Using Surfactants in Optimizing Water Usage on Turfgrasses

A Research Report by

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Abstract

The quantity and quality of irrigation water are limiting factors in maintaining high-quality turf grasses for landscapes and golf courses in Southern California. The incorporation of a surfactant (wetting agent) in the irrigation protocol is being encouraged in order to conserve irrigation water. Wetting agents are organic polymers, which can be injected into the irrigation lines in order to reduce water usage on landscapes and golf courses. Wetting agents help retain water in the soil profile for a longer period of time, and hence can increase the time in between irrigation cycles.

The objective of this research project was to evaluate three different surfactants and their interaction with two different water sources. The experiments were carried out in plots at the C-TILT (Center for Turf Irrigation and Landscape Technology); "California State Polytechnic University, Pomona. Twenty-four plots (3m by 3m) were laid out in a split-plot design, with three replicates. Each individual plot was irrigated separately, and water meters were installed on-line. During the experiment, twelve plots were irrigated with potable drinking water and twelve with recycled water. Irrigation-water quality (potable or recycled) was the primary factor and three different surfactants formed the secondary factor. Bermudagrass (GN-1) was sodden and maintained under golf-course fairway management conditions. The three different surfactants (Irrigaid at 1753 mL/hectare every two weeks, Dispatch and ACA 1897 at 877 mL/hectare every week) were injected into the irrigation lines. Volumetric moisture content (VMC) was measured with a "Time Domain Reflectance - TDR" probe at randomly selected spots and an automated "Time Domain Transmission - TDT" device measuring every hour after injection at 20 cm below soil surface. The experiments were started in May 2003, and the plots were irrigated at 100% of the reference evapotranspiration (ETo) for that month. In June, the amount of water was reduced to 70%ETo followed by a further reduction to 30%ETo in July. Finally in August, the plots were irrigated at 10%ETo to induce moisture stress.

Generally, all surfactant treatments helped retain more moisture compared to the untreated plots. There was no significant difference in soil temperature between all the treatments. Under moisture stress (10%ETo), all surfactant treatments resulted in higher volumetric moisture levels. Values resulting are given in the paper text.

INTRODUCTION

The quantity and quality of irrigation water are becoming the limiting factors in maintaining high quality turf for golf courses all across the United States. Golf course superintendents are facing difficult decisions related to obtaining sufficient volumes of high quality irrigation water. Issues surrounding the availability have led to blending water supplied from different sources. Others are relying on recycled water supplies. Periodically, there are considerable shifts in established precipitation patterns. As a result, affected golf courses begin to experience salt problems. The global demand for fresh potable water has been estimated to be doubling every 20 years. Golf course superintendents, increasingly, will be forced to utilize alternative water sources (Duncan *et al*. 2000). Recycled water (tertiary treated effluent from wastewater treatment plants) is being considered as an alternative source for irrigation water available to many golf courses throughout the Southwestern United States. Many sites have started using recycled water successfully (Huck *et al*. 2000).

As golf course superintendents are asked to switch to alternative water supplies, they have to respond with the implementation of integrated approaches that match proper agronomic practices to individual sites. Mastering management practices, based on soil sampling, soil testing, irrigation water analysis reports, and site-specific monitoring becomes critical. Irrigation water quality is a significant variable, with a recognized impact on the health of turf, and successful golf course superintendents develop the means to monitor interactions between their water supplies, fertilizers, herbicides, pesticides, and soil chemistry closely.

High salt content in water can prevent the turfgrasses from properly absorbing water (through osmosis). Salinity problems, observed mainly during periods of high temperature and drought, stresses the turf. The potential damage from salinity varies from mild discoloration, to wilting, and even death. The first sign of salinity problems, in an established turf, is a blue-green coloration and as the stress due to salinity increases, the plants start to wilt. Ultimately turf density declines (Throssel, 1996). When the sodium content in soils is high, the soil colloids get dispersed, ultimately leading to lower water infiltration rates. The permeability of soils has been shown to be a function of both the total salinity and the exchangeable sodium percentage (ESP) (Mitchell and Donovan, 1991). Lower water-infiltration rates are detrimental to turfgrass growth because of reduced water availability to the plant, limited salt leaching capacity, and potential 'ponding' in depressions that result in reduced aeration following irrigation (Mitchell and Donovan, 1991). Under severe salinity conditions, turf may be lost and the exposed soil surfaces can develop moss and/or algal growth.

