

## **Evaluation of various soil surfactants for creeping bentgrass sand-based putting green management. Purdue University, 2006**

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### **Objective:**

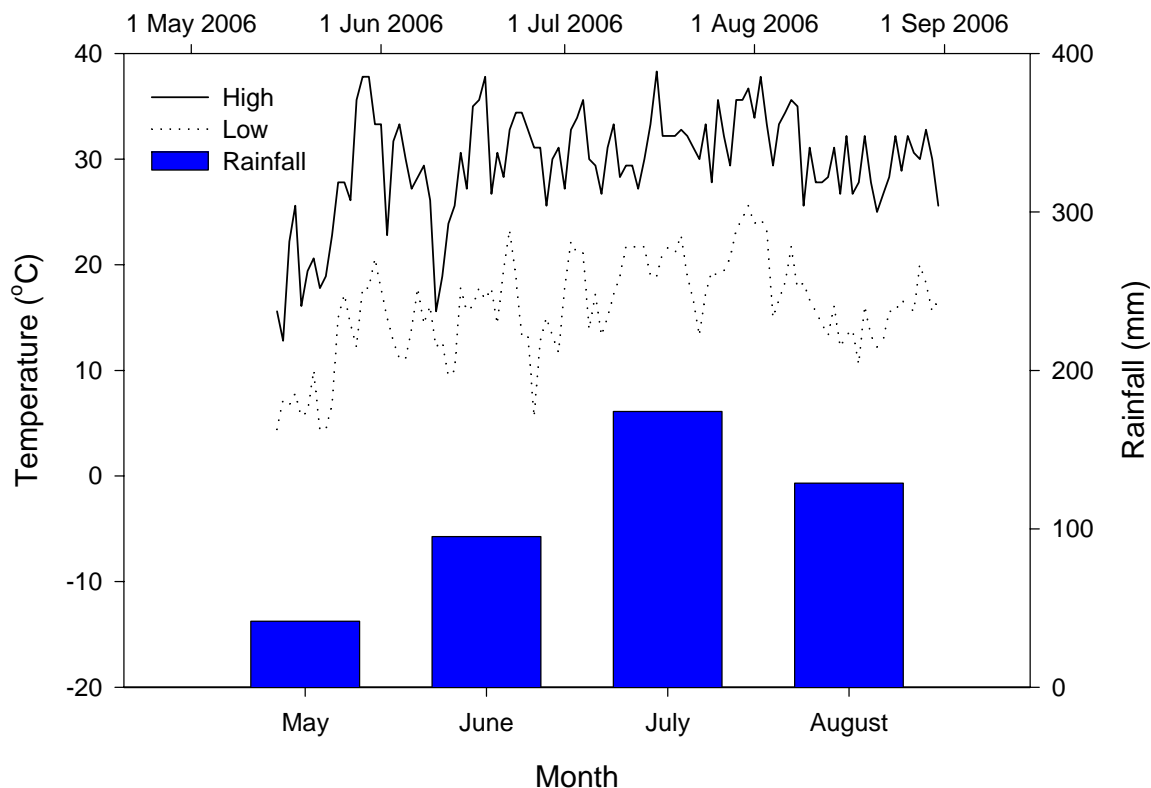
To evaluate the effects of various commercially available and experimental soil surfactants for improving creeping bentgrass performance and management of soil hydrophobicity on a sand-based rootzone.

### **Experimental Procedures:**

This field experiment was conducted from 23 May – 31 Aug., 2006 at the W.H. Daniel Turfgrass Research and Diagnostic Center in West Lafayette, IN on a mature eight year-old creeping bentgrass ‘Pennlinks’ research putting green being grown on a sand-based rootzone and an adjacent Purdue University golf course practice green. Management practices for these areas were daily tri-plex mowing at 0.140 inches with clippings removed, approximately 2.5 lbs N/1000 ft<sup>2</sup> yr<sup>-1</sup> and irrigation to prevent stress. Treatments were initiated on 23 May, 7 day treatments were reapplied on 1 June and monthly treatments reapplied on 23 June and 21 July as specified by the research protocol. All treatments were applied with a pressurized CO<sub>2</sub> (35 psi) sprayer equipped with TeeJet XR 8010E tips calibrated to deliver 2.0 gallons of spray volume per 1000 ft<sup>2</sup>. The exact chemical rates and dates of all applications are noted in each data table. Plots were 5 ft x 5 ft and arranged in a randomized complete block with three replications of each treatment. Each set of treatments were applied in the morning and the entire study area was then irrigated by overhead irrigation to supply approximately 0.25 inches of water within 30 minutes of treatment application. The soil moisture status prior to each application was adequate and the turf never appeared under severe environmental stress at the time of any treatment application.

