-262: 22.3 l/ha (7 oz./1000 $ft.^2$) in 814.9 liters of water/ha (2.0 gallons of water /1000 $ft.^2$) applied on 6/14/07 and 6/21/07.
4. Cascade Plus: 25.5 l/ha (8 oz./1000 $ft.^2$) in 814.9 liters of water/ha (2.0 gallons of water /1000 $ft.^2$) applied on 6/14/07 and 6/21/07.
5. Control.

Visual turfgrass color (1 to 9, 1 = brown, dead turf and 9 = dark green, healthy turf) and quality (1 to 9, 1 = very poor quality and 9 = excellent quality) ratings were taken on 6/14/07 (before treatment application), 6/15/07, 6/17/07, 6/21/07, 7/12/07, 8/9/07, 9/6/07 and 10/4/07.

Soil water repellency was determined by the molarity of ethanol droplet test (MED) on 6/14/07 (before treatment application), 6/21/07, 7/12/07, 8/9/07, 9/6/07 and 10/4/07 (24). Soil samples were taken with a 0.64 cm (0.25 inch) soil probe to a depth of 5 cm (2.0 in.). Five soil samples were taken from each plot and combined into one bulk sample per plot. Samples were dried for 24 hours in an oven at 35 C (95 F). After drying, samples were removed from the oven and allowed to equilibrate to room temperature [21.1 - 23.9 C (70 - 75 F)] and humidity (60 - 65%). Samples were sieved through a 2 mm (#10 United States Standard Series) mesh screen and the MED test was performed on the sieved, dried soil.

The soil was placed in a 5 cm (2.0 in.) diameter X 1 cm (0.39 in.) deep dish to provide a uniform surface and depth. A series of 40 uL aqueous ethanol droplets at 0.4 M intervals were placed on the soil surface. The molarity of the droplet that completely infiltrated within 5 seconds was recorded as the soil MED value (0 = non-water repellent, 4 = extremely water repellent). Experimental design was a randomized complete block with four replications per treatment. Data were subjected to analysis of variance (ANOVA) procedures with treatment means separated by Duncan's Multiple Range Test at the 0.05 level of probability.

RESULTS AND DISCUSSION

Turfgrass Color

No differences in turfgrass color were observed before initial treatment application (Table 1). On 6/14/07 experimental plots had an average turfgrass color rating of 8.3 (Table 1). Turfgrass color ratings of the SMS-700 treated plots were not different than the color ratings of the control plots and the EXP-255, EXP-262 and Cascade Plus treated plots on 6/15/07 (Table 1). Color ratings of the EXP-255, EXP-262 and Cascade Plus treated plots were lower than the color ratings of the control plots. However, no differences in turfgrass color were observed among the EXP-255, EXP-262 and Cascade Plus treatments on 6/15/07 (Table 1).

On 6/17/07 a reduction in turfgrass color was observed with all treatments as compared to the control (Table 1). However, no differences in color were observed among the treatments. On 6/21/07 turfgrass color ratings of the SMS-700 treated plots were not different than the color ratings of the control plots and the EXP-255, EXP-262 and Cascade Plus treated plots (Table 1). Color ratings of the EXP-255, EXP-262 and Cascade Plus treated plots were lower than the color ratings of the control plots. However, no differences in turfgrass color were observed among the EXP-255, EXP-262 and Cascade Plus treatments on 621/07 (Table 1).

No differences in turfgrass color were observed among the treatments and control on 7/12/07, 8/9/07, 9/6/07 and 10/4/07 (Table 1). Therefore, under the conditions of this study, the data indicate that EXP-255, EXP-262 and Cascade Plus caused a reduction in turfgrass color. However, the reduction in turfgrass color dissipated within 4 weeks. The data also demonstrate that SMS-700 caused a reduction in turfgrass color 3 days after application. However, the reduction in turfgrass color was not severe and dissipated within 7 days.

Turfgrass Quality

No differences in turfgrass quality were observed before initial treatment application (Table 2). Experimental plots had an average turfgrass quality rating of 8.4 on 6/14/07 (Table 2). No differences in turfgrass quality were observed among the treatments and the control on 6/15/07 (Table 2). On 6/17/07 turfgrass quality ratings of the Cascade Plus treated plots were lower than the control plots, but not different than the SMS-700, EXP-255 and EXP-262 treated plots (Table 2). Turfgrass quality ratings of the SMS-700, EXP-255 and EXP-262 treated plots were not different than the control plots on 6/17/07 (Table 2).

