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WETTING AGENT TREATED HYDROPHOBIC SOIL AND ITS EFFECT ON COLOR, QUALITY AND ROOT GROWTH OF CREEPING BENTGRASS

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ABSTRACT

Localized dry spot (LDS) caused by hydrophobic soil is a common problem on sand based golf greens established to creeping bentgrass *(Agrostis palustris* Huds.)- This study was conducted to determine the effect of a soil wetting agent (WA) on relieving soil hydrophobicity and its effect on root growth and shoot quality of'Penncross' creeping bentgrass. The study was conducted in the University of Georgia Rhizotron, Athens, GA in 1997 and 1998. Root observation chambers were prepared according to USGA Green Section specification for golf green construction. The top 10.1 cm of the root zone consisted of a hydrophobic soil having a molarity of ethanol droplet test (MED) value of 2.4 to 2.6. MED values typically range from 0 (no hydrophobicity) to 4 (extreme hydrophobicity). The WA was applied as a single application at 50.88 1 ha '. Overall, the WA treatment significantly improved turfgrass color and quality throughout the entire study. Root length was also significantly improved by the WA treatment. A 27 percent increase in root length occurred at the 0 to 8 cm depth. Turfgrass response was apparently due to an increased volumetric moisture content of the hydrophobic soil layer. The WA significantly reduced the MED of the hydrophobic soil for up to 12 weeks after application. A single application of the WA used in this study appears to be an effective way of managing LDS caused by hydrophobic soil on sand based golf greens established to creeping bentgrass.

Keywords

Dry patch; hot spots; isolated dry spots; water repellent soil

INTRODUCTION

Creeping bentgrass is the most commonly used cool-season turfgrass on golf greens in the United States. Since the optimum growth temperature range for cool season turfgrasses is 15 to 24 ° C, shoot growth rate begins to decline when temperatures rise above 24 ° C [Beard,1973]. The decrease in bentgrass quality at supraoptiminal temperatures is often referred to as "summer bentgrass decline" [Carrow, 1996]. This summer decline is thought to be a combination of both abiotic (high temperatures, excessive soil moisture, deficient soil oxygen, drought, shade, etc.) and biotic (diseases, insects, nematodes, etc.) factors [Dernoeden, 2000]. Decreased root growth is almost always associated with summer bentgrass decline. When soil temperatures rise above 18 °C, cool-season turfgrass root growth begins to decline [Beard, 1973].

Localized dry spots (LDS) could be considered as an advanced stage of summer bentgrass decline. LDS is sometimes referred to as isolated dry spots, dry patch or hot spots [Karnok and Tucker, 1999]. LDS can be defined as the occurrence of an irregular area of turfgrass that for no apparent reason begins to show signs typical of drought stress. There are several possible causes of LDS including excessive thatch, compacted soil, poor irrigation coverage, steep sloping grade (water runoff), high soil salinity, improper chemical usage, insects, diseases, and water repellent soil [Karnok and Tucker, 2000]. Hydrophobic soil is often associated with high sand content root zones. Some research has shown that the hydrophobicity is due to an organic coating that envelops soil particles of both naturally deposited soils [van't Woudt, 1959; Roberts and Carbon, 1971; McGhie and Posner, 1980] and the artificial soils of golf putting greens [Wilkinson and Miller, 1978; Tucker, et al., 1990, Karnok, et al. 1993]. Both humic [Roberts and Carbon, 1972] and fulvic acids [Miller and Wilkinson, 1979] have been implicated as the organic coating substance responsible for soil hydrophobicity. Both organic acids become hydrophobic after prolonged drying [Miller and Wilkinson, 1979]. These organic coatings are not unique to sand golf greens since they have also been reported on grasslands in Australia [Bond, 1968], citrus groves in Florida [Jamison, 1942], and in burned forest lands in southern California [DeBano et al., 1970].

Wetting agents are the most effective method for reducing or eliminating LDS caused by hydrophobic soils on golf greens [Wilkinson and Miller, 1978; Karnok and Tucker, 1999]. Wetting agents are either applied to the entire putting green surface or just those areas showing LDS. Since water repellent soil has been found to

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vary in severity across a golf green, there can be variable wetting/drying of the rooting medium and consequently variable root and shoot growth [Karnok and Tucker, 2000]. There are few if any published reports showing the effects of wetting agents applied to a hydrophobic soil on turfgrass root growth. The objective of this study was to determine the root and shoot response of Penncross creeping bentgrass to a wetting agent applied to a hydrophobic soil.

