Control Your Water, Control Your Results: Improving Irrigation Audits and Reducing Soil Hydrophobicity.

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Abstract. *A new, superior irrigation unit and a twenty year old irrigation unit have one thing in common: irrigation audits must be performed regularly to maintain or maximize the benefits of these systems. Enhancing irrigation efficiency and distribution uniformity will allow turfgrass managers to control the water from the irrigation head to below the surface of the soil. As water costs increase, public scrutiny will intensify making the role golf course superintendents and landscape managers crucial for conserving water while enhancing the cosmetic appearance of turfgrass and landscape areas. The objective of this presentation is to review irrigation audit procedures and introduce concepts such as soil water repellency; which may be inhibiting the performance of the irrigation system and reducing turfgrass quality. Soil surfactants will be discussed as tools to improve irrigation efficiency and water distribution in the soil.*

Keywords. irrigation audits, distribution uniformity, irrigation efficiency, soil water repellency, surfactants.

Introduction

It is widely accepted that water conservation laws will be tightened over the next few years due to a growing population and a 10% increase in agricultural withdrawals by 2050 (FAO, 2005). Focus on golf courses and landscape management irrigation practices will be closely monitored, particularly since this land is often designated as recreational land, not critical for water use. Maintaining irrigation system operation is critical to sustain irrigation efficiency and to conserve water use. Despite impressive improvements in irrigation systems and maintaining these systems, soil water repellency may be negatively impacting distribution uniformity.

Soil water repellency (SWR) may be defined as the resistance of soil to wetting and the inability of soil to retain water within the soil profile. The term “hydrophobic” or non-wettable is often used to describe these soils. Soil texture and the water content of soils plays an important role in the development and severity of SWR. Soils with coarse texture – and therefore a smaller surface area – were more prone to SWR then clay soils with larger surface area (Ma'shum et. al., 1988; Cisar et. al., 2000). However, soils with significant amounts of clay (>20%) also exhibited hydrophobicity (McGhie et. al., 1980). Coarser texture soils such as sand do not retain water within the soil profile so extreme wetting and drying cycles occur, exacerbating the water repellent coatings (Miller, 1998). Dekker et. al., (2001) refer to the range between which samples are hydrophilic at upper water content and hydrophobic at the lower content as the "transition zone". If soils are maintained at the higher water content, then soils remain wettable and are easy to re-wet (Dekker et. al., 2001; Wessolek et.al., 2008). Difficulty lies in maintaining soils at the critical water content where organic coatings remain hydrophilic. Golf greens are dried down on an almost daily basis for faster play and to keep the predominantly sand greens from saturation. This daily "dry down" reduces volumetric water content, increases SWR, and therefore LDS and overall poor turf quality is a major issue on greens. To rewet water repellent soils requires significantly more water and defeats water conservation attempts.

Irrigation practices and soil surfactants are effective management tools. It is the objective of this paper to provide information on 1) improving distribution uniformity and irrigation efficiency via irrigation audits and 2) to highlight the success of soil surfactants for ameliorating soil water repellency. Mechanical and chemical management practices are key to water conservation and optimum turfgrass quality.

Irrigation Efficiency

Do you know how effectively your irrigation practices meet turfgrass requirements? Irrigation efficiency determines if you are overwatering and/or underwatering. Improvement of irrigation efficiency promotes turfgrass health and reduces water consumption, electricity and costs. There are three main requirements to improve irrigation efficiency: 1) improve distribution uniformity, 2) reduce irrigation precipitation rates such that it is less than soil infiltration rates and 3) determine field capacity of soil.

Distribution Uniformity

Distribution Uniformity (DU) is a measure of how evenly water is applied by an irrigation system. A DU of > 80% is considered excellent while DU<55% is poor and significant improvements should be made to the irrigation system. Figures 1, 2, 3 and 4 (Courtesy of Rain Bird) illustrate the importance of uniform distribution. The black dashed line is the rootzone and the dark brown area is the wetting front. In Fig. 1, water moves past the rootzone and an uneven wetting front indicates poor irrigation coverage. Water is lost, energy is wasted and high costs are consequences of excessive watering. As illustrated in Fig. 2, poor DU is a consequence of insufficient irrigation. A consequence of underwatering is reduced turf quality. An example of good DU is found in Fig. 3, but irrigation efficiency will be low due to excessive irrigation. Again, the consequence of good DU but poor IE is water waste and higher energy costs. A perfect world is achieved in Fig. 4. Irrigation is evenly distributed and sufficiently wets the rootzone.

