New Mexico State University researchers found that the efficacy of wetting agents varied over depth and was most pronounced at depths of 2.5cm or less

Water repellency in sandy rootzones treated with wetting agents

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US researchers have conducted a two-year project to examine the effect 10 different wetting agents have on sand-based rootzone hydrophobicity and putting green turf appearance.

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 fertilisers 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).

Localised dry spot (LDS), a major problem in turf areas, is a condition characterised 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 volume 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 phase. Surfactants can aid in combating LDS by re-wetting the rootzone through increased moisture retention (2, 19, 21), which results in improved turf vigour and quality (4, 23).

The application of surfactants, particularly non-ionic block copolymer surfactants, has been the traditional tool to manage the LDS phenomenon in soils (17). Approximately 80 per cent of all golf course superintendents in the United States use wetting agents as part of regular maintenance programmes (12, 14).

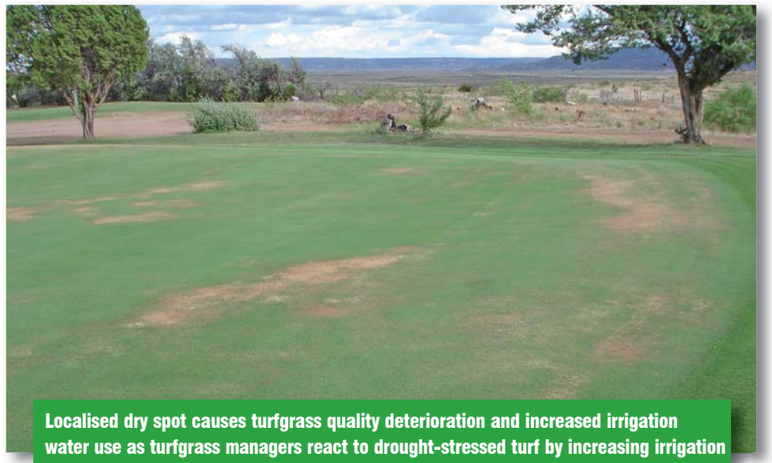
Numerous products are currently used by turf managers throughout the US, despite the lack of research results from multi-year studies on the efficacy of surfactants to mitigate water repellency and LDS.

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 localised 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 localised dry spots. Bigelow et al. (1) and Park (23) reported a decrease in localised dry spots after the application of wetting agents, but no reduction in soil water repellency.

All the aforementioned studies were conducted on golf greens with a sandy rootzone in 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 the study. Furthermore, all of 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 colour 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).



Localised dry spot causes turfgrass quality deterioration and increased irrigation water use as turfgrass managers react to drought-stressed turf by increasing irrigation volume and application frequency

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. Ten wetting agents commonly used in turfgrass management were applied to 1m×3m plots on a practice putting green. Each treatment was replicated four times.

The green was built in 1992 according to California specifications with a 300mm deep straight sand rootzone layer. The rootzone consisted of 96.3 per cent sand (6.9 per cent very coarse, 21.7 per cent coarse, 44.6 per cent medium, 17.6 per cent fine, and 5.5 per cent very fine), 1.4 per cent silt, and 1.25 per cent clay and had less than 1 per cent organic matter accumulation when averaged over the 30cm depth.

Turf cover on the green consisted of creeping bentgrass (Penncross) which was mowed daily at a height of 2.8mm. During both years the green was fertilised with N at 30.5g/m^2, P_2O_5 at 13g/m^2, and K_2O at 49.9g/m^2 and was irrigated every other day at 80 per cent 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 27 June and 17 May respectively. Accumulated pET for 27 June to 21 August 2003 was 540mm and 510mm for 17 May to 11 July, 2004. No precipitation occurred during these periods.

Turfgrass colour and quality ratings were taken every two weeks at seven, 21, 35, 49, and 63 days after the first treatment (DAT). Colour 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, 6cm long and 2cm 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-microlitre droplet of deionized water on the cores at depths of 0.5, 1.5, 2.5, 3.5, 4.5, and 5.5cm (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.

TURFGRASS COLOUR AND QUALITY

Analysis of turfgrass colour 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 colour 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 colour than the untreated plots in 2003 (Table 2). Naiad-treated plots ranked lower than the untreated plots in 2003 for quality and colour. These findings agree with those of Frank and Bryan (11), who also reported lower quality ratings on Naiad-treated plots when compared to other treatments.