High sodium percent base saturation in the soil creates additional problems for other plants in the landscape. Plant roots absorb the sodium and transport it to leaves, where it can accumulate and cause injury. The leaf symptoms of sodium toxicity resemble those of 'salt burn'. Salt burn occurs when sodium is absorbed directly by leaves from irrigation water with a high level of sodium salts. High sodium irrigation water can be particularly toxic if applied to plant leaves via. overhead sprinklers (Harivandi, 2000).

The objectives of the trial were to develop a protocol to optimize irrigation scheduling based on evapotranspiration (ET) demand and study the potential of water conservation by injecting surfactants into the irrigation line.

MATERIALS AND METHODS

The experiments were conducted at the Center for Turf Irrigation and Landscape Technology (C-TILT), California State Polytechnic University, Pomona, U.S.A. The plots were laid out in a split-plot design with two factors. Irrigation water quality (potable or recycled) was the primary factor and the injection of different surfactants (Irrigaid at 1753 mL/hectare every two weeks, Dispatch and ACA 1897 at 877 mL/hectare every week) was the secondary factor. Twenty four plots (3 m by 3 m) were constructed with individual irrigation control (Figure 1.). The soil at the experimental site was a clay loam. Bermudagrass (GN-1) was sodded and was maintained at a golf course fairway height. During the experiment, twelve plots were irrigated with potable drinking water and twelve with recycled water.

Irrigation Scheduling

Irrigation scheduling was based on the evapo-transpiration (ET) demand for each month. Injection of surfactants was started in April, 2003 and continued till September, 2003. The plots were irrigated at 100% of the cumulative ET demand for the month of May, 70% ET demand in the month of June, 30% of ET in month of July and finally 10% of ET in August.

Photo1. Irrigation trenches being dug

Photo 2. Data from the Aquaflex® sensors being uploaded

Data Collection

Turfgrass Visual Performance

The turf plots were evaluated by the visual turf-score rating method on a weekly basis. The turf visual quality assessment included density, texture, and color scoring. A color rating meter was also used to measure the percentage of reflectance of red, blue and green light.

Moisture Content

The volumetric moisture content in the soil was measured in two ways.

Time Domain Reflectometry (TDR)

A TDR probe was used to monitor localized moisture readings at 4 randomly selected locations in each plot. Two sets of TDR probes (8 cm and 20 cm long) were used to measure the soil moisture

Photo 3. Aquafkex® sensors being installed in each plot

Time Domain Transmission (TDT)

Aquaflex® sensors (Streat Instruments, New Zealand) were installed in each plots at 15 cm below the soil surface. Each sensor was programmed to measure volumetric moisture content every hour. The sensors measured the moisture content over the entire 3 m plot length in a cylindrical volume of 6 liters of soil. Soil temperature was also measured every hour with the help of the sensors and the data was uploaded with a help of a handheld Palm top organizer from the data loggers. The TDT provides spatial averaging and compensation for soil temperature and soil conductivity.

Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

Electrical conductivity (EC) and total dissolved solids (TDS) in the soil were measured every month.