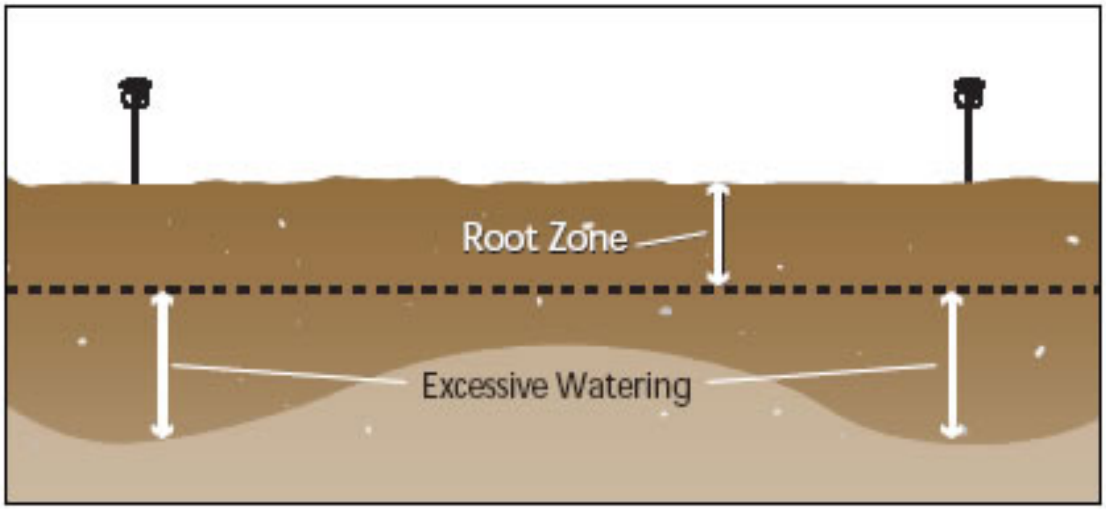

FIGURE 1: Depiction of irrigation resulting in poor DU and excessive watering

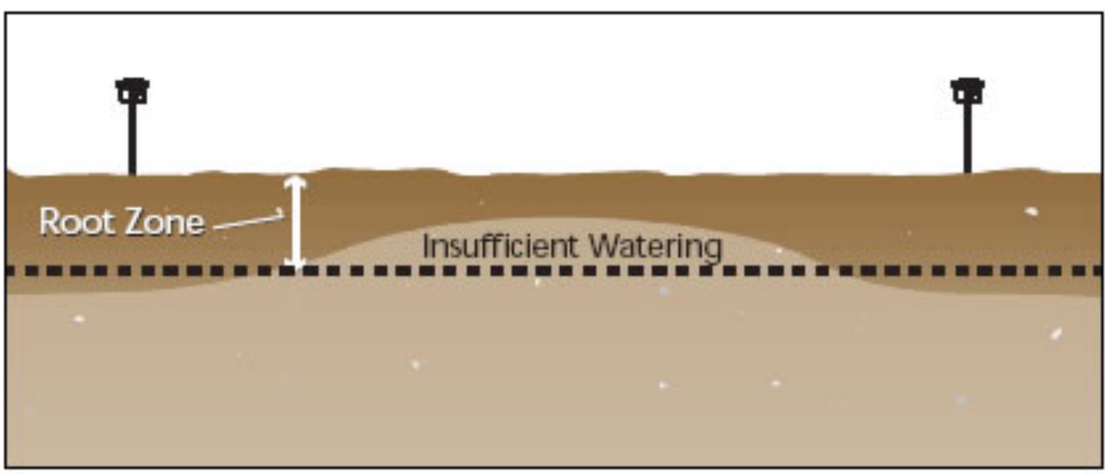

FIGURE 2: Depiction of irrigation resulting in poor DU and insufficient irrigation in parts of the field