Throughout the study the plots were visually assessed for turfgrass quality using a 0-10 scale with 0=brown dead turf, 10=optimum greenness, density and uniformity and  $\geq 7$  = acceptable putting green turf. Chemical phytotoxicity was visually rated on a 0-10 scale where 10 = severe injury and substantial turf yellowing and 0= no injury. Canopy greenness was quantified using a hand-held reflectance meter (FieldScout CM-1000, Spectrum Technologies Inc.). Five measurements were taken per plot using a systematic grid pattern which measured the four corners and center regions of each plot. These five measurements were averaged to produce a single plot measurement and are reported as a unitless color index. The soil water content in the upper 2 inches of the rootzone was measured at least twice weekly throughout the study using a portable moisture sensor (Pogo Soil Moisture Sensor, Stevens Water Monitoring Systems, Inc., Beaverton, OR). Five measurements were recorded per plot using a systematic grid patten described previously and averaged into a single value. The ability of the surfactants to improve and/or sustain the wetting of the sand-based rootzone media with depth (0-6 cm) was determined throughout the study using the water droplet penetration method. Four soil cores were removed from each plot on 23 May, prior to treatment application, selected plots on 13 June and all plots on 3 and 27 July and 31 August. Cores were air dried for a minimum of 14 days and approximately 1 mL of distilled, deionized water was placed at 1 cm depths from 0-6 cm across the core. The severity of hydrophobicity is based on the following scale where: 0-5 sec = wetttable, 6-60 sec = slightly hydrophobic, 61-600 = hydrophobic, and > 600 = water repellent. The visual and rootzone moisture content

portions of this study were conducted on the research green, whereas the assessment of soil hydrophobicity was conducted on the adjacent golf practice green. This alternative location was selected because of its higher soil organic matter content which may have made the rootzone more conducive to the development of hydrophobic conditions. The physical and chemical properties of each rootzone are detailed in Table 1. All data was subjected to analysis of variance using the SAS system (Statistical Analysis Systems Institute Inc., Cary, N.C.) and treatment means separated using Fisher's protected least significant difference (LSD) test at the ( $p=0.05$ ) level. Daily weather conditions were recorded throughout the study using Purdue University's automated local weather stations.



**Figure 1.** Maximum and minimum daily temperatures and monthly rainfall during 2006.

**Results:**

**Visual appearance ratings, canopy greenness and soil water content measurements**

Significant differences in visual appearance or turfgrass quality (TQ) were observed for the various soil surfactants tested with values ranging from 5.5 to 9.0 (Table 2). The mean TQ values for the study ranged from 7.4 to 7.9 with all products resulting in a mean TQ value that would be considered acceptable ( $TQ \geq 7.0$ ). Two products, Revolution (ACA 1820) and ACA 2634 all ranked in the highest statistical category for TQ as well as the untreated control. The two previously mentioned products were not different than Affinity or ACA 2540. Early in the study, 27 – 6 June, a significant decline in TQ was observed for several products; Tri-cure, Capacity, Cascade Plus, ACA 1935 and ACA 1936. All products affect the dew pattern of the turf following application (Figure 2). The decline in TQ for some products, however, was primarily attributed to significant

chemical phytotoxicity which appeared as very mild to severe yellowing (Figure 3) of the plots (Table 3) which ranged from 0.2 to 4.3 and varied by product, application rate and rating date. The products with the least noticeable injury following initial application rated on 27 May were Affinity, Revolution, ACA 1936, ACA 2540, and ACA 2634. Moderate injury, highly noticeable yellowing, resulted from Tri-cure, ACA 1935 and Capacity and Cascade Plus at their initial 8 oz rate. The most injurious products were Capacity and Cascade Plus both at the 16 oz rate single applications. These products caused severe, sustained yellowing and a noticeable loss in turf vigor that persisted for nearly two weeks following application and last observed on 13 June. This response was most likely due to true chemical phytotoxicity and not a combination of chemical and environmental stress since the air temperatures at application were 75 and 71 °F with light cloud cover on 23 May and 1 June, respectively. This yellowing was reflected in the canopy greenness values during this period with lower color index values for those treatments with increased phytotoxicity ratings (Table 4). In addition, other factors such as the severity of localized dry spot (LDS) also influenced TQ ratings (Table 5). LDS was most severe on 28 July ranging from 0 – 20 % of plot areas affected, however, no product was consistently superior to the untreated turf for prevention of LDS. Although previous reports have demonstrated the benefits of soil surfactants for the management of LDS in sand-based rootzones, this response was not observed in this particular study. The primary explanation for this result could be the frequent summer rainfall throughout much of late-June and July (Figure 1). For example 1.5 inches (38 mm) or rainfall had occurred immediately prior to the 11 August rating where LDS only ranged from 0-4 % compared to the 7 Aug. rating date where LDS ranged from 1-13 % and the significant rainfall events probably account for the relatively high soil moisture values throughout much of the study (Figure 4, Table 6). Surprisingly the high soil moisture values were most frequently observed in the untreated plots with volumetric soil content only falling below 20% on three dates, 2, 19 and 21 August. The driest period occurred from 26 July through 7 August, with soil moisture values ranging from 13.2 to 20.9 %. Although there were significant product differences from the untreated control, differences among specific surfactant products were inconsistent.