Photo 4. Surfactant injection ports

Photo 5. Data loggers attached to a Palm® device

PLOT DIAGRAM

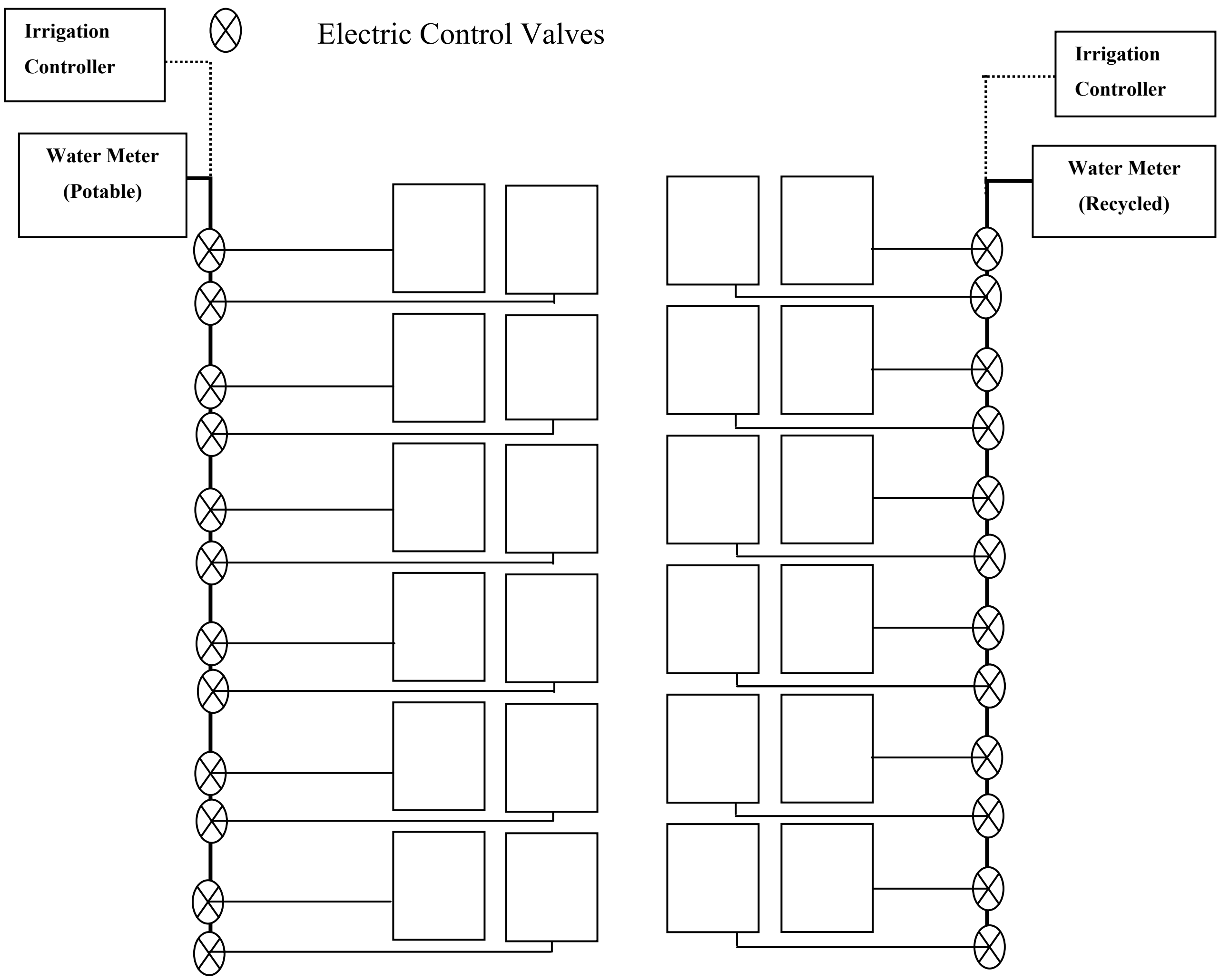

Figure 1. Plot diagram of the research plots showing all the irrigation components.

Specifications

1. The irrigation for each plot was individually controlled by electric control valves.
2. The plots were 3 m by 3 m in dimension.
3. The irrigation system had 4 rotary spay heads (MP 2000, Walla Walla Co.) at four corners of each plots.
4. A Campbell scientific weather station was installed on site.

