IMPACT OF SOIL MOISTURE ON WATER RELEASE FROM DRiWATER TIME RELEASE WATER

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Introduction

The DRiWATER Time Release Water is a water-based gel that was developed to provide water to various plant systems where installation of a permanent irrigation system is not feasible. The gel, a mixture of vegetable gum (2%) and water (98%), is placed in contact with the soil where the gum is metabolized by soil microorganism, resulting in the release of the water. A limited amount of information is available regarding the impact of soil moisture content on water release from DRiWATER. This report provides the results of a laboratory study designed to provide additional quantitative data on how soil moisture impacts the rate of water release from DRiWATER.

Materials & Methods

The study was conducted in the laboratory at the University of Arizona Karsten Turf Research Facility (KTRF) located in Tucson, AZ. Thirty-six soil containers were constructed using 30 cm (12") lengths of 10 cm (4") diameter PVC sewer pipe. Each length of pipe was capped on one end using a 10 cm (4") diameter PVC end cap which served as the bottom of the soil container. The top of each container was constructed so as to provide a port through which an DRiWATER reservoir could be inserted into the container. Tops were made by first drilling a 4.3 cm (1.625") diameter hole in the center of a 10 cm (4") diameter PVC end cap and then inserting a 12.7 cm (5") length of 3.2 cm (1.25") diameter Schedule 40 PVC pipe through the hole such that one end of the pipe was flush with the top of the endcap and the other end extended into and below the open end of the cap. The pipe was attached to the end cap using PVC adhesive. The end extending below the end cap served as the access port (casing) for the DRiWATER reservoir and was sharpened using a bench grinder to improve entry into soil.

The DRiWATER reservoirs were constructed of 15.2 cm (6") lengths of 2.54 cm (1.0") diameter Schedule 40 PVC pipe. A 2.54 cm (1.0") PVC end cap was placed on one end of the pipe, but was not secured with adhesive so as to make the cap removable. Nylon window screen (1.15 mm (0.045") mesh; percent open area = 80%) was used to cover the end of the reservoir intended to contact the soil. The screen was cut into circular pieces that matched the outside diameter of the reservoir. These screen pieces were then attached to the end of the reservoir using contact cement. The window screen served to retain the DRiWATER in the reservoir while still allowing for soil contact.

Each soil container was filled with the farm soil from the KTRF which is classified as sandy clay loam. Soil was removed from the upper 10 cm of the soil profile and air dried outside by placing the soil on an a concrete slab for a period of two days. The air dried soil was then processed through a sieve to remove particles in excess of 2 mm in diameter and placed in a drying oven at 100$_o$C for 48 hrs.

Approximately 3 kg of oven dried soil was placed in each of the 36 soil containers. The volume occupied by the soil was determined by measuring the height of the soil in the container and then computing the resulting volume using the diameter of the container. Six moisture treatments, consisting of 0; 6; 12; 18; 24; and 30% volumetric soil moisture, were established by applying the required amounts of distilled, deionized water to the surfaces of the containers. For the five treatments requiring water applications, a coffee filter was placed on the surface of the soil prior to water application to help distribute the water uniformly over the surface. Following application of water, each soil container was covered with plastic and allowed to equilibrate for a period of 48 hours. The study was set up as a completely randomized experimental design with six replications per treatment.

The study was initiated on 19 July 2003 when the lids were placed on the soil containers. Placement of the lids forced the DRiWATER reservoir access ports into the soil. Soil that pushed up into access ports was removed with a small spoon and spatula. The DRiWATER reservoirs were filled by removing the endcap and forcing the open end down into a DRiWATER Gel Pack that had been opened on one end. This technique forced the DRiWATER into the reservoir. The filling process continued until DRiWATER was just beginning to ooze through the window screen on the opposite end of the reservoir. The endcap was replaced on a full reservoir and the reservoir was stored in a humidified box until insertion in the soil. Once all reservoirs were filled, they were assigned to the soil containers, and the matched containers and reservoirs were weighed on a scale with a resolution of 0.5 g. The reservoirs were then inserted through the ports until they made contact with the soil. Each reservoir was then rotated one quarter turn to ensure good contact between the reservoir and the soil. The soil containers were placed on a bench in the lab where the temperature was set at $25^{o}C$ +/- $1^{o}C$. Soil containers and their affiliated DRiWATER reservoirs were weighed every 3-7 days using a scale (0.5 g resolution). Specific measurements included: 1)gross container mass (reservoir plus container), 2) container mass without DRiWATER reservoir, and 3) mass of DRiWATER reservoir. Changes in container and reservoir mass were used to evaluate the rate at which DRiWATER was converted into water and stored as soil moisture. The study was terminated on 18 September 2003 (61 days after initiation). Half of the soil containers were sampled at the conclusion of the study to examine soil moisture profiles below the DRiWATER reservoir. Soil moisture profiles were obtained by first removing the DRiWATER reservoir, then inserting a standard core soil sampler through the access port. The core removed by the sampler was then subdivided into three, 5 cm segments with soil from each segment placed in metal sampling cans. The sampling cans were weighed, placed in an oven at $100^{o}C$ for 48 hours and then weighed again to obtain dry weights. Soil moisture content was then calculated by dividing the sample water content (wet minus dry weight) by the dry weight of the soil. The values were converted to volumetric soil moisture by multiplying by the mean soil bulk density in the containers (1.51 g/cm^3).