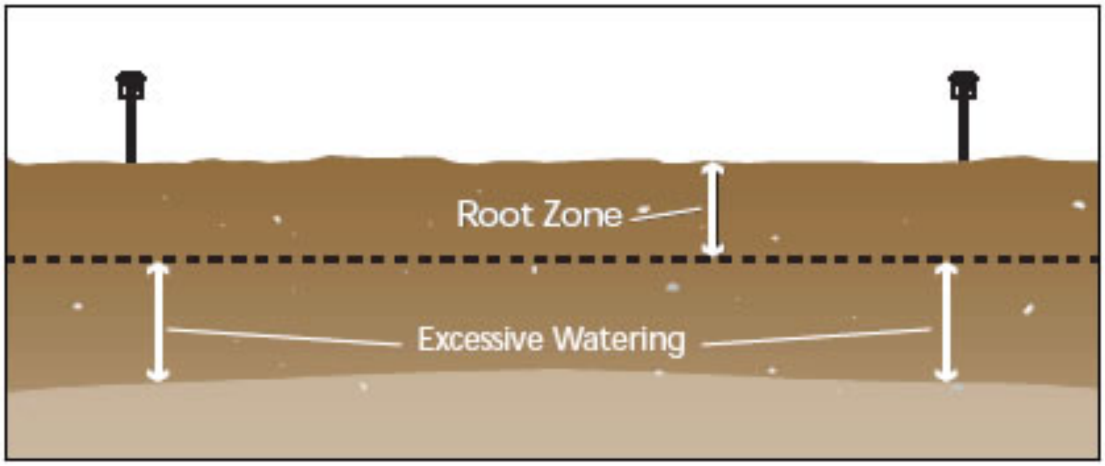

FIGURE 3: Depiction of irrigation resulting in good DU but poor irrigation efficiency

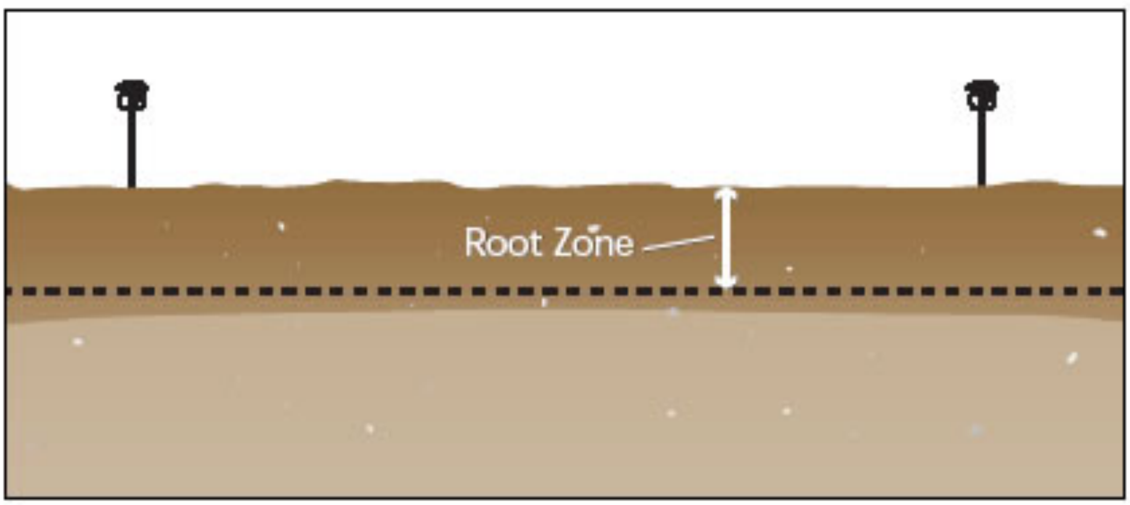

FIGURE 4: Depiction of irrigation sufficiently watering the entire field with good DU and irrigation efficiency

*Figures 1-4 courtesy of Rain Bird.

Method to Determine DU:

An irrigation audit is simple and can be done on your own. Catch containers are placed in an irrigation area (greens – 15 ft. spacing, fairways – 25 ft. spacing). Any type of container can be used; all of them need to be the same size and have the same size opening. Regardless of the area you are measuring, 24 catch containers are necessary to achieve accurate results. Number each container 1-24 with a permanent marker before placing in the test area. Making an overhead “map” of the area and placement of containers will allow you to refer back to the container location for review after you collect and review the data.