Localized Dry Spots (LDS)

Localized dry spots (LDS) are also called isolated dry spots or hot spots. These spots are characterized as irregular areas of stressed and declining turf, usually with a restricted root system (Karnok and Tucker, 1989). The plots were rated for LDS once in spring, summer and fall.

Photo 6. Layout of the plots at the research facility

Data Analysis

Statistical analysis was conducted to assess the changes in volumetric soil moisture and changes in EC and TDS. The data was analyzed with analysis of variance (ANOVA) with the general linear model (GLM) program of SAS (SAS, 1989). Normality and significance at $p \leq 0.05$ and $p \leq 0.01$ were calculated. Expected mean squares were calculated for all main effects and their expected interactions (Damon and Harvey, 1987). Error terms were calculated with the expected mean squares and were used as denominators in F-test validity calculations. If the ANOVA did not reveal significant interactions ($p \leq 0.05$) the data was pooled over replicates.

Photo 7. Setting up catch cans to measure the precipitation rate

Photo 8. Injecting surfactants using an injection pump

RESULTS AND DISCUSSIONS

Overall all the surfactant treatments helped retain higher levels of soil moisture between irrigation cycles at 15 cm from the soil surface compared to the untreated plots.

Irrigation at 100% ET

During the month of May, 2003 the turfgrass plots received 100% of the cumulative ET demand for the month. The bermudagrass turf did not experience much moisture stress during this month and there was no significant difference in turf color or quality between the treatments. Highest soil moisture was observed with the Dispatch treatments for both the water sources followed by Irrigaid in the potable water and ACA 1897 in the recycled water. There was no significant difference between the ACA 1897 and the untreated check in the potable water source. With the recycled water irrigated plots there was no statistical difference between the Irrigaid and untreated plots (Table 1.)

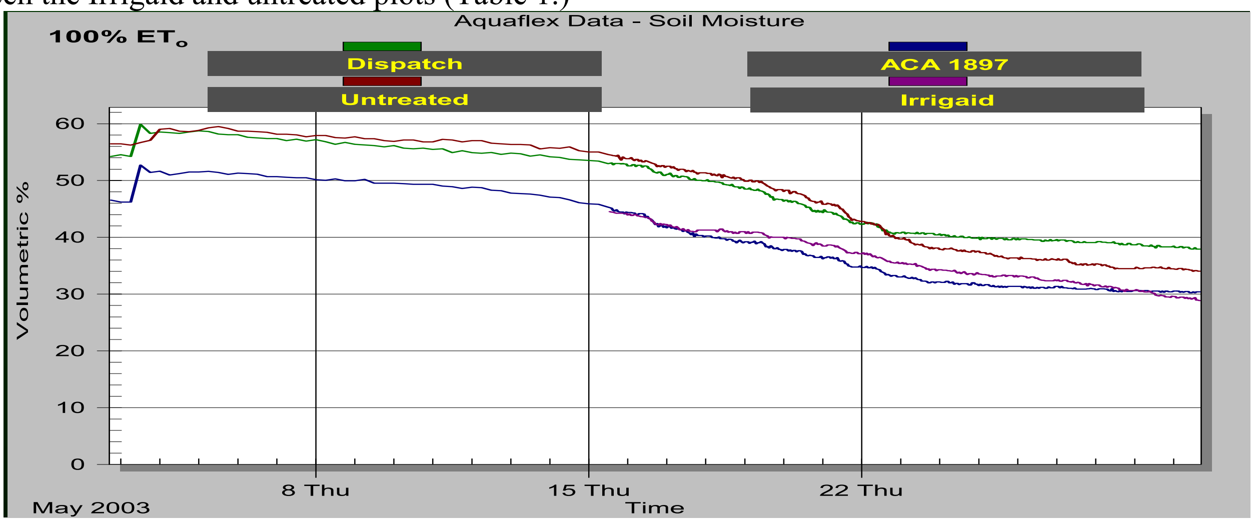

Figure 2. Changes in the volumetric soil moisture content (%) at a depth of 15 cm in May 2003 (100% ET)

