Turfgrass and Environmental Research Online

...Using Science to Benefit Golf

Scientists conducted research at New Mexico State University during the summer months of 2003 and 2004 to investigate the effects of several wetting agents on sand-based root-zone hydrophobicity and putting green turf appearance.

Volume 6, Number 6
March 15, 2007

PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

Editor

Jeff Nus, Ph.D.
1032 Rogers Place
Lawrence, KS 66049
jnus@usga.org
(785) 832-2300
(785) 832-9265 (fax)

Research Director

Michael P. Kenna, Ph.D.
P.O. Box 2227
Stillwater, OK 74076
mkenna@usga.org
(405) 743-3900
(405) 743-3910 (fax)

Water Repellency in Sandy Rootzones Treated with Wetting Agents

Bernd Leinauer, Douglas Karcher, Ty Barrick, Yoshiaki Ikemura, Heidi Hubble, and Jose Makk

SUMMARY

A study was conducted at New Mexico State University during the summer months of 2003 and 2004 to investigate the effects of several wetting agents on sand-based rootzone hydrophobicity and putting green turf appearance. Results of the study include:

- The efficacy of wetting agents varied over depth and was most pronounced at depths of 2.5 cm or less.
- All treated plots with the exception of Naiad and Respond 2 plots exhibited lower water repellency than the untreated plots at a depth of 0.5 cm.
- Plots treated with Aqueduct and LescoFlo showed consistently lower water repellency at rootzone depths of 0.5, 1.5, and 2.5 cm than the untreated plots.
- Naiad-treated rootzones exhibited greater hydrophobicity at depths of 0.5, 1.5, 2.5 and 3.5 cm compared to the untreated rootzones.
- In 2003, plots treated with Brilliance, Cascade Plus, HydroWet, LescoFlo, and Primer Select had higher turfgrass quality than the untreated plots, while Naiad-treated plots showed lower quality and color ratings than other plots.
- There were no differences in color or quality among the treatments in 2004.

Water repellency or hydrophobicity is a widely reported phenomenon in agricultural and turfgrass soils (7). Severe hydrophobicity can reduce water percolation and infiltration to such an extent that even extremely long periods of irrigation are unsuccessful in wetting the soil. The soil properties associated with water repellency have major consequences on soil water retention, plant growth, and ultimately turfgrass appearance. Inhibited turf growth, increased run-off, uneven wetting patterns, preferential flow, and accelerated leaching of applied fertilizers and chemicals are all a result of hydrophobic soil conditions (17). Soil repellency can be attributed to hydrophobic compounds present either in the soil as interstitial matter or on soil mineral or aggregate surfaces (9, 10, 26). The hydrophobic organic compounds are released from roots (6, 8), fungal or microbial by-products (13, 24), or can be produced directly by decomposing organic matter (20).

Localized Dry Spot (LDS), a major problem in turf areas, is a condition characterized by irregular areas of stressed turf and results from hydrophobic conditions present in turfgrass rootzones. The sandy nature of turfgrass rootzones like golf greens and tees further promotes the occurrence of LDS, as susceptibility to water repellency development is particularly pronounced in coarse textured soils (9). LDS causes turfgrass quality deterioration and increased irrigation water use as turfgrass managers react to drought stressed turf by increasing irrigation vol-

Researchers at New Mexico State University investigated the effects of wetting agents on soil hydrophobicity and color and quality of turf grown in a sandy rootzone in that arid climate.

BERND LEINAUER, Ph.D., Department of Extension Plant Sciences, New Mexico State University, Las Cruces; DOUGLAS KARCHER, Ph.D., Department of Horticulture, University of Arkansas, Fayetteville; and TY BARRICK, Department of Extension Plant Sciences, YOSHIAKI IKEMURA, Department of Plant and Environmental Sciences, and HEIDI HUBBLE, and JOSE MAKK, Department of Extension Plant Sciences, New Mexico State University, Las Cruces.

USGA Turfgrass and Environmental Research Online 6(6):1-9.
TGIF Record Number: 123686

Product	Application rate	Spray volume	Application frequency
	(liters)	(liters/1000 m²)	(DAT)
Aqueduct	0.24	40.7	0, 7, 28, and 56
Brilliance	0.24	81.5	0 and 10
Cascade Plus	0.24	81.5	0 and 10
HydroWet	0.24	407.5	0 and 14
	0.06	203.7	28, 42, and 56
LescoFlo	0.24	407.5	0, 14, 28, 42, and 56
Naiad	0.24	407.5	0 and 14
	0.17	407.5	42
Primer Select	0.17	81.5	0, 28, and 56
Respond 2	0.30	326.0	0 and 56
Surfside 37	0.94	407.5	0
	0.12	407.5	14, 28, 42, and 56
Tri-Cure	0.17	81.5	0, 28, and 56

Table 1. Application rates (liters),spray volumes (liters per 1000 m²) and application frequency (DAT) for products included in the study

ume and application frequency.