Researchers collect cores from the trial plots for assessment

With the exception of Naiad, all treated plots had ratings of greater than 6 (the minimum acceptable colour 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 colour and quality from the untreated plots and turfgrass colour and quality increased from 2003 to 2004. Heavy rains in March of 2004 totaling 84mm compared to the 30-year average of 5mm (22) are most likely the cause of reduced rootzone hydrophobicity and subsequent increase in turfgrass colour and quality compared to 2003.

REPELLENCY AFFECTED BY WETTING AGENT TREATMENTS AT DIFFERENT 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 were pooled over DAT and year and presented as treatment means for each depth (Fig. 1).

Contrary to other studies (3) in which repellency declined progressively with rootzone depth, plots in this study had a tendency for greater water repellency at a depth of 1.5cm 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 0.5cm than at 1.5cm (Fig. 1).

At a soil depth of 0.5cm 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 1.5cm, Aqueduct, Brilliance, and LescoFlo reduced water repellency, while Naiad-treated plots showed greater water droplet penetration time compared to the untreated plots.

At 2.5cm 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 depth of 3.5cm, 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 an impact on water repellency at depths of 4.5 and 5.5cm.

Plots treated with Aqueduct and LescoFlo consistently showed lower water repellency at rootzone depths of 0.5, 1.5, and 2.5cm compared to the untreated plots. For all other wetting agents, watering every other day at 80 per cent 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 3.5cm. Most wetting agents included in this study reduced water repellency at 0.5cm depths. However, only Aqueduct and LescoFlo percolated to greater depths and reduced hydrophobicity.

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

Wetting Agent	Application rate (litre)	Spray volume (l/1000 m²)	Application frequency (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

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 times were pooled over sampling depths and presented separately for DAT and year (Fig. 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 (Fig. 2). Twenty-eight DAT, Aqueduct, HydroWet, LescoFlo, Primer Select and Tri-Cure reduced repellency compared to the untreated and Naiad-treated plots exhibited again greater repellency than the untreated plots (Fig. 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 (Fig. 3) than in 2003 (Fig. 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 (Fig. 2).

Table 2. Visual turfgrass quality and colour 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 colour/quality.

	Turfgrass quality		Turfgrass colour	
Wetting Agent	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).

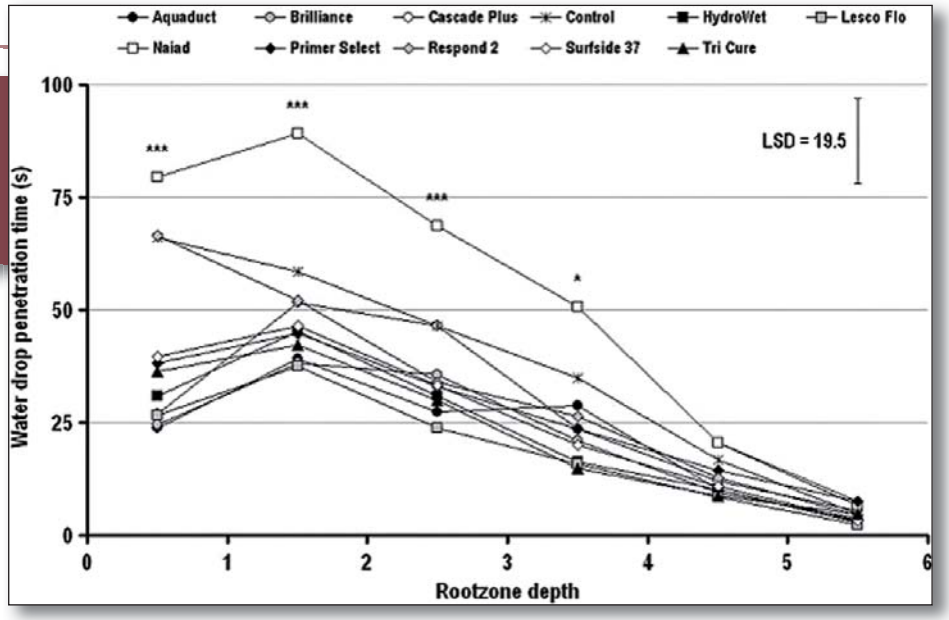


Figure 1. Water repellency expressed as water droplet penetration time (s) in rootzone depths of 0.5, 1.5, 2.5, 3.5, 4.5, and 5.5cm for wetting agents treatments.