Irrigation at 70% ET

The turf plots received 70% of the cumulative ET demand for the month of June, 2003. The Dispatch treatment resulted in the highest amount of volumetric moisture content in soil for both the water sources. There was no statistical difference between the Irrigaid and ACA 1897 treatments in the potable water source. In the recycled water irrigated plots the AC 1897 treatment had higher amount of soil moisture compared to the Irrigaid treatment. There was no statistically significant difference between the Irrigaid and the untreated check plots with the recycled water source.

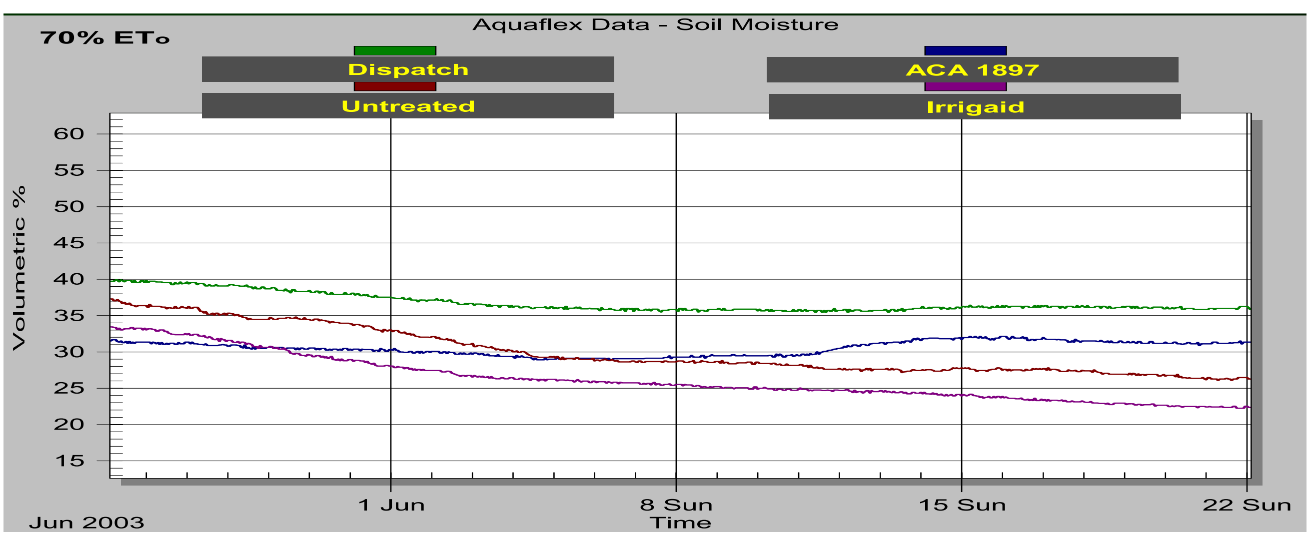

Figure 3. Changes in the volumetric soil moisture content (%) at a depth of 15 cm in June 2003 (70% ET)

Irrigation at 30% ET

The soil at the experimental site is a clay loam soil and it held moisture for a long period of time. The soil did not dry between the irrigation cycles when we irrigated the plots with 100% or 70% of the ET demand for those months and the bermudagrass experienced marginal moisture stress. So, we reduced the amount of irrigation water to 30% of the ET demand in the month of July, 2003.

All the surfactant injection treatments resulted in significantly higher amount of volumetric soil moisture content compared to the untreated check. The turf experienced drought stress and localized dry spots started to appear but there was no significant difference between the treatments. The Dispatch treatment helped the soil maintain higher amount of soil moisture compared to the other treatments followed by Irrigaid in the recycled water and ACA 1897 in potable water. There was no statistically significant difference between the Irrigaid and ACA 1897 treatments with the recycled water source.