Surfactants, wetting agents, or (soil) penetrants are terms used to describe surface-active materials that lower interfacial tension between a hydrophilic and a hydrophobic condition. Surfactants aid in combating LDS by re-wetting the rootzone and increasing moisture retention (2,19,21), which results in improved turf vigor and quality (4,23). The application of surfactants, particularly nonionic block copolymer surfactants, has been the traditional tool to manage localized dry spot in soils (17). Approximately 80% of all golf course superintendents in the United States use wetting agents as part of their regular maintenance programs (12,14).

Numerous products are currently used by turf managers throughout the US, despite the lack of research results from multi-year studies on the efficacy of surfactants to mitigate water repellency and LDS. Results from studies that examined efficacy of soil surfactants have been inconsistent. Whereas some studies suggested wetting agents reduced both LDS and water repellency (4), others found that surfactants decreased repellency but not localized dry spots (3).

Karnok and Tucker (15,16) also showed a decrease in water repellency after wetting agents were applied but did not test for localized dry spot. Bigelow et al. (1) and Park (23) reported a decrease in localized dry spot after the application of wetting agents but no reduction in soil water repellency. All these studies were conducted on golf greens with sandy rootzones under a wide range of climatic conditions. Both Carey and Gunn (3) and Bigelow et al. (1) suspected wet and cool weather conditions were confounding factors influencing the outcome of these studies. Furthermore, these studies were carried out as single-year experiments.

We conducted a two-year study at New Mexico State University to investigate the effects of wetting agents on soil hydrophobicity and color and quality of turf grown in a sandy rootzone in an arid climate. The objective of the research was to determine if repeated applications of soil surfactants could prevent soil water repellency and improve turfgrass quality. The study was part of a nation-wide trial funded by the United States Golf Association and Golf Course Superintendents Association of America in which similar studies were conducted concurrently at several other universities across the country (25).

Project Site and Maintenance

The study was conducted during the summer months of 2003 and 2004 at New Mexico State University's golf course in Las Cruces, NM. Ten wetting agents commonly used in turfgrass management were applied to 1 by 3 meter plots on a practice putting green. Each treatment was replicated four times. The green was built in 1992 according to California specifications (5) with a 300-mm deep straight sand rootzone layer. The rootzone consisted of 96.3% sand (6.9% very coarse, 21.7% coarse, 44.6% medium, 17.6% fine, and 5.5% very fine), 1.4% silt, and 1.25% clay and had less than 1% organic matter accumulation when averaged over the 30-cm depth.

Turf cover on the green consisted of creeping bentgrass cv. Penncross, which was mowed daily at a height of 2.8 mm. During both years the green was fertilized with N at 30.5 g/m², P_2O_5 at 13 g/m², and K_2O at 49.9 g/m² and was irrigated every other day at 80% potential evapotranspiration (pET).

Wetting Agents Tested and Studied Effects

The wetting agents Aqueduct, Brilliance, Cascade Plus, HydroWet, LescoFlo, Naiad, Primer Select, Respond 2, Surfside 37, and Tri-Cure were applied according to label directions (Table 1). Untreated (control) plots received only water. All treatments were watered-in by hand immediately after application with the exception of Aqueduct, which was watered-in the following morning before mowing.

First treatments in 2003 and 2004 were applied on June 27 and May 17, respectively. Accumulated potential evapotranspiration for June 27 to August 21, 2003, was 540 mm and 510 mm for May 17 to July 11, 2004. No precipitation occurred during these periods.

Turfgrass color and quality ratings were taken every two weeks at 7, 21, 35, 49, and 63 days after the first treatment (DAT). Color ratings were taken on a scale from 1 to 9 with 1 = brown, 5 = medium green, and 9 = dark green. Turfgrass quality was also assessed visually every two weeks on a 1 to 9 scale where 1 = dead turf and 9 = dark green, uniform turf.