### **Sand-based rootzone water repellency measurements**

There were highly variable and significant differences observed among products evaluated and measurement dates and depths. Water droplet penetration times (WDPT) ranged from < 1 sec to 658 sec depending upon depth, measurement date and specific product (Table 7) The differences measured were primarily confined to the upper 2 cm depth. At the initial measurement date, 23 May, immediately prior to the application of any surfactant there was no difference among the research plots and all plots at the 0-2 cm depth would be classified as hydrophobic, WDPT > 60 sec. By 13 June, 21 days after application when selected treatments were measured the WDPT had significantly decreased compared to the untreated, 164 sec, with all four Capacity and Cascade Plus treatments at the 0 cm depth resulting in WDPT ≤ 8 sec. At the 1 cm depth all products except Affinity had significantly reduced water repellency compared to the untreated, 180 seconds.

By 3 July, all surfactant treated plots had received two product applications which resulted in significantly higher WDPT and less water repellency in all surfactant treated turf compared to the untreated, 658 sec, except for ACA 2540 which had a WDPT of 463 seconds. Eight surfactants were in the top statistical category with WDPT that would be classified as only “slight” water repellency, or times ranging from 6-60 sec. There were no treatment differences measured at the 1 cm, however, at the 2 cm depth all plots would

be classified “hydrophobic”, WDPT 61-600 sec., and no surfactant treatment was different than the untreated, which had a WDPT of 184 seconds.

On the 27 July, six days following the third 28 day treatment, differences in water repellency were only occurred at the 0 cm depth and all treatments were superior to the untreated which had a WDPT of 372 seconds. Nine of the eleven surfactants were in the top statistical category for reducing WDPT with WDPT ranging from 29-73 seconds. From 3 July to 27 July a general increase in water repellency was measured at the 3 cm depth for several treatments including Tri-Cure, Cascade Plus, 7 + 7 day, ACA 1820, ACA 1935, and ACA 2634.

### **Acknowledgements**

This research was made possible by grant-in-aid support from Aquatrols Corp., Becker Underwood, and the Mid-West Regional Turf Foundation. Sincere gratitude is expressed to Hummel & Co., Trumansburg, NY for conducting the sand-based rootzone physical property analysis.



**Figure 2.** Altered dew pattern of creeping bentgrass putting green turf as affected by the application of various soil surfactants, 27 May, 2006.



**Figure 3.** Comparative yellowing of creeping bentgrass putting green turf resulting from the application of various soil surfactants, 1 June, 2006.



**Figure 4.** Improved appearance of creeping bentgrass putting green turf (center of photo and left) compared to the adjacent untreated border (far right) as a result of various soil surfactant applications, 16 Aug., 2006.

**Table 1.** Physical properties of the sand-based rootzones used for the wetting agent evaluations.

Sample	Soil Separate (%)			Sieve Size/Sand Fraction Sand Particle Diameter % Retained						
	Sand	Silt	Clay	No. 10 Gravel (2mm)	No. 18 V. Coarse (1 mm)	No. 35 Coarse (0.5 mm)	No. 60 Medium (0.25 mm)	No. 100 Fine (0.15 mm)	No. 140 V. fine (0.1 mm)	No. 270 V. fine (0.05 mm)
Research Green	95.2	2.8	1.8	0.2	2.9	21.9	53.3	14.9	1.6	0.6
Practice Green	94.5	3.2	1.8	0.5	3.9	21.2	52.0	15.2	1.6	0.6
<b>USGA Recommendations</b>		≤ 5 %	≤ 3 %	≤ 3 % gravel ≤ 10 % combined		≥ 60 %		≤ 20 %	≤ 5 %	

Particle Shape/Particle Size Parameters/pH

Sample	Sphericity/Angularity	pH	D85	Cu	Gradation Index
Research Green	Low to high/sub-angular to well rounded	7.5	0.60	2.21	3.8
Practice Green	Low to high/sub-angular to well rounded	7.3	0.62	2.27	4.0

Physical properties of undisturbed cores (according to ASTM F-1815-97, modified for undisturbed cores)

Sample	Particle Density (g/cc)	Bulk Density (g/cc)	Ksat Infiltration Rate (in/hr)	Total Porosity (%)	Aeration Porosity (%)	Capillary Porosity † (%)	Organic Matter ‡ (% by weight)
Research Green	2.66	1.34	14.7	49.6	34.3	15.3	2.32
Practice Green	2.65	1.25	6.0	52.8	18.2	34.7	3.26
	<b>Desired values</b>		> 6.0	35-55	15-30	15-25	

† Determined at -40 cm tension

‡ Determined by Method 1 of ASTM F-1647

**Table 2.** Creeping bentgrass turfgrass quality grown on a sand-based research putting green as affected by various soil surfactant applications.