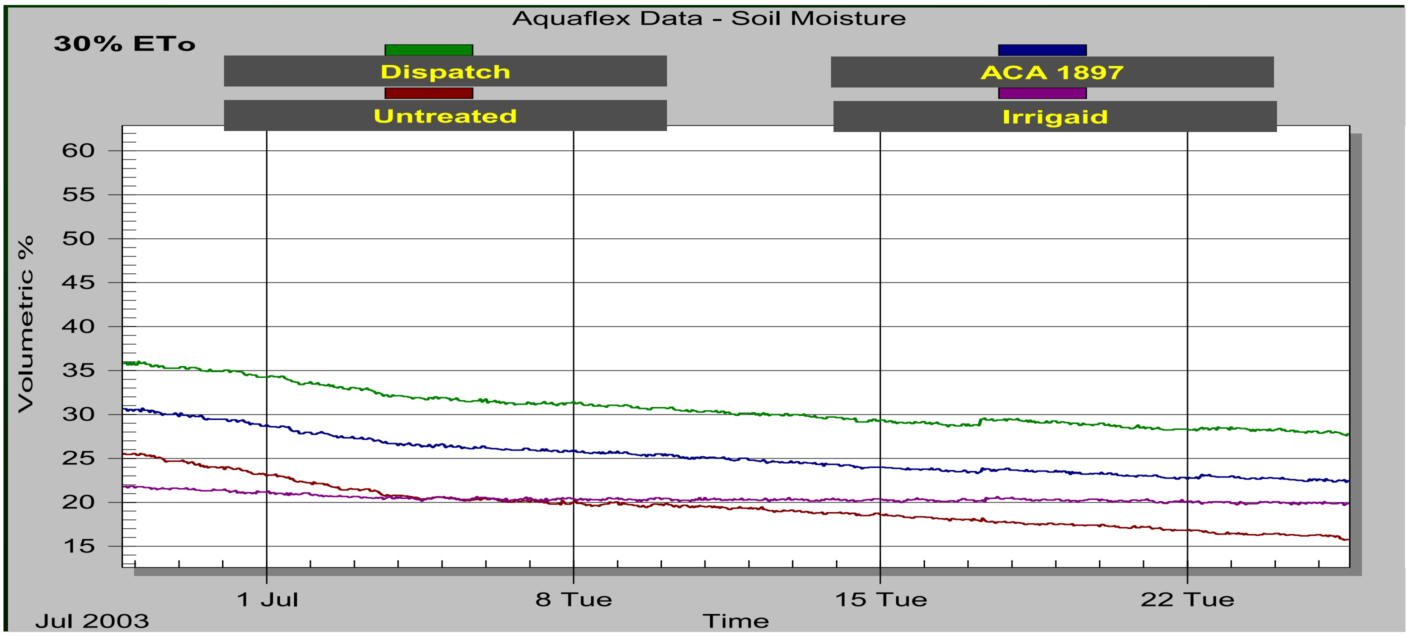

Figure 4. Changes in the volumetric soil moisture content (%) at a depth of 15 cm in July 2003 (30% ET)

Irrigation at 10% ET

All the turf plots were irrigated with only 10% of the cumulative ET demand in August, 2003. All the surfactant treatments reduced the total dissolved solids (TDS) and electrical conductivity (EC) in the soil compared to the untreated plots but there was significant difference between the surfactant treatments. During this month all the Dispatch treated plots irrigated with potable water had a significantly higher amount of volumetric soil moisture content at 15 cm from the soil surface compared to the other treatments. The Irrigaid and ACA 1897 treated plots had significantly higher amounts of soil moisture compared to the untreated plots but there was no statistical difference between the two treatments (Figure 2.).

The surfactant treatments did not have an effect on the soil temperature. The soil temperature varied from 28° C to 31° C during the month. All the surfactant treatments significantly reduced the presence of localized dry spots (LDS) in the plots compared to the untreated control but there was no statistical difference between the surfactant treatments.