The water droplet penetration test (WDP) was used to measure rootzone hydrophobicity. Four cores, six cm long and two cm in diameter, were taken from each plot, air-dried for two weeks and tested for water repellency. The WDP was performed by placing a 36-microliter droplet of deionized water on the cores at depths of 0.5, 1.5, 2.5, 3.5, 4.5, and 5.5 centimeters (measured from the turf canopy of the core downwards), and recording the time in seconds for the droplet to infiltrate the surface. Any water droplet remaining after 600 seconds was recorded as 600 seconds. Rootzone hydrophobicity was determined prior to the first treatment application, referred to as zero days after first treatment (0 DAT) and at 14, 28, and 56 DAT (days after the first application) of the wetting agent in both years of the study.

The experimental design was a randomized complete block with surfactants as the main plot treatment and depth, days after first application (DAT), and year as subplot treatments. Data were subjected to analysis of variance using SAS Proc Mixed (SAS Institute Inc., Cary, NC) followed by multiple comparisons of means using Fisher's LSD test at the 0.05 probability level.

Turfgrass Color and Quality

Analysis of turfgrass color and quality revealed wetting agent by year interactions but no significant three-way interaction between wetting agent, year, and DAT. Therefore, treatment means for quality and color were pooled over DAT and are presented separately for each year (Table 2).

In 2003, plots treated with Brilliance, Cascade Plus, HydroWet, LescoFlo, and Primer Select rated higher for turfgrass quality than the untreated plot. Aqueduct, HydroWet, LescoFlo, Primer Select, and Tri-Cure rated higher for turfgrass color than the untreated plots in 2003 (Table 2). Naiad-treated plots ranked lower than the untreated plots in 2003 for quality and color. These findings agree with those of Frank and Bryan (11), who also reported lower quality ratings on Naiad-treated plots when compared to

Wetting Agent	Turfgrass Quality		Turfgrass Color	
	2003	2004	2003	2004
Aqueduct	6.4 bcBx	7.7 A	6.4 bcdB	7.7 A
Brilliance	6.8 ab	7.6	6.8 abcdB	7.7 A
Cascade Plus	6.6 abB	7.4 A	6.6 abcdB	7.4 A
Control	6.2 cB	7.9 A	6.2 dB	7.9 A
HydroWet	7.1 ab	7.6	7.1 abc	7.6
LescoFlo	7.3 a	7.8	7.3 a	7.9
Naiad	5.2 dB	7.3 A	5.2 eB	7.4 A
Primer Select	7.3 a	7.9	7.3 a	7.8
Respond 2	6.3 cB	7.6 A	6.3 cdB	7.8 A
Surfside 37	6.4 bcB	7.8 A	6.4 bcdB	7.8 A
Tri-Cure	7.2 abc	7.8	7.2 abB	7.9 A

[x] Values followed by the same letter are not significantly different from one another (Fisher's protected LSD, a = 0.05).
Lower case letters denote differences between wetting agents (in columns). Upper case letters denote differences between years for each wetting agent (in rows).

Table 2. Visual turfgrass quality and color ratings for 2003 and 2004. Data were pooled over 5 sampling dates in each year. Ratings were taken on a scale from 1 to 9 with 1 = worst, 9 = best and 6 = minimum acceptable color/quality.

other treatments.

With the exception of Naiad, all treated plots had ratings of greater than 6 (the minimum acceptable color and quality). Therefore, these wetting agents appeared to have no negative impact on greens when applied at label rate. In 2004, none of the treated plots differed in color and quality from the untreated plots and turfgrass color and quality increased from 2003 to 2004. Heavy rains in March of 2004 totaling 84 mm compared to the 30-year average of 5 mm (22) are most likely the cause of reduced rootzone hydrophobicity and subsequent increase in turfgrass color and quality compared to 2003.

Water Repellency Affected by Wetting Agent Treatments at Different Rootzone Depths

There was no interaction between wetting agent, depth, and DAT, or between wetting agent, year of treatment, and depth. Therefore water droplet penetration time data were pooled over DAT and year and presented as treatment means for each depth (Figure 1). Contrary to other studies in which repellency declined progressively with rootzone depth (3), plots in this study had a tendency for greater water repellency at a depth of 1.5 cm than at more shallow depths. Only in untreated plots and plots treated with Respond 2 was water droplet penetration time greater at a depth of 0.5 cm than at 1.5 cm (Figure 1).

At a soil depth of 0.5 cm all products with the exception of Naiad and Respond 2 exhibited lower water droplet penetration time than in the untreated plots. At a depth of 1.5 cm, Aqueduct, Brilliance, and LescoFlo reduced water repellency, while Naiad-treated plots showed greater water droplet penetration time compared to the untreated plots.