MATERIALS AND METHODS

The effects of Tilwa wetting agent (proprietary blend of surfactants, polyethylene and polyproplylene glycols) (Turftech International, Ltd.) on the shoot and root growth of Penncross creeping bentgrass was conducted during the summers of 1997 and 1998 in the University of Georgia Rhizotron located at Athens, GA. The rhizotron permits non-destructive and continuous measurement of root growth under field conditions. The University of Georgia Rhizotron consists of 24 observation chambers and two instrument/laboratory areas. For use in this study, individual chambers were divided into four sub-chambers or plots (25.4 cm by 101.6 cm). Each chamber was prepared according to the USGA Green Section specifications for golf green construction [USGA, 1989]. The root zone was a 85/15 sand/peat mix consisting of the following particle sizes: <0.05 = 1.4%; 0.05-0.10=0.5%; 0.10-0.25 =28.4%; 0.25-0.5=67.6%; 0.5-1.0= 1.1%; 1.0-2.0=1.0%. Organic matter content was 2.1 %. To simulate the water repellent layer commonly found on sand based golf greens, 10.1 cm of the top root zone mix was replaced with a layer of hydrophobic soil. The hydrophobic soil was obtained from an abandoned Penncross bentgrass experimental green located on the University of Georgia campus. This green was constructed according to USGA Green Section specifications and was approximately 21 years old. The root zone of the experimental green was a 85/15 sand/peat moss mix. Particle size distribution was as follows: <0.002-0.50= 2.1%; 0.05-0.10 = 0.9%; 0.10-0.25 = 24.6%; 0.25-0.5=69.8%; 0.5-1.0=1.8%;1.0-2.0=0.8%. Organic matter content of this zone was 2.6%. Root zone pH was maintained between 6.3 and 6.5. MED test [Watson and Letey, 1970; King, 1981] of the hydrophobic soil was 2.5. All root zone mixes were packed to a 1.4 g cm ^{3} bulk density. Rhizotron chambers were sodded with soilless Penncross sod on 1 March 1997. Sod was washed and roots trimmed to the bottom of sod layer. A three month establishment period consisted of sufficient irrigation to prevent wilt, 7.3 kg N ha ' every two weeks and the use of fungicides and insecticides as needed. The turf was maintained at 0.64 cm cutting height which required almost daily mowing. Clippings were not returned. The application of other nutrients was determined by periodic soil testing. On 9 June 1997 and 16 June 1998,50.881 ha ' of wetting agent was applied with a watering can at a carrier rate of 30,000 1 ha '". Plots were maintained as discussed above except for the irrigation regime. When drought stress symptoms were observed on the control plots, all plots were irrigated with 0.64 to 0.95 cm water.

Turf color, quality and root growth were monitored from 9 June 1997 to 6 October 1997 and 16 June to 12 November 1998. Turf color was rated on a 1 to 9 scale with 1 being brown and 9 representing dark green. Turf quality was also rated on a 1 to 9 scale with 1 representing poor quality and 9 excellent quality. Color and quality ratings were taken every 2 weeks after initiation of the study. Soil hydrophobicity was determined by the MED test. Soil samples were taken 0 (before treatment application), 3,5,9, and 12 weeks after treatment (WAT) in 1997 and 1998. Five soil samples were taken from each plot with a 0.64 cm diameter soil probe to a depth of 5.1 cm and combined into one bulk sample per plot. Samples were allowed to air dry for three days. Samples were then sieved through a 2 mm mesh screen. The MED test was performed by placing the soil in a 5 cm diameter and 1 cm deep plastic dish and leveling it to a uniform depth and surface. A series of 40 uL aqueous ethanol droplets at 0.4 *M* intervals were placed on the soil surface. The molarity of the droplet which completely infiltrated within 5 seconds was recorded as the soil MED value. The greater the molarity of the ethanol droplet that completely infiltrated within 5 s, the greater the hydrophobicity. The MED scale used was 0 represented no hydrophobicity while 4 was equal to severe hydrophobicity.

Volumetric soil water content (VWC) was determined at 4 and 8 WAT in 1997 and 1998. Measurements were taken 24 h after irrigation by inserting a single pair of stainless steel rods, 0.32 cm diameter and 7.5 cm long, into the soil at a parallel distance of 5.1 cm. Soil electromagnetic capacitance was determined by pulsing a wave down the soil probes with a Tektronix 150B TDR Metallic Cable Tester (Tektronix, Beaverton, OR) and monitoring the reflectance pattern. The readings were converted to volumetric soil water content (VWC) according to previously determined empirical equations

Table 1. Penncross creeping bentgrass color as affected by a wetting agent in 1997 and 1998.

