Agricultural Water Management 99 (2011) 1–7

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Ameliorating water repellency under turfgrass of contrasting soil organic matter content: Effect of wetting agent formulation and application frequency

L. Barton*, T.D. Colmer

School of Plant Biology, Faculty of Natural and Agricultural Sciences, The University of Western Australia, 35 Stirling Highway, Crawley 6009, Western Australia, Australia

ARTICLE INFO

Article history:
Received 2 May 2011
Received in revised form 2 August 2011
Accepted 7 August 2011
Available online 27 August 2011

Keywords:
Dry patch
Molarity of ethanol droplet test
Sandy soils
Soil hydrophobicity
Soil water content
Turfgrass color

ABSTRACT

Water conservation strategies are being developed in regions of the world expected to experience decreases in water resources due to changing climates. Strategies advocated for improving water-use efficiency may increase the incidence of soil water repellency in sandy-textured soils. We evaluated the effect of soil wetting agent formulation, and application frequency, on water repellency in sandy soil with two contrasting organic matter (OM) contents under kikuyugrass [*Pennisetum clandestinum* (Holst. Ex Chiov)], and irrigated at 60% replacement of net evaporation in a climate subject to hot, dry summers. The randomized plot design included two turfgrass ages [established from 20 week (7.7% OM) or 20 year old (30% OM) turfgrass in 2005, the latter included a 50 mm 'mat' layer], two soil wetting agent formulations (granular or liquid); two application frequencies (one or two applications per irrigation season); and plots of both turfgrass ages that did not receive any wetting agent (nil control). Both wetting agent formulations contained the same active ingredient (propylene oxide–ethylene oxide block polymer), and all wetting agent treatments received the same rate (69 L active ingredient ha^{-1}). Water repellency in the surface soil (0–5 mm), measured using the molarity of ethanol droplet test (MED), ranged from 1.09 M to 4.32 M during the irrigation season, and was more severe in the soil with high OM (average MED, 3.3 M) than low OM content (average MED, 2.7 M). Applying one application of either granular or liquid soil wetting agent at the commencement of the irrigation season decreased the severity of soil water repellency by up to 30% in the high OM soil and by up to 60% in the low OM soil during the summer, and without the need for a second application. The decline in soil water repellency in response to soil wetting agent application was not matched by an increase in soil VWC in summer, and turfgrass quality was considered acceptable throughout the study. The soil wetting agents were less effective at treating water repellent sand containing a significant amount of OM than sand with low OM content.

1. Introduction

Water conservation strategies are being developed and implemented in regions of the world expected to experience a decrease in water resources due to changing climates. Irrigation scheduling based on the replacement of a proportion of evapotranspiration (ET) is recommended for improving water-use efficiency in irrigated agricultural and horticultural systems (Allen et al., 1999; Smith et al., 1996). However, while ET-replacement irrigation can optimize watering regimes, it can also increase the incidence of soil water repellency under turfgrass grown in sandy-textured soils (Augustin and Snyder, 1984; Cisar et al., 2000); especially if there is an organic matter (OM) layer immediately underlying the turfgrass (Barton and Colmer, 2011). Soil water repellency decreases turfgrass water-use efficiency by causing water to flow across the soil surface ('runoff'), or unevenly infiltrate the soil surface, bypassing a proportion of the roots via the formation of preferred flow paths ('preferential flow') (Dekker et al., 2001; Doerr et al., 2000).

Water repellency may lead to patches of turfgrass death if not treated. Applying soil wetting agents is a common method for overcoming soil water repellency (Hallett, 2008). Soil wetting agents increase the wetting capacity of water in a hydrophobic soil by reducing the interfacial tension between water and soil particles, thereby making it easier for water to infiltrate the soil (Hallett, 2008). The effectiveness of wetting agents for turfgrass management has mainly been investigated using liquid

Abbreviations: ET, evapotranspiration; LSD, least significant difference; MED, molarity of ethanol droplet; OM, organic matter; VWC, volumetric water content.

* Corresponding author at: School of Plant Biology (M084), The University of Western Australia, 35 Stirling Highway, Crawley 6009, Western Australia, Australia. Tel.: +61 8 488 2543; fax: +61 8 488 1108.
E-mail address: louise.barton@uwa.edu.au (L. Barton).

0378-3774/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.agwat.2011.08.009

formulations applied to sand-based soils, with low (<5%) OM contents (e.g., Cisar et al., 2000; Dekker et al., 2005; Karnok and Tucker, 2001; Kostka, 2000; Leinauer et al., 2007; Oostindie et al., 2008), with the exception of Lyons et al. (2009) whose study also included a granular wetting agent. Although these studies have shown liquid soil wetting agents can mitigate soil water repellency, the relative effectiveness of granular and liquid formulations applied at the same rate of active ingredient, and to sandy-textured soils of varying OM contents, has not been determined.

South-western Australia has a hot and dry summer climate, is dominated by free-draining sands prone to water repellency (McGhie and Posner, 1981; Tate et al., 1989), and has experienced a 15% reduction in winter rainfall since the late 1960s (Nicholls, 2010). Local government municipalities are responsible for managing large areas of turfgrass (i.e., broadacre parks and multi-purpose sports fields) in the region. Granular wetting agents, rather than liquid wetting agents, are often applied to broadacre turfgrass areas that can also contain high OM contents due to irregular renovation (Barton et al., 2009b). Consequently, the overall objective of our field-based experiment was to investigate the relative effectiveness of a granular and a liquid wetting agent to decrease soil water repellency under kikuyugrass [*Pennisetum clandestinum* (Holst. Ex Chiov)] of two ages and thus with contrasting OM contents in a sandy soil.