After the containers are placed in the area to be tested, run the sprinklers for a set period of time. It is best to run the sprinklers at night, when irrigation is typically applied to the entire course. Collecting water under the same conditions – flow rate and pressures – normally completed provides more realistic data. After the irrigation is run, put the containers in order of water volume from highest to lowest and record this information. Irrigation audit worksheets can be found at the following link: http://s3.amazonaws.com/aquatrols/20120224110212.xls. Add up the total water volume collected, and divide by the total number of catch containers used to determine the average. Now, determine the average volume of the lowest 25% of the catch containers. The lower quarter (LQ) is the weakest area of coverage for the irrigation system (IA. 2003, Kieffer and Huck, 2008).

If the audit results in low DU, there are several things that can be done to improve the number. For example, make sure the irrigation heads are the correct size for the area covered. Are the heads properly and evenly spaced? Check nozzles and replace them if they are worn. If the irrigation system pressure is not correct or the pipes are the not the right size, replace them. DU may be improved by making small changes such as correcting system pressure or replacing worn nozzles. Perhaps irrigation heads or pipes are not the right size and can be fixed. New irrigation systems should also be considered if DU is below <50 %.

Irrigation Precipitation Rate (PR)

Turfgrass managers water based on time, gallons, inches or area. However, it is important to know if the irrigation precipitation rate is less than the soil infiltration rate. If PR is greater than the soil infiltration rate, water will run off or sit on the soil surface and, in hot and dry climates, eventually evaporate. This misleads turfgrass managers into thinking they are applying a certain amount of water when most of it is not infiltrating the soil profile. Data used to calculate DU can also be used to calculate PR. A known PR determines how long to irrigate for a known volume of water.

Method to Determine PR

Measure the mouth of the catch container. If the container used is a square, collect the length (in.) and width (in.) and multiply together for the total of the container mouth. Record the test run time in minutes. Multiply the average volume of the containers (determined in DU calculations) and multiply by 3.66 (ml/min to in/hr. conversion factor);

this will be number 1. Multiply by the total run time by the area of the container mouth; this will be number 2. Divide number 1 by number 2. The result is your PR (in/hr.) (Kieffer and Huck, 2008).

Field Capacity

Field Capacity (FC) is the water holding capacity of the soil and is defined as the amount of water held in soil against the force of gravity. To determine FC, saturate the soil and then allow one day for the gravitational water to drain. Take soil moisture measurements using a moisture meter and determine the percent volumetric water content. This will be your FC. Wilt point (WP) is the amount of water that is not available for plant use (Brady and Weil, 2008). WP is determined by collecting soil moisture measurements when turfgrass begins to wilt. Collecting FC and WP will identify turfgrass areas which may need supplemental irrigation, but Kieffer and Huck, (2008), determined that DU calculated via soil moisture data rather than the catch can method would be higher. Handwatering turfgrass areas and then determining soil moisture via moisture meter probe assesses handwatering practices and measures soil moisture – also a good measure of DU of irrigation systems. It is important to remember that FC varies from one area to another, sometimes substantially. Therefore, it is important to use the same meter for every measurement and collect many measurements over the irrigated area.

Soil Water Repellency (SWR)

The cause of SWR is the hydrophobic organic coatings on soil and sand particles (Schreiner and Shorey, 1910). These non-polar, hydrophobic coatings surround the soil particle and prevent water, a polar molecule, from attaching to the soil surface. The origin of SWR is as varied as its distribution. Sources of organic acids which contribute to SWR are numerous (Fig. 5). Plant root exudates, fungal exudates and decomposing plant materials are just a few of the sources that contribute to the organic acid deposition on soil particles. Water repellent coatings influence water movement by decreasing water infiltration at the soil surface, and minimizing uniform water penetration throughout the soil profile (Fig.6). Effectiveness of irrigation systems is diminished by SWR. A perfect irrigation system may place a water drop exactly where it needs to go, but SWR prevents permeation of that water drop.