Treatment	2 WAT[1]		4 WAT		6 WAT		8 WAT		10 WAT		12 WAT		14 WAT		16 WAT		18 WAT	
	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98
	Color[2]																	
Wetting Agent	7.5a[3]	7.5a	7.3a	7.1a	7.4a	6.3a	7.4a	6.0a	7.4a	6.3a	7.6a	6.8a	8.0a	7.0a	8.0a	7.1a	8.0a	7.3a
Control	7.1a	7.1a	5.8b	6.0b	6.4b	5.5b	6.8b	5.3b	6.8b	5.6b	7.3a	6.0b	7.5b	6.6a	7.3b	6.8a	7.5b	7.1a

[1] WAT = weeks after treatment.

[2] Color, 1 = brown and 9 = very dark green.

[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 a wetting agent in 1997 and 1998.

Treatment	2 WAT[1]		4 WAT		6 WAT		8 WAT		10 WAT		12 WAT		14 WAT		16 WAT		18 WAT	
	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98	97	98
	Quality[2]																	
Wetting Agent	7.4a[3]	7.4a	7.4a	7.4a	7.4a	6.4a	7.3a	5.8a	7.4a	5.8a	7.1a	6.0a	7.5a	6.3a	7.6a	6.6a	7.9a	6.8a
Control	7.0a	7.0a	6.9b	6.9b	6.8b	5.6b	6.6b	5.1b	6.6b	5.1b	6.6b	5.3b	6.9b	5.6b	7.1b	6.1b	7.1b	6.3b

[1] WAT = weeks after treatment.

[2] Quality, 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.

WAT = weeks after treatment.
[2] Quality, 1 = very poor quality and 9 = excellent quality.
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Multiple Range Test.

[Topp et al., 1984]. Five VWC readings per plot were taken 24 hours after applying 1.3 cm of water.

Root length was determined using the line intersect method as described by Newman [1966]. In this study, a 2 cm grid system which was 8 cm wide and 24 cm long was drawn directly on the observation window of each chamber. Root length was determined each month for 4 and 5 months after treatment application in 1997 and 1998, respectively.

The experimental design was a randomized complete block with four replications. Since the same treatments were applied to the same plots each year, the data was analyzed as repeating measures. Data were subjected to general linear model (GLM) procedures in the SAS system [SAS Institute, 1987] with appropriate sources of variances for each type of measurement. Since there was a week x year and week x treatment interaction, P=0.0001 and P=0.0001, respectively, a combined overall analysis was used to make specific comparisons at weekly intervals.

RESULTS

Turf Color and Quality

No difference in turfgrass color or quality was observed between the WA and the control 2 WAT in either 1997 or 1998 (Tables 1 and 2). Other than color 12 WAT in 1997, the WA treated turfgrass had significantly higher color and quality ratings than the control 4, 6, 8, 10 and 12 WAT in 1997 and 1998 (Table 1 and 2). In fact, other than the color rating 12 WAT, color and quality ratings for the WA treatment were significantly better than the control throughout the study in 1997 (Tables 1 and 2). This was not the case in 1998. Although there was no difference in color between the WA treatment and the control 14, 16, and 18 WAT, turfgrass quality was significantly improved by the WA treatment compared to the control during this period (Tables 1 and 2). Overall, of the 36 color and quality measurements taken over both years, turfgrass color and quality were significantly improved by the WA treatment 28 times or 78 percent of the time.

Soil Hydrophobicity and Volumetric Soil Water Content

The initial soil hydrophobicity was the same for both the WA and control plots in both 1997 and 1998 (Table 3). The initial 2.4 to 2.6 MED would be considered a significant degree of hydrophobicity. The WA treatment significantly reduced soil hydrophobicity 3, 5, and 9 WAT in both years. The WA treated plots had a significantly lower MED (1.4 versus 2.1) than the control 12 WAT in 1998 but not in 1997. Volumetric soil water content for both years at each measurement date was significantly higher for the WA treated soil than the control. When data were pooled for both years, the WA treated soil had a significantly greater volumetric water content than the control, 8.3 % and 3.5 %, respectively.

Root Length

There was no difference in total root length between the WA treated turf and the control prior to treatment application in both 1997 and 1998 (data not shown). When root length data were pooled for both years for the months of June, July and August, there was a significant WA treatment response (Table 4). June, July and August are the most stressful summer months in the southeastern United States. This is also the time of year that LDS become most apparent and the use of wetting agents most critical to the survival of the turf. The WA treatment resulted in a significant increase in root length at the 0 to 8 cm depth. This was also the primary zone in which the hydrophobic soil was placed. There was no

Table 3. Soil water repellency as affected by a wetting agent in 1997 and 1998.