At 2.5-cm rootzone depths, Aqueduct and LescoFlo-treated plots exhibited less repellency compared to the untreated plots, while Naiad-treated plots showed greater droplet penetration time when compared to the untreated plots. At a

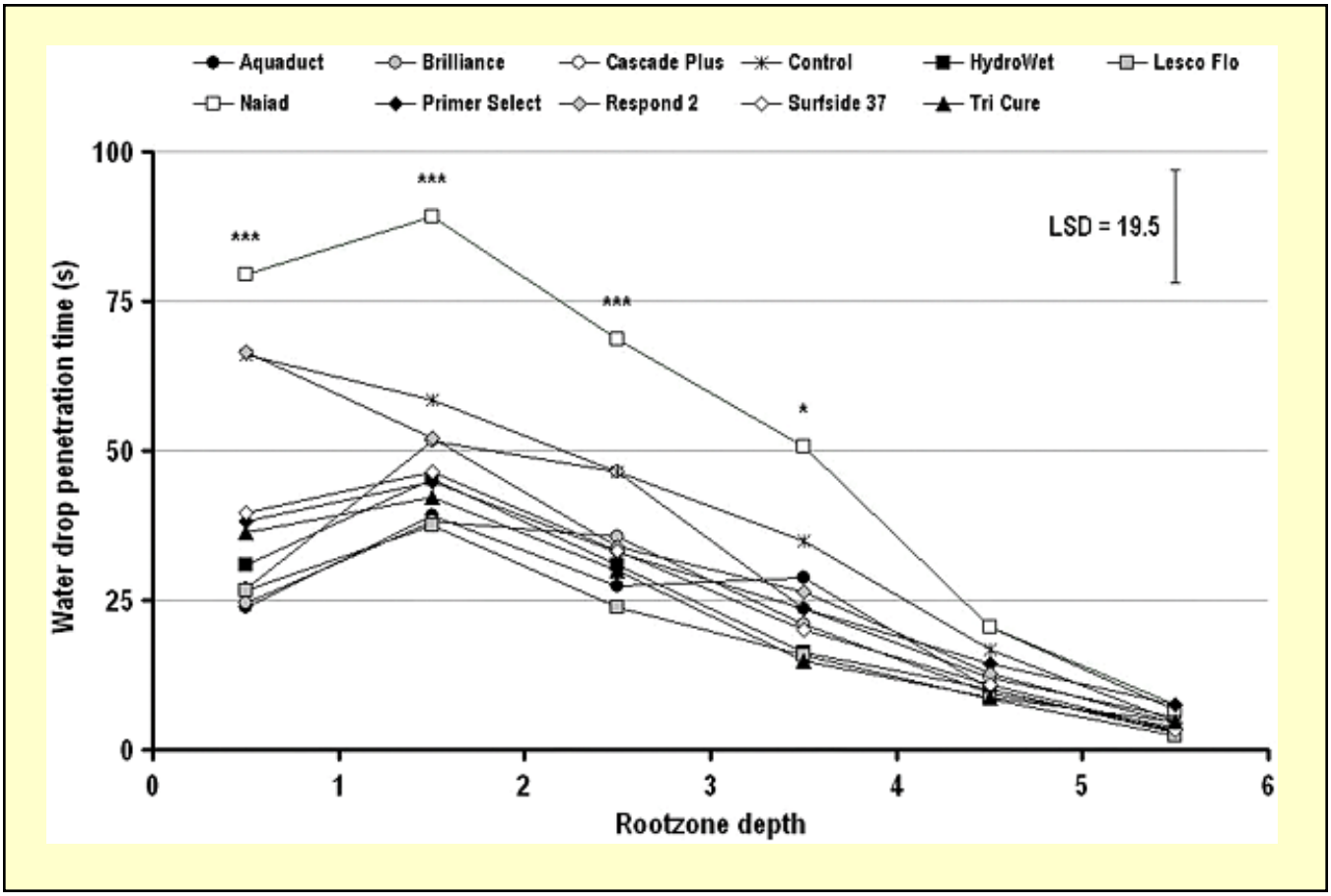

Figure 1. Water repellency expressed as water droplet penetration time (s) in rootzone depths of 0.5, 1.5, 2.5, 3.5, 4.5, and 5.5 cm for wetting agents treatments. Data are pooled over all sampling dates. LSD (Least Significant Difference) values indicate significant statistical differences (P = 0.05) between treatments and depths.

depth of 3.5 cm, repellency in Naiad-treated plots did not differ from the untreated plots, but was greater than all other wetting agents included in the study. None of the tested wetting agents had a impact on water repellency at depths of 4.5 and 5.5 cm. Plots treated with Aqueduct and LescoFlo consistently showed lower water repellency at rootzone depths of 0.5, 1.5, and 2.5 cm compared to the untreated plots.