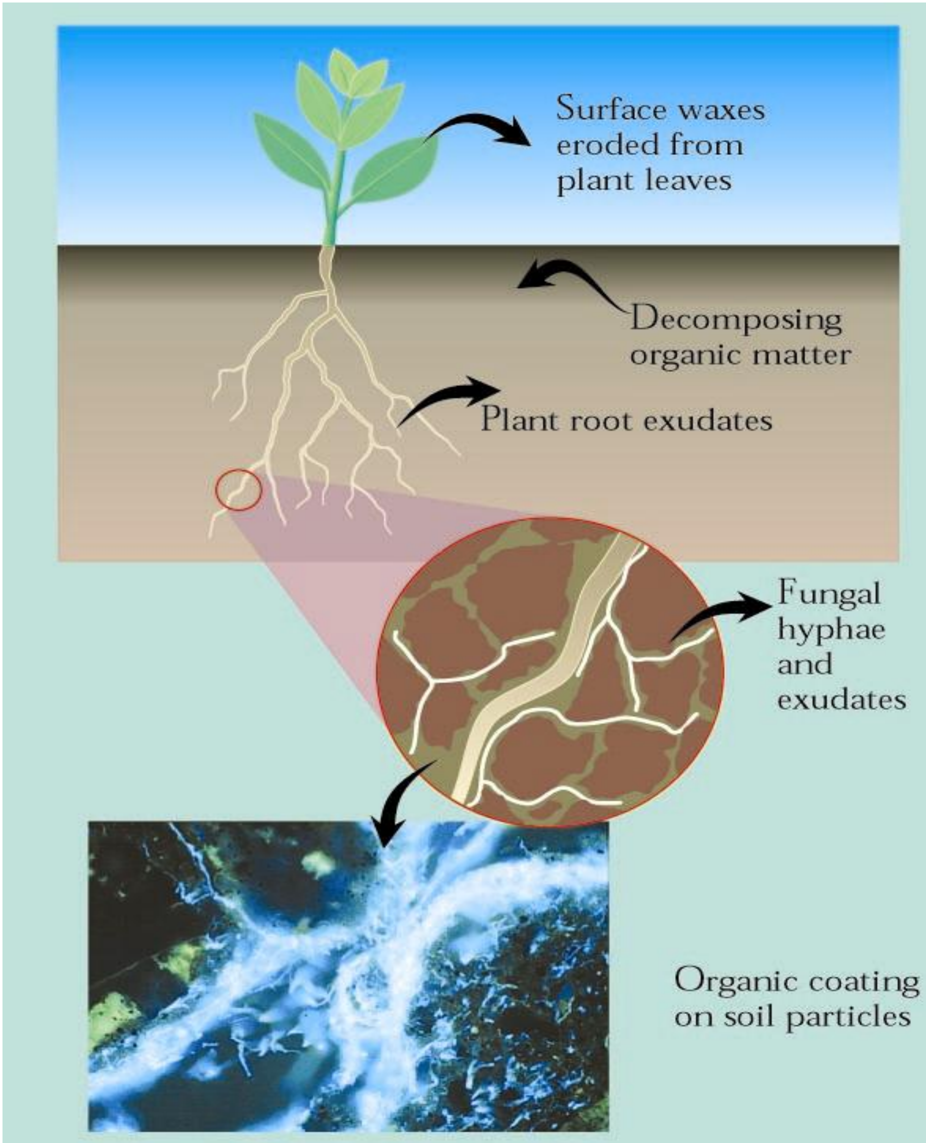

Figure 5. Sources of organic acids. Courtesy of Paul Hallett, Scottish Crop Research Institute

How to Determine Soil Water Repellency

Soil water repellency is determined by a water drop penetration test (WDPT) (Letey, 1969). Using a soil probe, collect a soil sample and air dry at room temperature for two weeks. Soil must be completely dry to determine degree of soil water repellency. Place a water droplet, using a straw or pipette, at one cm intervals along the soil core as exhibited by Fig. 6. Time how long the soil core takes to move into the soil core.

Figure 6. WDPT conducted on a soil core. Photo courtesy of Demie Moore.

Severity of soil water repellency may be determined using Table 1. The more severe the soil hydrophobicity, the more difficult soils are to rewet. Difficulty rewetting soils precedes poor turf quality.

Table 1. Soil Water Repellency Classification. (Ritsema and Dekker, 1996)

WDPT time (sec)	Classification
< 5	Wettable
5-60	Slightly Water Repellent
60-600	Strongly Water Repellent
600-3600	Severely Water Repellent

Surfactants

To minimize the effects of SWR, soil surfactants are applied via irrigation systems. Surfactants are molecules with a hydrophilic end to attract water and a hydrophobic end to attach to hydrophobic coatings on soil particles. Surfactants work in two ways: 1) by reducing surface tension at the soil-air interface and 2) coating hydrophobic soil particles to create hydrophilic particles. Reducing surface tension at the soil-air interface improves water infiltration and reduces runoff.