CONCLUSION

Most wetting agents included in this two-year study alleviated hydrophobicity in a sandy turfgrass rootzone at depths of 0.5cm and 1.5cm. 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 colour 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.

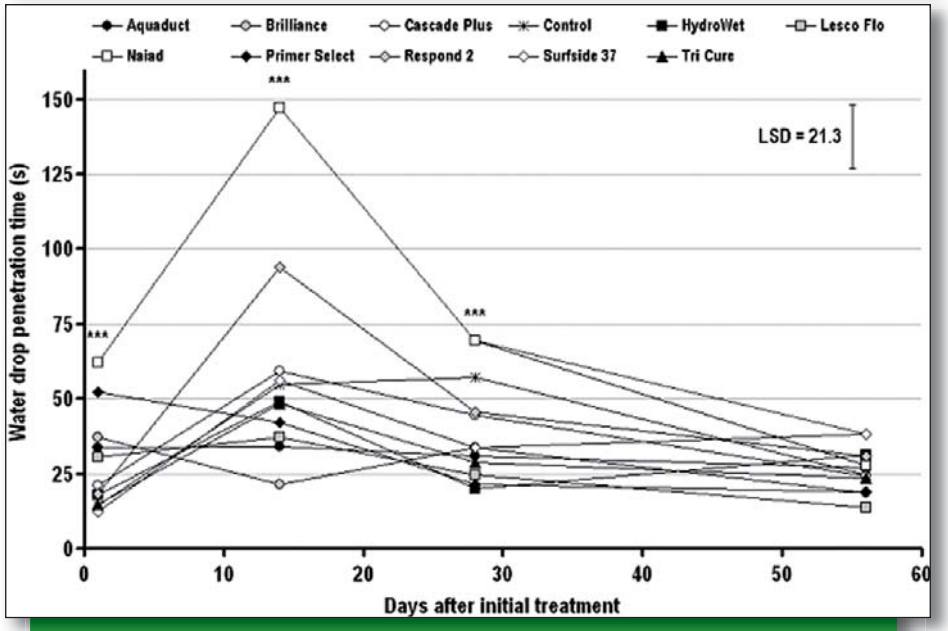


Figure 2. Water repellency expressed as water droplet penetration time (s) at 0, 14, 28, and 56 days after the first treatment in 2003. Data are pooled over all sampling depths.

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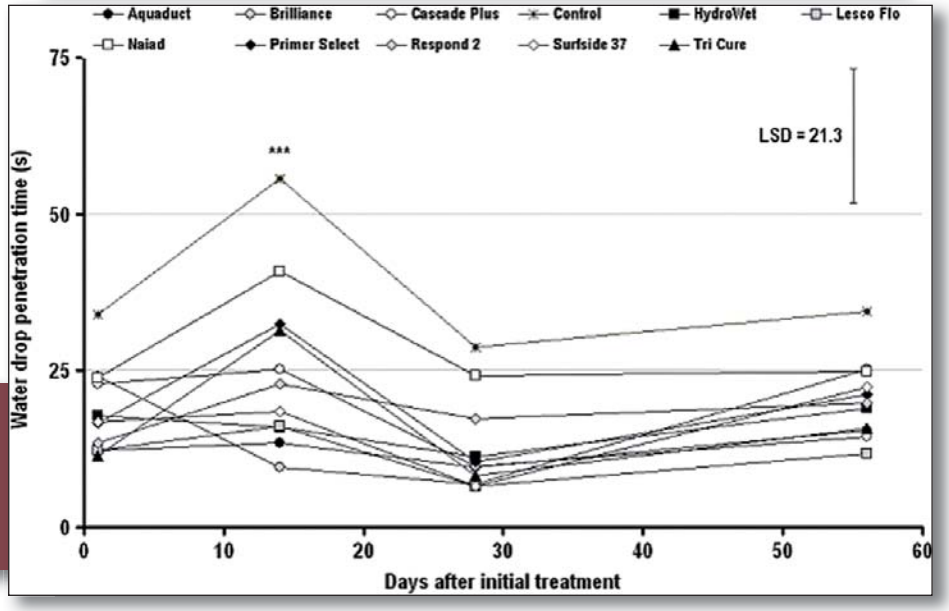

Figure 3. Water repellency expressed as water droplet penetration time (s) at 0, 14, 28, and 56 days after the first treatment in 2004. Data are pooled over all sampling depths.