No differences in turfgrass quality were observed among the treatments and control on 6/21/07, 7/12/07, 8/9/07, 9/6/07 and 10/4/07 (Table 2). Therefore, under the conditions of this study, the data demonstrate that Cascade Plus caused a reduction in turfgrass quality, as compared to the control, 3 days after application (6/17/07). However, the reduction in turfgrass quality was not severe and dissipated within 7 days. The data also indicate that SMS-700, EXP-255 and EXP-262 did not positively or negatively affect turfgrass quality.

Soil Water Repellency

Moderately high soil water repellency (MED 2.4 to 2.5) was observed for all plots before initial treatment application on 6/14/07 (Table 3). One week after initial treatment application (6/21/07) soil water repellency of all treatments was lower than the control (Table 3). However, no differences in soil water repellency were observed among the treatments.

On 7/12/07 soil water repellency of the EXP-262 treatment was lower than the control and Cascade Plus treatment, but not different than the SMS-700 and EXP-255 treatments. Soil water repellency of the Cascade Plus treatment was lower than the control and higher than the EXP-262 treatment, but not different than the soil water repellency of the SMS-700 and EXP-255 treatments (Table 3). Soil water repellency of the SMS-700 and EXP-255 treatments was lower than the control, but not different than the EXP-262 and Cascade Plus treatments (Table 3).

On 8/9/07 soil water repellency of the EXP-262 treatment was lower than the control and the SMS-700 and Cascade Plus treatments, but not different than the EXP-255 treatment (Table 3). Soil water repellency of the SMS-700 and Cascade Plus treatments was lower than the control and higher than the EXP-262 treatment, but not different than the soil water repellency of the EXP-255 treatment (Table 3). Soil water repellency of the EXP-255 treatment was lower than the control, but not different than the SMS-700, EXP-262 and Cascade Plus treatments (Table 3).

On 9/6/07 soil water repellency of all treatments was lower than the control (Table 3). However, no differences in soil water repellency were observed among the treatments. No differences in soil water repellency were observed among the treatments and control on 10/4/07 (Table 3). Therefore, under the conditions of this study, the data indicate that the efficacy of all wetting agents tested was at least 11 weeks after the last application, but less than 15 weeks.

SUMMARY

Under the conditions of this study, the data indicate that all wetting agents tested did reduce turfgrass color. The reduction in color caused by SMS-700 was not severe and dissipated within 7 days. The reduction in color caused by EXP-255, EXP-262 and Cascade Plus was visible 7 days after initial application, but had dissipated before color ratings were taken 4 weeks after initial application. Turfgrass quality was not positively or negatively affected by SMS-700, EXP-255 and EXP-262 on any observation date. Turfgrass treated with Cascade Plus did exhibit a reduction in quality 3 days after initial application. However, the reduction in quality was not severe and dissipated within 7 days. On 9/6/07 and 10/4/07 a reduction in turfgrass color and quality was observed on all experimental plots. The reduction in color and quality was likely due to the extremely high air temperatures (See Appendix) and drought conditions experienced during August.

In terms of soil water repellency, the data indicate that the wetting agents tested can reduce soil water repellency. In general the wetting agents performed similarly in regards to the degree and duration of soil water repellency reduction. EXP-262 treated plots did exhibit a greater reduction in soil repellency than Cascade Plus treated plots 4 and 8 weeks after initial application. No differences in soil water repellency were observed among the SMS-700, EXP-255 and Cascade Plus treatments on any observation date. The efficacy of SMS-700, EXP-255 EXP-262 and Cascade Plus was at least 11 weeks after the last application, but less than 15 weeks.

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Table 1. 'Penncross' creeping bentgrass color as affected by several wetting agents.

Treatment	Application Dates	6/14[1]	6/15	6/17	6/21	7/12	8/9	9/6	10/4
		----------Color[2]----------							
SMS-700: 22.3 l/ha	6/14, 6/21	8.3a[3]	7.6ab	7.4b	7.3ab	8.0a	7.6a	6.0a	6.9a
EXP-255: 22.3 l/ha	6/14, 6/21	8.4a	7.1b	7.3b	7.0b	7.8a	7.8a	5.8a	6.5a
EXP-262: 22.3 l/ha	6/14, 6/21	8.3a	7.4b	7.1b	6.9b	7.6a	7.4a	5.8a	6.5a
Cascade Plus: 25.5 l/ha	6/14, 6/21	8.1a	7.3b	7.3b	6.5b	7.5a	7.3a	5.5a	6.8a
Control	-----	8.3a	8.1a	8.3a	8.0a	7.9a	7.6a	6.4a	7.1a

[1]Color ratings taken before initial treatment application.
[2]Color - 1 to 9 (1 = brown, dead turf and 9 = dark green, healthy turf).
[3]Means in the same column joined by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

Table 2. 'Penncross' creeping bentgrass quality as affected by several wetting agents.