For all other wetting agents, watering every other day at 80% pET without additional rainfall may not be adequate to move the surfactants through the profile to greater depths. Naiad-treated plots had greatest water droplet penetration time at depths of 0.5, 1.5, 2.5 and 3.5 cm. Most wetting agents included in this study reduced water repellency at 0.5-cm depths. However, only Aqueduct and LescoFlo percolated to greater depths and reduced hydrophobicity.

Efficacy of Wetting Agents Over Time

Statistical analyses revealed a significant interaction between wetting agents, DAT, and year, but no four-way interaction between wetting agent, DAT, depth and year. Therefore, water droplet penetration time data were pooled over sampling depths and presented separately for DAT and year (Figure 2). At the beginning of the study in 2003 (0 DAT), soil water repellency in Naiad and Primer Select-treated plots was greater compared to all other plots.

After 14 days, Brilliance-treated plots showed lower water droplet penetration time compared to the untreated plots. Rootzones in both Naiad and Respond 2-treated plots exhibited greater water repellency than in untreated plots (Figure 2). Twenty eight DAT, Aqueduct, HydroWet, Lesco Flo, Primer Select, and Tri Cure

reduced repellency compared to the untreated and Naiad-treated plots exhibited again greater repellency than the untreated plots (Figure 2).

Despite similar weather conditions during the research periods in 2003 and 2004, overall water repellency in the rootzone at 0, 14, and 28 DAT was lower in 2004 (Figure 3) than in 2003 (Figure 2). Relatively high soil moisture during spring of 2004 caused by an unusual wet March may have prevented the onset of more severe rootzone hydrophobicity in early to mid-summer, particularly in the untreated plots. With the exception of Naiad and Primer Select, all tested wetting agents reduced repellency in plots compared to the untreated plots 14 DAT in 2004 (Figure 2).

Conclusion

Most wetting agents included in this two-year study alleviated hydrophobicity in a sandy turfgrass rootzone at depths of 0.5 cm and 1.5 cm. Also, water repellency in the rootzone had a direct impact on turfgrass quality. Plots with highest rootzone hydrophobicity exhibited lower stand quality. Despite similar weather conditions during the course of the two-year study, results for hydrophobicity, turfgrass quality, and color differed from one year to the next. Unusually wet weather conditions before the start of the second-year study prevented the development of more severe hydrophobic rootzone conditions and may explain the differences observed from one year to the next.

This study underscores the value of longer-term trials by demonstrating that results can vary substantially from year to year, depending on weather conditions. Multiple-year studies which consider annual variations in weather conditions may be more useful in assessing the overall performance of individual wetting agents.