Trt†	Product	Application	Application	23 May	27 May	1 June	6 June	9 June	13 June
		Rate	Interval						
		oz/1000 ft <sup>2</sup>		----- Visual quality rating (0-10 scale) ‡-----					
1	Affinity	6 + 4 + 4	monthly	9.0 a*	8.5 a	8.5 a	8.5 a	8.7 a	8.5 a
2	Tri-cure	6 + 4 + 4	monthly	9.0 a	7.1 b	7.3 b	7.3 c	8.7 a	8.2 ab
3	Capacity	8 + 8	Initial + 7 day	9.0 a	7.1 b	7.3 b	7.5 c	7.7 b	8.2 ab
4	Cascade Plus	8 + 8	Initial + 7 day	9.0 a	7.2 b	7.3 b	7.0 c	7.3 b	8.3 ab
5	Capacity	16	Once	9.0 a	6.5 c	7.0 cd	7.3 c	8.3 a	7.8 b
6	Cascade Plus	16	Once	9.0 a	6.5 c	6.8 d	7.2 c	7.7 b	8.0 ab
7	Revolution	6	monthly	8.7 a	8.3 a	8.5 a	8.5 a	8.7 a	8.3 ab
8	ACA 1935	4	monthly	8.8 a	7.1 b	7.2 bc	7.4 c	8.5 a	8.0 ab
9	ACA 1936	4	monthly	8.8 a	7.3 b	7.4 b	7.5 c	8.8 a	8.0 ab
10	ACA 2540	6	monthly	8.8 a	8.5 a	8.5 a	8.0 b	8.8 a	8.5 a
11	ACA 2634	6	monthly	8.8 a	8.3 a	8.3 a	8.0 b	8.5 a	8.3 ab
12	Untreated	---	---	8.8 a	8.5 a	8.5 a	8.3 ab	8.7 a	8.5 a

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and 28-day, monthly treatments were reapplied on 23 June and 21 July, 2006. All products were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Turfgrass quality was visually rated on a 0-10 scale where 0 equals brown, dead turf, 10 equals optimum greenness and uniformity and values  $\geq 7$  equal acceptable putting green turf.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 2 cont.**

Trt‡	Product	Application Rate oz/1000 ft <sup>2</sup>	Application Interval	20 June	27 June	8 July	14 July	24 July	4 Aug.
				----- Visual quality rating (0-10 scale) †-----					
1	Affinity	6 + 4 + 4	monthly	8.5 b*	8.3 a	7.2 a	6.8 ab	6.0 bc	6.0 ab
2	Tri-cure	6 + 4 + 4	monthly	8.7 a	8.3 a	7.2 a	6.7 b	5.5 c	5.8 b
3	Capacity	8 + 8	Initial + 7 day	8.5 ab	8.3 a	7.2 a	6.8 ab	5.7 bc	6.0 ab
4	Cascade Plus	8 + 8	Initial + 7 day	8.5 ab	8.3 a	7.3 a	7.2 ab	6.5 abc	6.3 ab
5	Capacity	16	Once	8.2 bc	8.3 a	7.2 a	6.7 b	6.2 bc	6.2 ab
6	Cascade Plus	16	Once	8.0 c	8.5 a	7.3 a	7.0 ab	6.7 ab	6.5 ab
7	Revolution	6	monthly	8.3 bc	8.3 a	7.3 a	6.8 ab	6.5 abc	6.0 ab
8	ACA 1935	4	monthly	8.2 bc	8.3 a	7.2 a	6.8 ab	6.0 bc	6.0 ab
9	ACA 1936	4	monthly	8.0 c	8.3 a	7.0 a	6.7 b	6.3 abc	6.5 ab
10	ACA 2540	6	monthly	8.5 ab	8.2 a	7.0 a	6.7 b	6.0 bc	6.0 ab
11	ACA 2634	6	monthly	8.5 ab	8.0 a	7.0 a	6.7 b	6.7 ab	6.7 a
12	Untreated	---	---	8.5 ab	8.2 a	7.2 a	7.3 a	7.3 a	6.5 ab

Trt	Product	Application Rate	Application Interval	12 Aug.	22 Aug.	2 Sept.	Study Mean
1	Affinity	6 + 4 + 4	monthly	7.3 ab	7.3 a	7.2 b	7.7 b
2	Tri-cure	6 + 4 + 4	monthly	7.0 b	6.7 b	7.3 b	7.4 c
3	Capacity	8 + 8	Initial + 7 day	7.3 ab	7.3 a	7.5 ab	7.4 c
4	Cascade Plus	8 + 8	Initial + 7 day	7.3 ab	7.3 a	7.7 ab	7.5 c
5	Capacity	16	Once	7.5 ab	7.5 a	7.8 ab	7.4 c
6	Cascade Plus	16	Once	7.7 ab	7.7 a	7.7 ab	7.5 c
7	Revolution	6	monthly	7.7 ab	7.7 a	7.3 ab	7.8 ab
8	ACA 1935	4	monthly	7.7 ab	7.5 a	7.3 ab	7.5 c
9	ACA 1936	4	monthly	7.7 ab	7.5 a	7.2 ab	7.5 c
10	ACA 2540	6	monthly	7.7 ab	7.5 a	7.5 ab	7.7 b
11	ACA 2634	6	monthly	8.0 a	7.5 a	7.5 ab	7.8 ab
12	Untreated	---	---	7.8 ab	7.2 ab	7.8 a	7.9 a

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Turfgrass quality was visually rated on a 0-10 scale where 0 = brown, dead turf, 10 = optimum greenness and uniformity  $\geq 7$  acceptable.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 3.** Creeping bentgrass phytotoxicity as affected by various soil surfactants on a sand-based research putting green.