Table 1. Effect of surfactants on volumetric soil moisture (VMC) (%) content in soils. Data from the 15th of each month was used for the analysis. The means followed by the same letter do not significantly differ. (P = 0.05 Duncan's New Multiple Range Test).

Treatments	Volumetric Soil Moisture Content in Soils (%)							
	100% ET		70% ET		30% ET		10% ET	
	Potable	Recycled	Potable	Recycled	Potable	Recycled	Potable	Recycled
Irrigaid	50 b	49 c	30 b	29 c	20 c	27 b	20 b	23 b
Dispatch	56 a	58 a	36 a	35 a	29 a	32 a	28 a	27 a
ACA 1897	48 c	52 b	32 b	32 b	24 b	28 b	21 b	24 b
Untreated	46 c	40 c	28 c	28 c	18 d	22 c	16 c	17 c

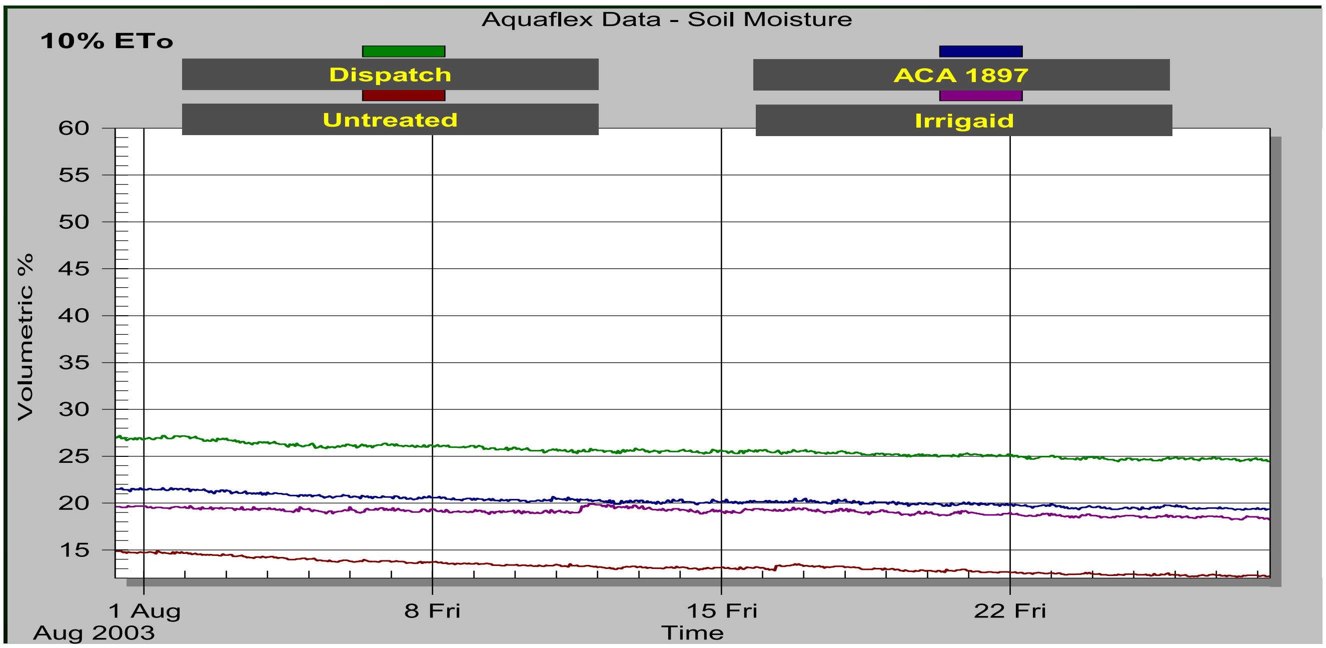

Figure 5. Changes in the volumetric soil moisture content (%) at a depth of 15 cm in August 2003 (10% ET)