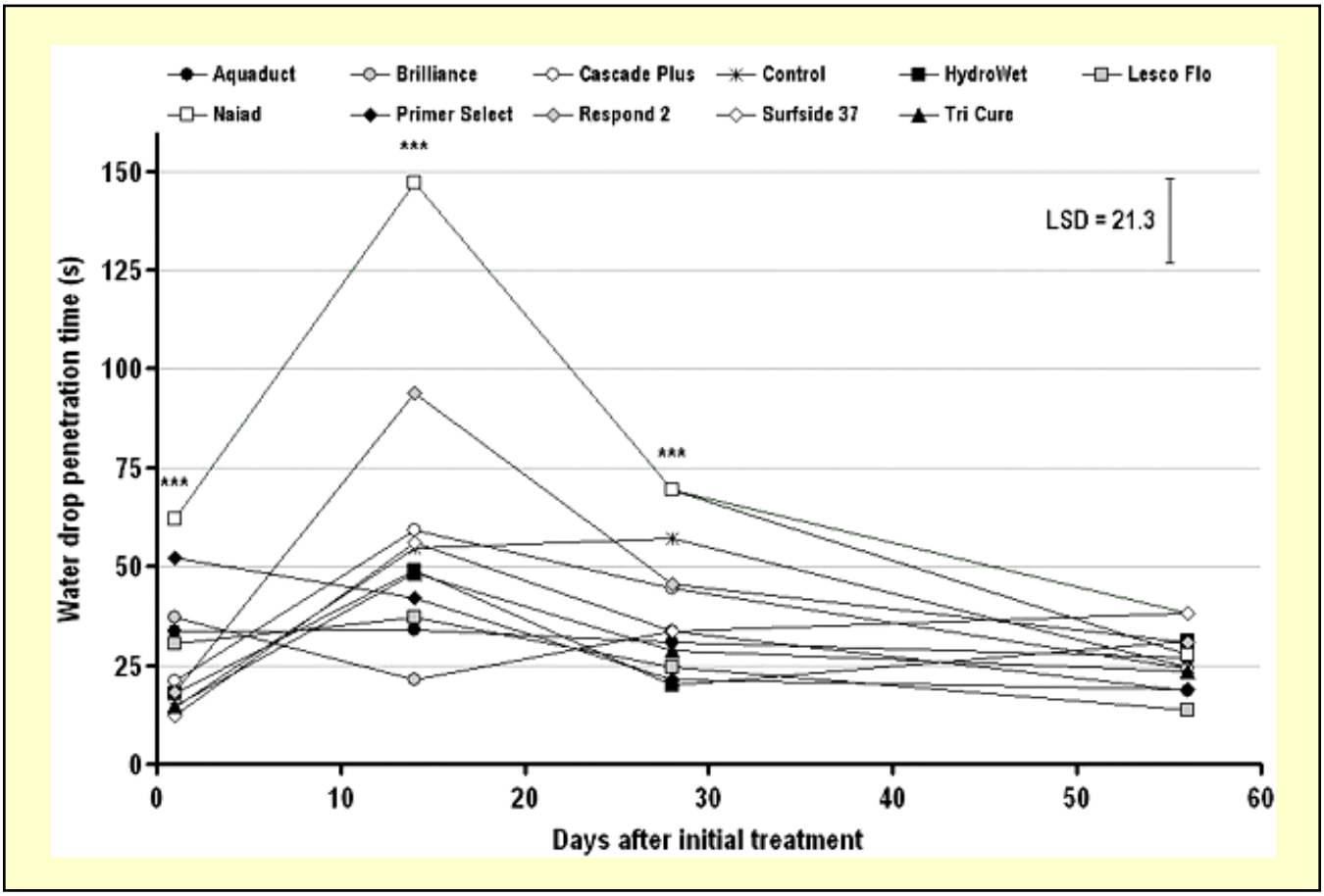

Figure 2. Water repellency expressed as water droplet penetration time (s) at 0, 14, 28, and 56 days after the first treatment in 2003. Data are pooled over all sampling depths. LSD (Least Significant Difference) values indicate significant statistical differences (a = 0.05) between treatments and days after initial treatments.