Trt†	Product	Application	Application	27 May	29 May	1 June	3 June	6 June	13 June
		Rate	Interval						
				----- Visual rating (0-10 scale) ‡-----					
1	Affinity	6 + 4 + 4	monthly	0.0 f *	0.3 d	0.0 e	0.0 b	0.0 b	0.0 b
2	Tri-cure	6 + 4 + 4	monthly	1.7 d	0.7 cd	0.2 de	0.2 b	0.1 b	0.0 b
3	Capacity	8 + 8	Initial + 7 day	1.3 d	1.3 bc	0.3 cde	1.3 a	1.3 a	0.1 a
4	Cascade Plus	8 + 8	Initial + 7 day	2.3 c	2.0 b	0.8 c	1.2 a	1.8 a	0.2 a
5	Capacity	16	Once	3.0 b	3.7 a	2.8 b	1.0 a	1.2 a	0.1 a
6	Cascade Plus	16	Once	4.0 a	4.3 a	4.0 a	1.3 a	1.2 a	0.2 a
7	Revolution	6	monthly	0.7 e	0.7 cd	0.0 e	0.0 b	0.0 b	0.0 b
8	ACA 1935	4	monthly	2.3 c	0.5 cd	0.7 cd	0.3 b	0.2 b	0.0 b
9	ACA 1936	4	monthly	0.7 e	0.0 d	0.0 e	0.0 b	0.0 b	0.0 b
10	ACA 2540	6	monthly	0.0 f	0.0 d	0.2 de	0.0 b	0.0 b	0.0 b
11	ACA 2634	6	monthly	0.0 f	0.7 cd	0.0 e	0.0 b	0.0 b	0.0 b
12	Untreated	---	---	0.0 f	0.7 cd	0.0 e	0.0 b	0.0 b	0.0 b

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Chemical phytotoxicity was visually rated on a 0-10 scale where 0 = no injury and 10 = severe canopy chlorosis and leaf bronzing.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 4.** Creeping bentgrass canopy greenness when grown on a sand-based rootzone and affected by various soil surfactant applications.

Trt†	Product	Application Rate oz/1000 ft <sup>2</sup>	Application Interval	29 May	2 June	9 June	13 June	7 July	16 July
				color index (spectrum units) ‡					
1	Affinity	6 + 4 + 4	monthly	282 ab*	281 ab	285 ab	292 a	320 a	334 a
2	Tri-cure	6 + 4 + 4	monthly	280 ab	280 abc	281 bc	286 a	311 a	317 abc
3	Capacity	8 + 8	Initial + 7 day	267 bc	263 de	265 d	288 a	316 a	313 c
4	Cascade Plus	8 + 8	Initial + 7 day	284 ab	272 bcd	278 bc	293 a	307 a	315 c
5	Capacity	16	Once	251 cd	270 cde	294 a	292 a	316 a	323 abc
6	Cascade Plus	16	Once	239 d	260 e	279 bc	291 a	320 a	319 abc
7	Revolution	6	monthly	269 bc	279 abc	275 bcd	284 a	319 a	326 abc
8	ACA 1935	4	monthly	275 b	279 abc	277 bcd	285 a	312 a	333 ab
9	ACA 1936	4	monthly	296 a	286 a	282 abc	289 a	313 a	317 abc
10	ACA 2540	6	monthly	285 ab	281 abc	274 bcd	286 a	308 a	311 c
11	ACA 2634	6	monthly	277 ab	276 abc	270 cd	277 a	310 a	316 bc
12	Untreated	---	---	282 ab	281 abc	278 bc	278 a	319 a	327 abc

Trt	Product	Application Rate oz/1000 ft <sup>2</sup>	Application Interval	21 July	30 July	11 Aug.	19 Aug.	31 Aug.	Study Mean
				color index (spectrum units) -----					
1	Affinity	6 + 4 + 4	monthly	307 ab	295 ab	284 d	271 b	294 c	295 abc
2	Tri-cure	6 + 4 + 4	monthly	306 ab	289 b	285 cd	281 ab	298 abc	292 bc
3	Capacity	8 + 8	Initial + 7 day	303 b	304 ab	291 bcd	289 ab	301 abc	291 bc
4	Cascade Plus	8 + 8	Initial + 7 day	306 ab	300 ab	297 abcd	287 ab	295 bc	294 abc
5	Capacity	16	Once	313 ab	305 a	296 abcd	290 ab	306 abc	296 abc
6	Cascade Plus	16	Once	314 a	309 a	308 a	300 a	309 ab	295 abc
7	Revolution	6	monthly	304 ab	303 ab	297 abcd	293 a	300 abc	295 abc
8	ACA 1935	4	monthly	306 ab	299 ab	291 bcd	290 ab	293 c	294 abc
9	ACA 1936	4	monthly	311ab	308 a	296 abcd	295 a	300 abc	299 ab
10	ACA 2540	6	monthly	309 ab	296 ab	299 ab	293 a	300 abc	295 abc
11	ACA 2634	6	monthly	312 ab	310 a	299 ab	299 a	297 abc	295 abc
12	Untreated	---	---	314 ab	307 a	303 ab	295 a	310 a	300 a

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. Treatments were applied in 2 gal. spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Greenness was measured using a hand-held reflectance meter (CM-1000) with five measurements per plot recorded in a systematic grid pattern.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 5.** Localized dry spot severity in a sand-based rootzone treated with various soil surfactants.