Treatment	Application Dates	6/14[1]	6/15	6/17	6/21	7/12	8/9	9/6	10/4
		----------Quality[2]----------							
SMS-700: 22.3 l/ha	6/14, 6/21	8.4a[3]	8.4a	8.1ab	8.1a	8.3a	7.9a	6.1a	6.9a
EXP-255: 22.3 l/ha	6/14, 6/21	8.3a	8.1a	8.4ab	8.3a	8.1a	8.0a	6.1a	6.5a
EXP-262: 22.3 l/ha	6/14, 6/21	8.5a	8.3a	8.1ab	8.0a	8.0a	8.0a	5.8a	6.5a
Cascade Plus: 25.5 l/ha	6/14, 6/21	8.5a	8.1a	8.0b	7.8a	8.0a	8.0a	6.0a	6.8a
Control	-----	8.5a	8.5a	8.5a	8.4a	8.1a	8.1a	6.8a	7.1a

[1]Quality ratings taken before initial treatment application.
[2]Quality - 1 to 9 (1 = very poor quality and 9 = excellent quality).
[3]Means in the same column joined by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

Table 3. Soil water repellency as affected by several wetting agents.

Treatment	Application Dates	6/14[1]	6/21	7/12	8/9	9/6	10/4
		----------Soil Water Repellency[2]----------					
SMS-700: 22.3 l/ha	6/14, 6/21	2.4a[3]	0.0b	1.1bc	1.7b	1.7b	2.1a
EXP-255: 22.3 l/ha	6/14, 6/21	2.4a	0.1b	1.1bc	1.6bc	1.7b	2.2a
EXP-262: 22.3 l/ha	6/14, 6/21	2.5a	0.0b	0.7c	1.3c	1.4b	2.2a
Cascade Plus: 25.5 l/ha	6/14, 6/21	2.5a	0.2b	1.2b	1.7b	1.6b	2.1a
Control	-----	2.5a	2.5a	2.3a	2.2a	2.3a	2.4a

[1]Soil water repellency readings taken before initial treatment application.
[2]Soil Water Repellency - 0.0 to 4.0 (0.0 = non-water repellent and 4.0 = extremely water repellent).
[3]Means in the same column joined by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

APPENDIX

2007
WEATHER DATA

Daily maximum and minimum temperatures and rainfall data of June 2007 at the University of Georgia Rhizotron and Turfgrass Facility.

Date	Maximum Temp F	Maximum Temp C	Minimum Temp F	Minimum Temp C	Rainfall (in)	Rainfall (cm)
6/1	89	31.7	63	17.2	0.00	0.00
6/2	76	24.4	64	17.8	0.33	0.84
6/3	88	31.1	62	16.7	0.16	0.41
6/4	90	32.2	64	17.8	0.00	0.00
6/5	89	31.7	65	18.3	0.22	0.56
6/6	92	33.3	62	16.7	0.00	0.00
6/7	95	35.0	68	20.0	0.00	0.00
6/8	94	34.4	70	21.1	0.00	0.00
6/9	97	36.1	69	20.6	0.00	0.00
6/10	94	34.4	67	19.4	0.00	0.00
6/11	89	31.7	68	20.0	Trace	Trace
6/12	85	29.4	60	15.6	0.71	1.80
6/13	87	30.6	58	14.4	0.08	0.20
6/14	84	28.9	60	15.6	0.00	0.00
6/15	82	27.8	65	18.3	Trace	Trace
6/16	89	31.7	62	16.7	0.00	0.00
6/17	94	34.4	67	19.4	0.00	0.00
6/18	94	34.4	68	20.0	Trace	Trace
6/19	93	33.9	67	19.4	0.03	0.08
6/20	91	32.8	70	21.1	0.00	0.00
6/21	91	32.8	63	17.2	0.00	0.00
6/22	95	35.0	62	16.7	0.00	0.00
6/23	97	36.1	63	17.2	0.00	0.00
6/24	99	37.2	67	19.4	0.00	0.00
6/25	96	35.6	69	20.6	Trace	Trace
6/26	93	33.9	67	19.4	0.64	1.63
6/27	93	33.9	68	20.0	0.00	0.00
6/28	94	34.4	70	21.1	0.00	0.00
6/29	96	35.6	68	20.0	0.00	0.00
6/30	98	36.7	69	20.6	0.00	0.00

Daily maximum and minimum temperatures and rainfall data of July 2007 at the University of Georgia Rhizotron and Turfgrass Facility.