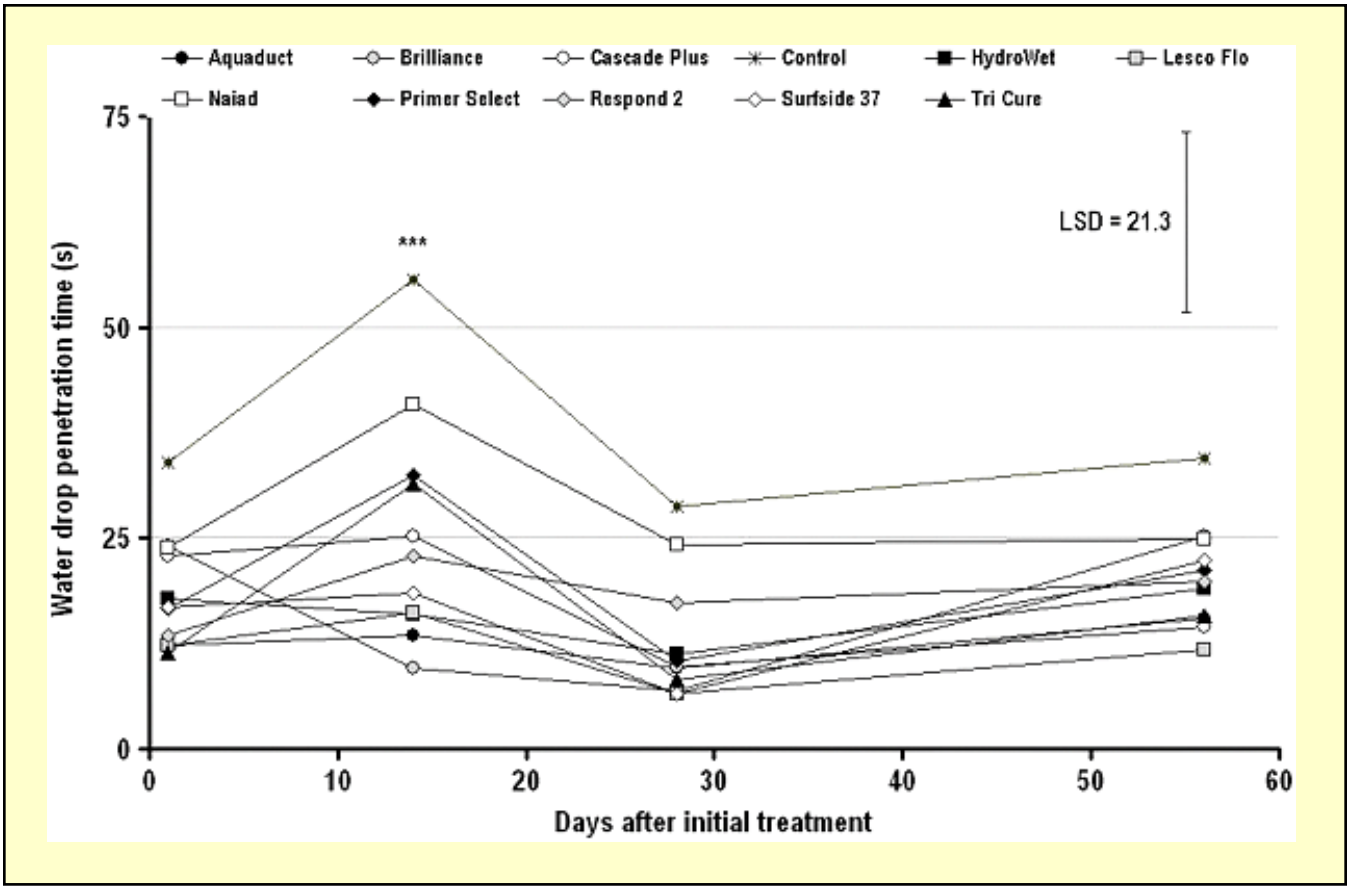

Figure 3. Water repellency expressed as water droplet penetration time (s) at 0, 14, 28, and 56 days after the first treatment in 2004. Data are pooled over all sampling depths. LSD (Least Significant Difference) values indicate significant statistical differences (a = 0.05) between treatments and days after initial treatments.

Acknowledgments

This study was made possible through the financial support of New Mexico State University's Agricultural Experiment Station, the Golf Course Superintendents Association of America, and the United States Golf Association. Support was also provided by the Cooperative State Research, Education, and Extension Service, USDA, under Agreement No. 2005-34461-15661 and 2005-45049-03209. The assistance of Bruce Erhard, golf course superintendent at New Mexico State University's golf course, is also greatly appreciated.

Editor's Note:

This article first appeared in *Applied Turfgrass Management* as shown in the following citation:

Leinauer, B., Karcher, D., Barrick, T., Ikemura, Y., Hubble, H., and Makk, J. 2007. Water repellency varies with depth and season in sandy rootzones treated with ten wetting agents. Online. *Applied Turfgrass Science* doi:10.1094/ATS-2007-0221-01-RS.

Full and complete credit is given *Applied Turfgrass Management* and Plant Management Network for publishing this report and allowing subsequent publication of these results in *USGA Turfgrass and Environmental Research Online*.

Literature Cited

1. Bigelow, C. A., G. A. Hardebeck, K. S. Walker, and J. Newman. 2004. Evaluation of various wetting agents and flutalonil for suppression of localized dry spot on a sand-based rootzone. Pages 73-87. *In* Annu. Rep. Purdue Univ. Turfgrass Sci.

Progr. Purdue Univ., West Lafayette, IN. (TGIF Record 107425)

2. Blodgett, A. M., D. J. Beattie, and J. White. 1993. Hydrophilic polymers and wetting agents affect absorption and evaporative water loss. *HortScience* 28:633-635. (TGIF Record 28051)

3. Carey, K., and E. Gunn. 2004. Field evaluation of experimental soil surfactants: 2004 season. *Guelph Turfgrass Inst. Res. Rep*. 18:24-37. (TGIF Record 107533)

4. Cisar, J. L., K. E. Williams, H. E. Vivas, and J. J. Haydu. 2000. The occurrence and alleviation by surfactants of soil-water repellency on sand-based turfgrass systems. *J. Hydrol.* 231,232:352-358. (TGIF Record 74006)

5. Davis, W. B., J. L. Paul, and D. Bowman. 1990. The sand putting green: construction and management. Div. of Agric. and Nat. Resources., Publ. No. 21448. Univ. of Calif., Davis, CA. (TGIF Record 14801)

6. Dekker, L. W., and C. J. Ritsema. 1996. Variation in water content and wetting patterns in Dutch water repellent peat clay and clayey peat soils. *Catena* 28:89-105.