Trt†	Product	Application Rate	Application Interval	28 July	7 Aug.	11 Aug.	19 Aug.	27 Aug.
				----- LDS severity (0-100 %) ‡ -----				
1	Affinity	6 + 4 + 4	monthly	12.7 ab*	10.3 ab	3.3 ab	5.0 a	3.3 ab
2	Tri-cure	6 + 4 + 4	monthly	20.0 a	12.7 a	4.3 a	5.0 a	6.7 a
3	Capacity	8 + 8	Initial + 7 day	11.0 ab	6.0 abc	2.7 ab	1.7 ab	2.7 ab
4	Cascade Plus	8 + 8	Initial + 7 day	5.0 b	4.3 abc	1.7 ab	2.3 ab	3.7 ab
5	Capacity	16	Once	6.7 b	4.3 abc	0.3 b	1.0 b	2.3 b
6	Cascade Plus	16	Once	2.7 b	2.7 bc	0.7 b	0.3 b	1.0 b
7	Revolution	6	monthly	4.3 b	6.0 abc	1.0 ab	2.3 ab	1.7 b
8	ACA 1935	4	monthly	10.0 ab	6.0 abc	0.3 b	1.7 ab	4.3 ab
9	ACA 1936	4	monthly	3.7 b	2.7 bc	0.3 b	1.0 b	0.3 b
10	ACA 2540	6	monthly	6.0 b	5.0 abc	0.0 b	1.0 b	3.3 ab
11	ACA 2634	6	monthly	2.7 b	2.7 bc	0.0 b	0.3 b	1.3 b
12	Untreated	---	---	0.0 b	1.0 c	0.3 b	2.7 ab	1.3 b

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Localized dry spot was rated on a 0-100 % linear scale where 0 equals no visible symptoms and 100 equals complete plot affected.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 6.** Soil water content of a sand-based research putting green as affected by various soil surfactant applications.

Trt†	Product	Application	Application	14 June	19 June	23 June	26 June	28 June	3 July
		Rate	Interval						
		oz/1000 ft <sup>2</sup>		----- Volumetric water content (%)‡-----					
1	Affinity	6 + 4 + 4	monthly	20.1 a*	22.6 a	23.1 a	22.6 bc	21.3 a	27.2 a
2	Tri-cure	6 + 4 + 4	monthly	21.5 a	22.2 a	22.7 a	22.3 bc	22.1 a	26.2 a
3	Capacity	8 + 8	Initial + 7 day	20.8 a	23.1 a	22.2 a	23.9 abc	21.5 a	27.4 a
4	Cascade Plus	8 + 8	Initial + 7 day	21.3 a	23.1 a	23.7 a	22.7 bc	22.5 a	26.1 a
5	Capacity	16	Once	20.3 a	22.4 a	22.6 a	22.5 bc	21.7 a	26.3 a
6	Cascade Plus	16	Once	19.9 a	22.1 a	22.7 a	23.9 abc	22.2 a	27.4 a
7	Revolution	6	monthly	21.1 a	22.6 a	22.3 a	23.0 abc	21.3 a	26.0 a
8	ACA 1935	4	monthly	19.8 a	22.5 a	21.9 a	22.2 c	21.4 a	26.6 a
9	ACA 1936	4	monthly	20.9 a	23.4 a	23.4 a	24.3 ab	22.5 a	26.8 a
10	ACA 2540	6	monthly	22.6 a	23.3 a	23.1 a	23.1 abc	22.8 a	28.1 a
11	ACA 2634	6	monthly	21.0 a	23.7 a	22.3 a	23.8 abc	21.9 a	27.3 a
12	Untreated	---	---	22.5 a	24.0 a	23.3 a	24.8 a	23.4 a	28.1 a

Trt	Product	Application	Application	7 July	24 July	26 July	31 July	2 Aug.	7 Aug.
		Rate	Interval						
		oz/1000 ft <sup>2</sup>		----- Volumetric water content (%)‡-----					
1	Affinity	6 + 4 + 4	monthly	25.4 bcd	17.7 bc	15.0 b	16.5 d	13.5 d	13.9 c
2	Tri-cure	6 + 4 + 4	monthly	24.8 cd	18.1 bc	15.6 b	16.3 d	13.2 d	15.4 bc
3	Capacity	8 + 8	Initial + 7 day	25.9 abcd	18.2 bc	16.0 b	18.6 abcd	16.1 abcd	17.2 abc
4	Cascade Plus	8 + 8	Initial + 7 day	25.5 bcd	18.2 bc	16.3 b	17.4 d	14.8 bcd	15.5 abc
5	Capacity	16	Once	25.4 bcd	19.5 abc	16.8 ab	18.1 abcd	15.8 abcd	17.8 abc
6	Cascade Plus	16	Once	26.0 abcd	19.1 abc	18.1 ab	18.5 abcd	16.9 abcd	17.8 abc
7	Revolution	6	monthly	24.9 cd	17.5 bc	15.7 b	17.0 d	14.0 cd	15.6 abc
8	ACA 1935	4	monthly	24.4 abc	17.1 c	16.3 b	17.5 cd	15.6 abcd	16.0 abc
9	ACA 1936	4	monthly	26.6 ab	22.9 a	20.5 a	20.5 abc	17.9 ab	19.6 a
10	ACA 2540	6	monthly	26.8 ab	19.4 abc	17.5 ab	17.8 bcd	16.5 abcd	17.6 abc
11	ACA 2634	6	monthly	25.7 abcd	20.8 abc	18.9 ab	20.6 ab	17.4 abc	18.7 ab
12	Untreated	---	---	27.6 a	21.7 ab	20.5 a	20.9 a	18.7 a	18.8 ab

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. ‡ Soil water content in the upper 2 inches was measured with a portable soil moisture probe at five locations per plot on a systematic grid pattern.. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application. \* Means in the same column followed by the same letter are not significantly different according to Fishers protected LDS (p=0.05).