2. Materials and methods

2.1. Soil and site

The effect of soil wetting agent formulation and the application frequency was investigated at the University of Western Australia's (UWA) Turf Research Facility in Perth (31°56′S, 115°47′E). The site included kikuyugrass [*P. clandestinum* (Holst. Ex Chiov)] plots planted on the 19 January 2005 for a previous study (Barton et al., 2009a). Perth has a Mediterranean-type climate, and in the last 16 years has had an annual rainfall of 748 mm, mainly (79%) falling from late autumn to early spring (May–September), a mean annual maximum temperature of 24.5 °C and a mean annual minimum temperature of 12.6 °C (Commonwealth Bureau of Meteorology, http://www.bom.gov.au/climate/averages).

The soil at the site is known locally as Karrakatta Sand (McArthur and Bettenay, 1960), and is classified as a Dystric Xeropsamments using soil taxonomy (USDA, 1992). Prior to planting, the surface soil (0–150 mm) had an average pH of 4.7 (1:5 soil: 0.01 M $CaCl_2$ extract), electrical conductivity of 0.01 dS m^{-1} (1:5 soil: water extract), cation exchange capacity of 3.22 cmol kg^{-1}, C concentration of 6.5 mg g^{-1}, and N concentration of 0.4 mg g^{-1}. The surface soil contained 92% coarse sand, 2% fine sand, 2% silt, and 4% clay (Pathan et al., 2003).

The site included a variable-speed travelling irrigator (Short and Colmer, 2007) with a fixed-boom coupled with a weather station (WeatherMaster 2000, Environdata Australia). The median daily efficiency of discharge [(actual irrigation depth/programmed irrigation depth) × 100)] was 97% (data not shown). The weather station (Barton et al., 2009a) was installed to measure climatic parameters, plus calculate daily evaporative demand of the environment (also called reference ET), for use by the irrigator program.

2.2. Experimental design and approach

The unbalanced, completely randomized, experimental design consisted of two turfgrass ages with contrasting soil OM content, two soil wetting agent formulations, two frequencies of application, and five replicates; each turfgrass age also included five plots that did not receive any wetting agent (nil control), giving a total of 25 plots (each 10 m^2) per turfgrass age. The two turfgrass ages were established from 20 year old turfgrass ('older' turfgrass) or from 20 week old turfgrass ('younger' turfgrass). The older turfgrass was cut from a golf course fairway to a depth of 50 mm so as to include a mat layer of high OM content, while the younger turfgrass was newly grown sod with a depth of 15 mm. The soil OM content of the surface 50 mm of the older turfgrass was 30 ± 8% OM, and for the younger turfgrass was 7.7 ± 1% OM; measured on the 19 November 2009 using combustion at 600 °C (Barton et al., 2009b; Carrow et al., 1987). The soil wetting agent formulations were granular or liquid; both contained ethylene oxide–propylene oxide block polymer as the active ingredient (considered to be the 'backbone' of the soil wetting agent industry; Kostka and Bially, 2005). In the granular formulation, the active ingredient was impregnated on a spongelite carrier. The frequencies of application were one application (69 L active ingredient ha^{-1}) per irrigation season (spring; dates provided in next paragraph), or two applications (34.5 L active ingredient ha^{-1} per application) per irrigation season (spring, mid-summer). Consequently, the total amount of active ingredient applied to the turfgrass plots during the study was the same for all wetting agent treatments, and applied at the annual rate recommended for the granular product (400 kg ha^{-1}; 17% active ingredient). Applying the same rate of active ingredient for both granular and liquid wetting agent treatments meant that the one application of liquid wetting agent (69 L active ingredient ha^{-1}) contained 7-times more active ingredient than the manufacturer recommended be applied in a single application (no adverse effects were visible nor measured for turfgrass growth or color—see Section 3).

Soil wetting agent was first applied on 18 September 2009, and for plots with two applications the second was applied on 11 December 2009. The granular wetting agent was applied evenly across the turfgrass surface by hand, whereas the liquid wetting agent was diluted in water (1:80 for treatment of one application per season; 1:160 for treatment of two applications per season) and evenly applied using a watering can. At least 5 mm of irrigation water was applied to all turfgrass plots immediately following the application of the wetting agent treatments. At other times, turfgrass plots were irrigated at a rate of 60% replacement of net evaporation summed and applied three times per week; which is sufficient to maintain younger kikuyugrass in south-western Australia (Short, 2002). All plots received a soluble granular fertiliser four times per year (two applications in spring, two in autumn), which was watered in with at least 5 mm of water. Each application was equivalent to 50 kg N ha^{-1}, 7.3 kg P ha^{-1}, 25 kg K ha^{-1}, 65 kg S ha^{-1}, 16 kg Ca ha^{-1}, 2.0 kg Fe ha^{-1}, 1.6 kg Mn ha^{-1}, 0.4 kg Cu ha^{-1}, and 0.4 kg Zn ha^{-1}.

2.3. Turfgrass growth and quality

Growth of each plot was assessed using the dry mass of mowing clippings. Plots were mown weekly, at a height of 15 mm, and the mass of the fresh clippings weighed. A sub-sample (20–25 g) of the fresh clippings was collected and weighed, and then dried (60 °C) for at least one week before reweighing to determine the fresh:dry mass ratio. After collecting the sub-sample, the remaining fresh clippings were immediately redistributed across the surface of the respective plot. The dry mass of clippings from the plot was calculated from the fresh:dry mass ratio. Shoot dry mass was also measured immediately prior to and at the end of the study to document any changes during the study. The dry mass of shoots was determined by collecting two cores (each core was 72 mm in diameter) from each plot, and these were washed with tap water to remove the soil, roots excised, before oven drying (60 °C) and then recording the dry mass.