Field Trial #1

Research was conducted by Nuno Bobone Sepulveda at Ohio State University in Wooster, Ohio in 2004. *L93* bentgrass was established on a silt loam soil with a 4% slope and maintained as a golf course fairway. Plots were arranged in a complete randomized block design with three replicates. Runoff was collected at the end of the slope using a tipping bucket flow meter with a flume. An APG-E soil surfactant was injected weekly through an irrigation system at a rate of 1.74 L/ha. Runoff measurements were collected during rainfall events on 4 different days. Data was collected as the number of tippings that occurred after four rainfall events and the mean average was determined. Data presented in Figure 7, reveals significant reduction in runoff in the surfactant treated plots (Sepulveda, 2004). Reduced runoff enhances DU and improves irrigation efficiency.

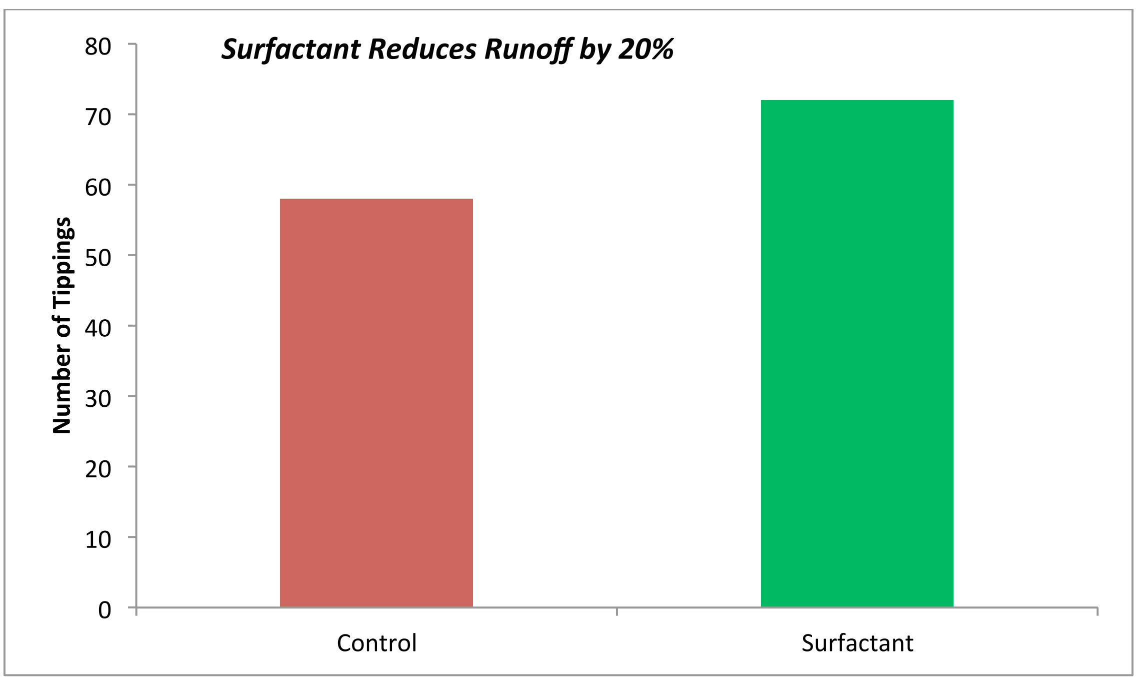

Fig. 7. Surfactant plots significantly reduced runoff. Research conducted at Ohio State University, Wooster, 2004.

Field Trial #2

SWR in the soil profile creates preferential or “finger” flow paths (Fig. 8). Wettable soil particles create matrix flow of water through the profile. Generally, soil surfactants hydrophilize soil particles and increase volumetric water content of soils. A research project was conducted at the Center for Turf Irrigation and Landscape Technology, at California State Polytechnic University, Pomona, California in 2003 and 2004. Bermudagrass plots grown in a clay loam soil and maintained as a golf course fairway were laid out in a split plot design with three replicates.