**Table 6 cont.**

Trt†	Product	Application	Application	11 Aug.	15 Aug.	19 Aug.	21 Aug.	31 Aug.
		Rate	Interval					
		oz/1000 ft <sup>2</sup>	----- Volumetric water content (%)‡ -----					
1	Affinity	6 + 4 + 4	monthly	18.8 c	16.6 c	17.1 d	17.0 ab	20.4 ab
2	Tri-cure	6 + 4 + 4	monthly	19.8 bc	18.0 bc	17.5 d	16.1 ab	19.8 b
3	Capacity	8 + 8	Initial + 7 day	21.8 abc	19.5 abc	19.2 abcd	18.5 ab	20.7 ab
4	Cascade Plus	8 + 8	Initial + 7 day	21.4 abc	19.0 abc	18.5 cd	17.2 ab	20.6 ab
5	Capacity	16	Once	21.4 abc	18.9 abc	18.2 cd	16.8 ab	20.9 ab
6	Cascade Plus	16	Once	22.4 ab	20.3 abc	20.9 abc	18.2 ab	21.7 ab
7	Revolution	6	monthly	21.4 abc	18.6 abc	18.9 abcd	16.6 ab	20.1 ab
8	ACA 1935	4	monthly	21.1 abc	18.4 abc	18.7 bcd	15.6 b	21.1 ab
9	ACA 1936	4	monthly	23.7 a	22.1 a	22.2 a	19.5 a	22.4 ab
10	ACA 2540	6	monthly	20.3 abc	18.9 abc	18.6 bcd	17.6 ab	21.2 ab
11	ACA 2634	6	monthly	23.6 a	22.0 a	21.9 ab	19.6 a	22.3 ab
12	Untreated	---	---	22.8 ab	21.0 ab	19.9 abcd	19.3 ab	22.8 a

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Soil water content in the upper 2 inches was measured with a portable soil moisture probe at five locations per plot on a systematic grid pattern.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 7.** Water droplet penetration times of sand-based rootzone cores as affected by various soil surfactant applications

Trt†	Product	Application Rate	Application Interval	Soil depth (cm)						
				0	1	2	3	4	5	6
				----- seconds ‡ -----						
				<b>23 May</b>						
1	Affinity	6 + 4 + 4	monthly	423 a*	447 a	317 a	76 a	8 a	6 a	3 a
2	Tri-cure	6 + 4 + 4	monthly	408 a	445 a	372 a	58 a	5 a	6 a	4 a
3	Capacity	8 + 8	Initial + 7 day	429 a	473 a	168 a	44 a	8 a	5 a	3 a
4	Cascade Plus	8 + 8	Initial + 7 day	372 a	356 a	245 a	49 a	4 a	3 a	3 a
5	Capacity	16	Once	435 a	359 a	168 a	59 a	18 a	6 a	4 a
6	Cascade Plus	16	Once	459 a	598 a	301 a	74 a	18 a	11 a	5 a
7	Revolution	6	monthly	366 a	493 a	205 a	44 a	17 a	7 a	4 a
8	ACA 1935	4	monthly	443 a	409 a	172 a	50 a	6 a	5 a	3 a
9	ACA 1936	4	monthly	158 a	508 a	233 a	93 a	9 a	5 a	3 a
10	ACA 2540	6	monthly	340 a	387 a	292 a	68 a	4 a	3 a	4 a
11	ACA 2634	6	monthly	339 a	351 a	267 a	175 a	8 a	5 a	4 a
12	Untreated	---	---	396 a	369 a	309 a	102 a	8 a	4 a	3 a
				<b>13 June</b>						
1	Affinity	6 + 4 + 4	monthly	66 c	39 bc	129 a	31 a	6 a	4 a	1 a
2	Tri-cure	6 + 4 + 4	monthly	25 b	17 ab	162 a	32 a	7 a	5 a	1 a
3	Capacity	8 + 8	Initial + 7 day	7 a	10 ab	25 a	25 a	8 a	3 a	1 a
4	Cascade Plus	8 + 8	Initial + 7 day	8 a	3 a	25 a	25 a	8 a	4 a	1 a
5	Capacity	16	Once	6 a	3 a	34 a	21 a	6 a	3 a	1 a
6	Cascade Plus	16	Once	8 a	5 a	56 a	30 a	13 a	5 a	1 a
12	Untreated	---	---	164 d	180 c	91 a	17 a	5 a	4 a	1 a

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Water droplet penetration times are the back-transformed means (data transformed to log<sub>10</sub>) of four sub-samples per plot.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 7 cont.**