Date	Maximum Temp F	Maximum Temp C	Minimum Temp F	Minimum Temp C	Rainfall (in)	Rainfall (cm)
7/1	96	35.6	69	20.6	0.86	2.18
7/2	77	25.0	67	19.4	Trace	Trace
7/3	82	27.8	67	19.4	0.01	0.03
7/4	87	30.6	63	17.2	0.00	0.00
7/5	91	32.8	62	16.7	0.00	0.00
7/6	93	33.9	66	18.9	0.00	0.00
7/7	87	30.6	72	22.2	Trace	Trace
7/8	83	28.3	70	21.1	0.34	0.86
7/9	92	33.3	71	21.7	0.32	0.00
7/10	91	32.8	70	21.1	0.74	1.88
7/11	87	30.6	70	21.1	0.10	0.25
7/12	88	31.1	68	20.0	0.00	0.00
7/13	86	30.0	64	17.8	0.00	0.00
7/14	83	28.3	69	20.6	Trace	Trace
7/15	83	28.3	68	20.0	0.01	0.03
7/16	91	32.8	68	20.0	0.00	0.00
7/17	93	33.9	71	21.7	0.06	0.15
7/18	91	32.8	70	21.1	Trace	Trace
7/19	93	33.9	71	21.7	Trace	Trace
7/20	85	29.4	70	21.1	Trace	Trace
7/21	88	31.1	68	20.0	0.00	0.00
7/22	75	23.9	63	17.2	0.01	0.03
7/23	87	30.6	61	16.1	0.00	0.00
7/24	92	33.3	63	17.2	0.00	0.00
7/25	92	33.3	65	18.3	0.11	0.28
7/26	90	32.2	68	20.0	0.10	0.25
7/27	93	33.9	68	20.0	0.00	0.00
7/28	89	31.7	71	21.7	0.07	0.18
7/29	85	29.4	71	21.7	0.75	1.91
7/30	90	32.2	71	21.7	Trace	Trace
7/31	89	31.7	70	21.1	0.00	0.00

Daily maximum and minimum temperatures and rainfall data of August 2007 at the University of Georgia Rhizotron and Turfgrass Facility.

Date	Maximum Temp F	Maximum Temp C	Minimum Temp F	Minimum Temp C	Rainfall (in)	Rainfall (cm)
8/1	92	33.3	71	21.7	0.00	0.00
8/2	94	34.4	70	21.1	0.00	Trace
8/3	93	33.9	69	20.6	0.00	0.00
8/4	97	36.1	68	20.0	0.00	Trace
8/5	98	36.7	69	20.6	Trace	Trace
8/6	100	37.8	73	22.8	0.00	0.00
8/7	101	38.3	75	23.9	0.00	0.00
8/8	102	38.9	75	23.9	0.00	0.00
8/9	105	40.6	78	25.6	0.00	0.00
8/10	104	40.0	73	22.8	0.00	0.00
8/11	102	38.9	79	26.1	0.00	0.00
8/12	92	33.3	73	22.8	0.00	0.00
8/13	100	37.8	73	22.8	0.00	0.00
8/14	99	37.2	69	20.6	0.00	0.00
8/15	103	39.4	68	20.0	0.00	0.00
8/16	105	40.6	74	23.3	0.00	0.00
8/17	102	38.9	76	24.4	0.04	0.10
8/18	99	37.2	73	22.8	Trace	Trace
8/19	98	36.7	74	23.3	0.00	0.00
8/20	101	38.3	71	21.7	0.00	0.00
8/21	103	39.4	73	22.8	0.00	0.00
8/22	106	41.1	75	23.9	0.02	0.05
8/23	99	37.2	73	22.8	0.23	0.58
8/24	99	37.2	72	22.2	0.04	0.10
8/25	96	35.6	71	21.7	0.00	0.00
8/26	99	37.2	70	21.1	0.58	1.47
8/27	90	32.2	71	21.7	Trace	Trace
8/28	91	32.8	72	22.2	0.00	0.00
8/29	93	33.9	70	21.1	Trace	Trace
8/30	94	34.4	72	22.2	0.19	0.48
8/31	87	30.6	71	21.7	Trace	Trace

Daily maximum and minimum temperatures and rainfall data of September 2007 at the University of Georgia Rhizotron and Turfgrass Facility.