While irrigation water quality (potable and recycled) was the main factor, a soil surfactant was also evaluated. An APG-E soil surfactant was applied every week at a rate of .877 L/ha. In the first month of the trial, plots were irrigated at 100% reference cumulative evapotranspiration rates (ET_0) in the first month. ET_0 was reduced to 70%, 30% and 10% over the next 3 months, respectively. Volumetric water content was collected at 150 mm depth using time domain reflectometers. Data presented in Table 2 is the average of percent volumetric water content collected on the 15th day of every month during the trial. Surfactant treatment significantly increased VWC when compared to the control treatment (Mitra, et al., 2005). By enhancing uniform water flow throughout the soil profile, DU is maximized and all chemicals applied with surfactants are evenly distributed, enhancing turfgrass quality.

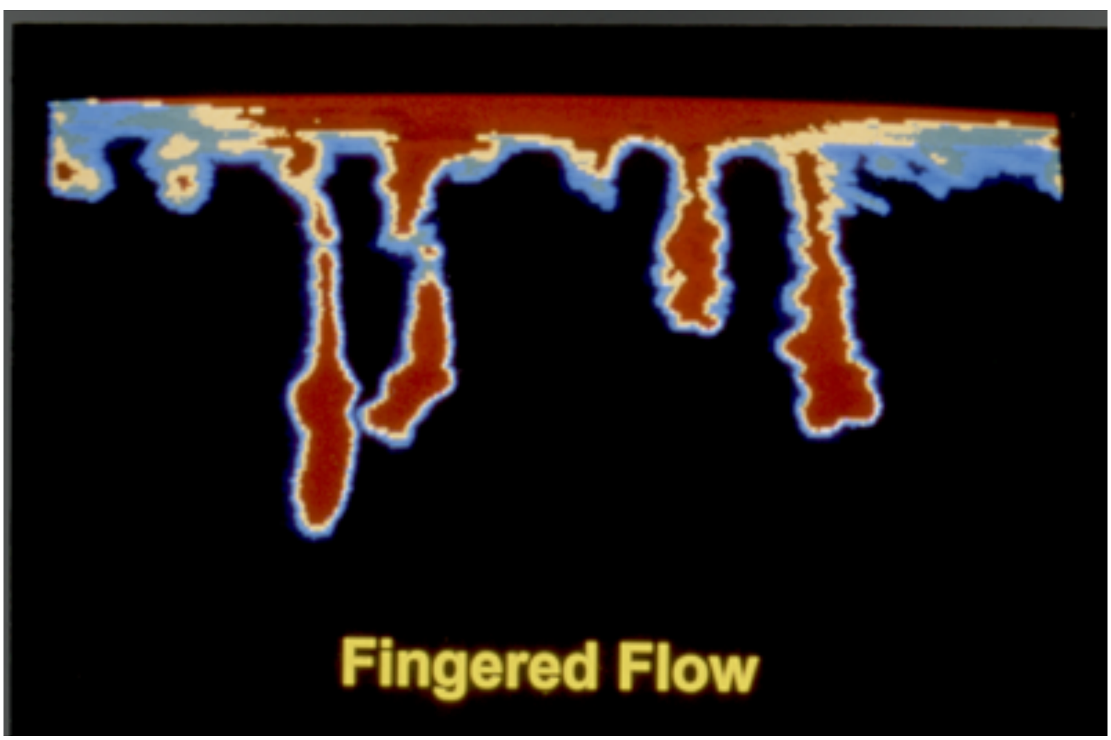

Figure 8. Preferential Flow Paths. Figure courtesy of Tammo Steenhuis, Cornell University.

Table 2. Effect of an APG-E soil surfactant on volumetric soil moisture (VWC) (%) content in soils.

Treatments	Volumetric Soil Water Content (%)							
	100% ET		70% ET		30% ET		10% ET	
	Potable	Recycled	Potable	Recycled	Potable	Recycled	Potable	Recycled
ACA1848	56 a*	58 a	36 a	35 a	29 a	32 a	28 a	27 a
Untreated	46 c	40 c	28 c	28 c	18 d	22 c	16 c	17 c

*The means followed by the same letter do not significantly differ. (P = 0.05 Duncan's New Multiple Range Test).

Conclusion

Distribution Uniformity is strongly influenced by soil water repellency. Soil surfactants are proven tools to mitigate soil water repellency and conserve water while enhancing turfgrass quality. Superior irrigation systems are only as effective as the wettability of your soil. By incorporating irrigation audits and soil surfactants into your turfgrass management practices, optimum DU is possible and the overall goal of water conservation is achieved.

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