Treatment	0 WAT[1]		3 WAT		5 WAT		9 WAT		12 WAT	
	97	98	97	98	97	98	97	98	97	98
	Soil Water Repellency (MED)[2]									
Wetting Agent	2.6a[3]	2.5a	1.5b	0.7b	2.1b	0.8b	2.1b	1.1b	2.3a	1.4b
Control	2.5a	2.4a	3.1a	2.1a	3.2a	2.1a	2.9a	2.0a	2.5a	2.1a

[1] WAT = weeks after treatment, 0 WAT = before treatment application.

[2] Soil water repellency (MED), 0 = non-water repellent and 4 = 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.

Table 4. Penncross creeping bentgrass total root length for June, July and August combined as affected by a wetting agent in 1997 and 1998.

	1997		1998		1997/1998	
Depth	WA*	Control	WA	Control	WA	Control
	Total Root Length (cm cm^{-2})					
0 to 8 cm	16.5	13.8	18.1	13.4	17.3a**	13.6b
9 to 16 cm	15.4	11.2	14.3	11.6	14.9a	11.4a
17 to 24 cm	4.5	3.2	2.2	1.4	3.4a	2.3b
0 to 24 cm	12.1	9.4	11.5	8.8	11.8a	9.1b

* WA = Wetting agent

** Means within the same row joined by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

significant difference in root length between the WA treatment and control at the 9 to 16 cm depth (Table 4). However, root length for all depths (0 to 24 cm) showed the WA treatment resulting in a 30 percent increase compared to the control (Table 4).

DISCUSSION

There was no significant difference in color or quality between the WA treatment and the control the first two weeks of the study for both years. This is not unusual since there was little stress due to lower temperatures and adequate soil moisture during this time. However, as summer temperatures increased and precipitation became more limiting, the wetting agent treatment allowed the hydrophobic soil layer to wet more readily than the non-treated water repellent soil. This is evident by the reduced MED readings shown by the WA treated soil throughout the majority of the study. In addition, volumetric soil water content of the top 7.5 cm of soil was consistently greater for the WA treatment compared to the control. Wetting agents have been reported to be effective in relieving LDS caused by hydrophobic soil by improving infiltration and moisture retention [Wilkinson and Miller, 1978; Karnok and Tucker, 2000]. As the study progressed into the fall, a positive effect due to the WA treatment was still evident. This indicates that even under more favorable conditions of moisture and temperature, WA may still provide an advantage to the turfgrass growing in hydrophobic soil. The continued improved turfgrass quality into the fall was probably also the result of improved turfgrass health which was maintained during the summer stress months.

Turfgrass treated with the wetting agent significantly improved root growth during the summer months. This was apparently due to improved moisture levels in the hydrophobic soil layer. The greatest root response to the wetting agent was in the top 8 cm of the root zone or the zone of hydrophobic soil. This is also the zone of greatest root growth for creeping bentgrass. It is not surprising that there was no difference in root length between the WA treatment and control at the 9 to 16 cm depth since this zone did not contain hydrophobic soil. It is well documented that the occurrence of hydrophobic soil on sand based golf greens is usually found within the top 5 cm of the soil profile [Karnok and Beall, 1995]. This is the region of greatest organic matter accumulation, root activity and microorganism populations, all of which are essential components for the development of hydrophobic soil. Since hydrophobicity decreases with soil depth, a significant rooting response to an applied wetting agent at deeper soil depths would be surprising. However, the effect of the WA on rooting was significant enough that it resulted in an overall increase in root length for the entire depth of the profile.

As shown by increasing MED values, WA efficacy declined to the point that soil hydrophobicity of the treated soil was not significantly different from the control at 12 WAT in 1997. However, turfgrass quality remained significantly higher for the WA plots through at least 18 WAT in both years. The improved quality into the fall was probably due to the higher quality (i.e. color and shoot density) maintained throughout the summer months. The improved health of the turfgrass coming out of the summer allowed for optimum growth during the improved growing conditions in the **fall.**

CONCLUSIONS

The results of this study show that hydrophobic soil treated with Tilwa wetting agent during summer stress can improve color, quality and root growth of creeping bentgrass. The authors can not say with certainty that the same effects would be observed with other wetting agents since other wetting agents were not tested. However, it should be noted that since the presence and severity of hydrophobic soil varies across a putting green these results suggests that there would be advantages to treating the entire green rather than simply spot treating the apparent LDS or hot spots as is often done. Treating the entire green would help minimize variability in wetting and drying of the soil profile, particularly the top 5 cm, thus resulting in more uniform and consistent root growth and shoot quality during the summer and early fall months.

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