CONCLUSION

The injection of surfactants into the irrigation lines increased moisture retention in the soil. Other researchers have also observed increased moisture retention in soils due to the application of wetting agents (Leinauer, B. 2002). The increase in water retention due to the application of surfactants can be explained by the mechanism in which the surfactant works. Surfactants reduce the surface tension of water and helps water infiltrate into the pore spaces in the soil. These pore spaces are not generally accessible to water without the surfactants (Leinauer, B. 2002). Some researchers have suggested that surfactants provide a hydrophilic coating to water repellent soil particles (Kostka et al. 1997). This organic hydrophilic coating on soil particles reduces water repellency and helps retain water in the soil profile.

Overall the surfactant injection treatments helped in retaining moisture in the soil. The treatment effect was more pronounced under moisture stress (30% and 10% of ET). We could maintain a live growing surface with only 10% of the ET demand but the turf quality was not optimum. Bermudagrass could be maintained under optimum growing conditions with 50-30% of the ET demand when grown on a fine textured soil. The irrigation schedule has to be modified when bermudagrss is grown on a more coarse textured soil. The infiltration rate in that particular soil should also be taken into consideration when growing turf on a coarse textured soil. The quality of irrigation water did not have detrimental effect on performance of the surfactants. Hence, we could conserve water by developing a proper program of systematic injection of surfactants into the irrigation lines.

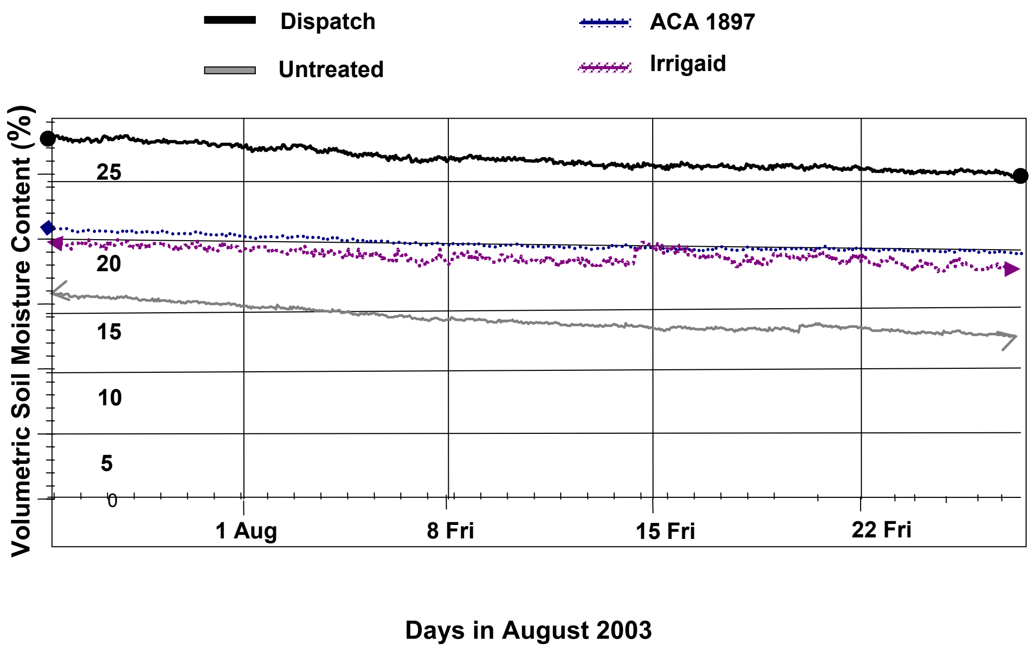

Figure 6. Changes in the volumetric soil moisture content (%) at a depth of 15 cm over a period of one month (August 2003) in the root zone of bermudagrass as affected by surfactant injection treatments irrigated with potable water. During August, 2003 the bermudagrass plots were irrigated at 10% of the cumulative ET demand for the month.

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