Trt†	Product	Application Rate	Application Interval	Soil depth (cm)						
				0	1	2	3	4	5	6
				----- seconds ‡-----						
				<b>3 July</b>						
1	Affinity	6 + 4 + 4	monthly	27 ab*	30 a	473 d	118 a	10 a	6 a	2 a
2	Tri-cure	6 + 4 + 4	monthly	55 bc	39 a	471 d	68 a	13 a	5 a	3 a
3	Capacity	8 + 8	Initial + 7 day	25 ab	11 a	88 a	66 a	9 a	4 a	1 a
4	Cascade Plus	8 + 8	Initial + 7 day	47 abc	4 a	139 abc	274 a	6 a	3 a	1 a
5	Capacity	16	Once	47 abc	20 a	205 abcd	75 a	6 a	3 a	3 a
6	Cascade Plus	16	Once	78 c	20 a	121 abc	68 a	6 a	4 a	1 a
7	Revolution	6	monthly	19 a	29 a	333 cd	101 a	9 a	5 a	3 a
8	ACA 1935	4	monthly	22 a	82 a	189 abcd	44 a	13 a	6 a	3 a
9	ACA 1936	4	monthly	27 ab	36 a	107 ab	34 a	8 a	3 a	2 a
10	ACA 2540	6	monthly	463 d	98 a	497 d	180 a	12 a	4 a	2 a
11	ACA 2634	6	monthly	17 a	12 a	281 bcd	74 a	6 a	3 a	2 a
12	Untreated	---	---	658 d	479 a	184 abcd	28 a	6 a	3 a	2 a
				<b>27 July</b>						
1	Affinity	6 + 4 + 4	monthly	32 ab	189 a	423 a	115 a	29 a	6 a	4 a
2	Tri-cure	6 + 4 + 4	monthly	58 abc	44 a	391 a	70 a	7 a	6 a	3 a
3	Capacity	8 + 8	Initial + 7 day	66 abc	70 a	90 a	63 a	31 a	7 a	4 a
4	Cascade Plus	8 + 8	Initial + 7 day	94 bc	246 a	381 a	71 a	25 a	10 a	3 a
5	Capacity	16	Once	48 abc	73 a	213 a	49 a	10 a	7 a	4 a
6	Cascade Plus	16	Once	121 c	165 a	166 a	72 a	10 a	10 a	3 a
7	Revolution	6	monthly	29 a	164 a	190 a	128 a	11 a	7 a	3 a
8	ACA 1935	4	monthly	73 abc	90 a	256 a	97 a	41 a	9 a	3 a
9	ACA 1936	4	monthly	61 abc	332 a	267 a	45 a	18 a	8 a	4 a
10	ACA 2540	6	monthly	55 abc	318 a	215 a	119 a	11 a	4 a	3 a
11	ACA 2634	6	monthly	46 abc	94 a	252 a	119 a	11 a	7 a	3 a
12	Untreated	---	---	372 d	328 a	209 a	26 a	7 a	5 a	3 a

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Water droplet penetration times are the back-transformed means (data transformed to log<sub>10</sub>) of four sub-samples per plot.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).

**Table 7 cont.**

Trt†	Product	Application Rate	Application Interval	Soil depth (cm)						
				0	1	2	3	4	5	6
				----- seconds ‡ -----						
				<b>31 August</b>						
1	Affinity	6 + 4 + 4	monthly	61 cd	179 bc	169 a	9 a	7 a	4 a	1 a
2	Tri-cure	6 + 4 + 4	monthly	16 ab	367 d	275 a	14 a	8 a	4 a	2 a
3	Capacity	8 + 8	Initial + 7 day	108 d	195 bcd	198 a	12 a	8 a	3 a	2 a
4	Cascade Plus	8 + 8	Initial + 7 day	148 d	266 bcd	300 a	10 a	6 a	4 a	2 a
5	Capacity	16	Once	113 d	65 a	369 a	15 a	14 a	3 a	2 a
6	Cascade Plus	16	Once	118 d	259 bcd	176 a	23 a	9 a	2 a	1 a
7	Revolution	6	monthly	29 abc	202 bcd	90 a	10 a	7 a	3 a	2 a
8	ACA 1935	4	monthly	32 abc	208 bcd	61 a	9 a	8 a	4 a	1 a
9	ACA 1936	4	monthly	14 a	121 ab	175 a	14 a	8 a	3 a	2 a
10	ACA 2540	6	monthly	51 bcd	206 bcd	108 a	11 a	6 a	3 a	1 a
11	ACA 2634	6	monthly	27 abc	107 ab	138 a	11 a	7 a	3 a	1 a
12	Untreated	---	---	317 e	504 d	221 a	11 a	7 a	3 a	

† All treatments were initially applied on 23 May, treatments 3 and 4 were reapplied on 1 June and monthly treatments were reapplied on 23 June and 21 July, 2006. All treatments were applied in 2 gallons spray volume per 1000 ft<sup>2</sup> and irrigated into the rootzone immediately following application.

‡ Water droplet penetration times are the back-transformed means (data transformed to log<sub>10</sub>) of four sub-samples per plot.

\* Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (p=0.05).