7. Dekker, L. W., K. Oostindie, and C. J. Ritsema. 2005. Exponential increase of publications related to soil water repellency. *Austral. J. Soil Res.* 43:403-441.

8. Doerr, S. H., R. A. Shakesby, and R. P. D. Walsh. 1998. Spatial variability of soil hydrophobicity in fire-prone eucalyptus and pine forests, Portugal. *Soil Sci.* 163:313-324.

9. Doerr, S. H., R. A. Shakesby, and R. P. D. Walsh. 2000. Soil water repellency: Its causes, characteristics and hydro-geomorphological significance. *Earth Sci. Rev.* 51:33-65.

10. Franco, C. M. M., P. J. Clarke, M. E. Tate, and J. M. Oades. 2000. Hydrophobic properties and chemical characterization of natural water repellent materials in Australian sands. *J. Hydrol.* 231-232:47-58.

11. Frank, K. W., and J. Bryan. 2005. Wetting agent study: Update, Michigan. *Golf Course Management* 73:80 (TGIF Record 106142)

12. Franklin, M. K., S. E. McCann, and S. J. Kostka. 2005. Evaluating turfgrass performance after surfactant application in a wettable and a non-wettable soil. *Intl. Turfgrass Soc. Res. J.* (Annexe) 10:85-86. (TGIF Record 105393)

13. Jex, G. W., B. H. Bleakley, D. H. Hubbel, and L.L.Munro.1985. High humidity-induced increase in water-repellency in some sandy soils. *Soil Sci. Soc. Am. J.* 49:1177-1182.

14. Karnok, K. J., K. Xia, K. A. Tucker. 2004. Wetting agents: What are they, and how do they work? *Golf Course Management* 72:84-86. (TGIF Record 95161)

15. Karnok, K. J., and K. A. Tucker. 2001. Effects of flutolanil fungicide and Primer wetting agent on water-repellent soil. *HortTechnology* 11:437-440. (TGIF Record 73977)

16. Karnok, K. J., and K. A. Tucker. 2001. Wetting agent treated hydrophobic soil and its effect on color, quality, and root growth of creeping bentgrass. *Intl. Turfgrass Soc. Res. J*. 9:537-541. (TGIF Record 74226)

17. Kostka, S. J. 2005. ACA 1820: A novel chemistry for Rootzone water management in turfgrass systems. *Intl. Turfgrass Soc. Res. J.* (Annexe) 10:89-90. (TGIF Record 105395)

18. Leinauer, B. 2005. Wetting agent study: Update, New Mexico: *Golf Course Management* 73:74 (TGIF Record 106133)

19. Leinauer, B., P. E. Rieke, D. VanLeeuwen, R. Sallenave, J. Makk, and E. Johnson. 2001. Effects of soil surfactants on water retention in turfgrass

rootzones. *Intl. Turfgrass Soc. Res. J.* 9:542-547. (TGIF Record 74227)

20. McGhie, D. A., and A. M. Posner. 1981: The effect of plant top material on the water repellence of fired sands and water repellent soils. *Austral. J. Soil Res.* 32:609-620.

21. Mitra, S., K. W. Kurtz, R. V. Plumb, A. Chavez, S. Kostka, and M. Franklin. 2005. Systematic injection of wetting agents can help retain higher moisture levels in the rootzone. *Intl. Turfgrass Soc. Res. J.* (Annexe) 10:91-92. (TGIF Record 105397)

22. National Oceanic and Atmospheric Administration (NOAA). 2002. Monthly normals of temperature, precipitation, and heating and cooling degree days, 1971-2000: New Mexico. Climatography of the United States No. 81:29.

23. Park, D. M., J. L. Cisar, K. E. Williams, and G. H. Snyder. 2004. Alleviation of soil water repellency in sand based bermudagrass in South Florida. *Acta Hort.* 661:111-115. (TGIF Record 101821)

24. Savage, S. M., J. Osborn, J. Letey, and C. Heaton. 1972. Substances contributing to fire induced water repellency in soils. *Soil Sci. Soc. Am. Proc.* 36:674-678.

25. Throssell, C. 2005. GCSAA-USGA wetting agent evaluation: Update. *Golf Course Management* 73:71 (TGIF Record 106115)

26. Tucker, K. A., K. J. Karnok, D. E. Radcliffe, G. Jr. Landry, R. W. Roncadori, and K. H. Tan. 1990. Localized dry spots as caused by hydrophobic sands on bentgrass greens. *Agron. J.* 82:549-555. (TGIF Record 18097)