Date	Maximum Temp F	Maximum Temp C	Minimum Temp F	Minimum Temp C	Rainfall (in)	Rainfall (cm)
9/1	87	30.6	70	21.1	0.00	0.00
9/2	86	30.0	68	20.0	0.00	0.00
9/3	91	32.8	63	17.2	0.00	0.00
9/4	95	35.0	68	20.0	0.00	0.00
9/5	94	34.4	62	16.7	0.00	0.00
9/6	91	32.8	66	18.9	0.00	0.00
9/7	89	31.7	69	20.6	0.00	0.00
9/8	93	33.9	64	17.8	0.00	0.00
9/9	94	34.4	64	17.8	0.00	0.00
9/10	97	36.1	67	19.4	0.00	0.00
9/11	95	35.0	64	17.8	0.05	0.13
9/12	90	32.2	71	21.7	0.13	0.33
9/13	87	30.6	70	21.1	0.00	0.00
9/14	86	30.0	69	20.6	0.21	0.53
9/15	87	30.6	64	17.8	0.00	0.00
9/16	77	25.0	62	16.7	0.00	0.00
9/17	82	27.8	59	15.0	0.00	0.00
9/18	80	26.7	56	13.3	0.00	0.00
9/19	84	28.9	57	13.9	0.00	0.00
9/20	80	26.7	64	17.8	Trace	Trace
9/21	78	25.6	68	20.0	0.01	Trace
9/22	90	32.2	67	19.4	0.00	0.00
9/23	94	34.4	68	20.0	0.00	0.00
9/24	94	34.4	68	20.0	Trace	Trace
9/25	92	33.3	68	20.0	0.00	0.00
9/26	93	33.9	60	15.6	0.00	0.00
9/27	88	31.1	64	17.8	0.10	0.25
9/28	89	31.7	64	17.8	0.00	0.00
9/29	84	28.9	58	14.4	0.00	0.00
9/30	82	27.8	52	11.1	0.00	0.00

Daily maximum and minimum temperatures and rainfall data of October 2007 at the University of Georgia Rhizotron and Turfgrass Facility.

Date	Maximum Temp F	Maximum Temp C	Minimum Temp F	Minimum Temp C	Rainfall (in)	Rainfall (cm)
10/1	81	27.3	55	12.6	0.00	0.00
10/2	82	27.5	57	14.0	0.00	0.00
10/3	78	25.3	71	21.4	0.00	0.00
10/4	81	27.0	69	20.6	0.07	0.18
10/5	82	27.5	70	21.2	0.01	0.03
10/6	83	28.2	68	19.9	0.00	0.00
10/7	85	29.6	65	18.3	0.00	0.00
10/8	89	31.7	65	18.3	0.00	0.00
10/9	88	31.0	62	16.9	0.09	0.23
10/10	84	28.8	59	14.9	0.00	0.00
10/11	71	21.6	48	9.1	0.00	0.00
10/12	74	23.5	44	6.4	0.00	0.00
10/13	75	23.9	44	6.6	0.00	0.00
10/14	80	26.8	49	9.2	0.00	0.00
10/15	81	27.0	51	10.6	0.00	0.00
10/16	76	24.2	58	14.5	0.00	0.00
10/17	80	26.4	61	16.0	0.00	0.00
10/18	77	25.1	63	17.4	0.00	0.00
10/19	74	23.5	57	13.8	0.71	1.80
10/20	77	24.7	51	10.6	0.00	0.00
10/21	80	26.4	47	8.1	0.00	0.00
10/22	70	21.2	61	16.1	0.25	0.64
10/23	82	28.0	59	15.1	0.34	0.86
10/24	64	17.6	53	11.8	0.14	0.36
10/25	68	19.7	45	7.0	0.00	0.00
10/26	71	21.8	53	11.4	0.00	0.00
10/27	72	22.1	49	9.2	0.00	0.00
10/28	69	20.7	46	7.9	0.00	0.00
10/29	62	16.4	41	5.2	0.00	0.00
10/30	66	19.0	37	3.0	0.00	0.00
10/31	72	22.3	44	6.4	0.00	0.00