Results and Discussion

Soil moisture did impact the rate of water release from DRiWATER (Figure 1). Figure 1 shows the mean mass of DRiWATER removed from the reservoirs and the corresponding mean increase in soil moisture obtained for each soil moisture treatment. The loss of DRiWATER from the reservoirs exceeded the measured increase in container soil moisture content by ~ 5 g across all treatments. This discrepancy between DRiWATER loss and the resulting increase in soil moisture is due to a slow rate of evaporation (from the soil containers) over the course of the study. Evidence to support evaporation as the cause of this difference comes from the fact that gross container mass (container plus DRiWATER reservoir) declined on average ~ 5 g over the course of the study. Because evaporation produced a bias in the data pertaining to container soil moisture, water release from DRiWATER was determined by analyzing the change in DRiWATER reservoir mass over time.

Figure 1 suggests the maximum rate of water release occurred at 12% volumetric moisture; however, statistical assessment of the study data set provides a slightly different interpretation. The analysis of variance used to analyze the entire study data clearly indicates that soil moisture impacts the rate of water release from DRiWATER (Table 1). However, when the Least Significant Difference technique was employed to examine whether particular treatment means were significantly different from one another, DRiWATER water release rates at 6%, 12%, and 18% volumetric soil moisture were not significantly different (Table 1), indicating water release from DRiWATER remains quite high over a broad range of soil moisture conditions.

Water release from DRiWATER was significantly reduced when soil moisture was either very dry or very wet. The rate of water release in dry soil (0% treatment) was reduced by nearly 40% compared to the average rate of water release obtained from the 6, 12, and 18% moisture regimes. Similar reductions in water release were measured when soil moisture was high. Water release in the 24% and 30% soil moisture treatments was reduced by 30% and 33%, respectively relative to the peak rate of water release (average of 6, 12, and 18% soil moisture treatments). The reduction in water release at higher soil moisture levels is important from a practical sense because the higher soil moisture treatments in this study replicate soil moisture levels at (24% treatment) and above (30% treatment) field capacity. Soils maintained at these moisture levels contain plenty of water for plant uptake and are also prone to losing moisture due to drainage and thus would not need additional water from DRiWATER.

The temporal pattern of water release for all moisture treatments is provided in Figure 2. Water release was similar from all except the 30% soil moisture treatment for the first 16 days of the study. Water release from the 30% soil moisture treatment was significantly reduced relative to the remaining treatments at 16 days after treatment initiation. Water release accelerated in the 6, 12, and 18% soil moisture treatments after day 16 of the study, and mean water release in these three treatments was significantly greater than water release from the 0, 24, and 30% treatments for the remainder of the study. Table 2 provides the mean rate of DRiWATER water release from each treatment for the first 33 days and the final 28 days of the study. While water release increased in all treatments during the last 28 days of the study, the increase was far greater in the 6, 12, and 18% soil moisture treatments. An explanation for why water release increased over time is not readily available from the data set collected in this study. However, a logical hypothesis would be that the accelerated water use reflects an increase in microbial activity near the DRiWATER-soil interface, especially in moist, but not overly wet soils.

Soil cores extracted from underneath the DRiWATER reservoir at the conclusion of the study provide further evidence of water release from DRiWATER. Figures 3 & 4 show the volumetric soil moisture content for the 0-5, 5-10, and 10-15 cm depth increments below the soil surface. In all treatments,

the soil moisture content below the reservoir was greater than the soil moisture content established at the initiation of the study, clearly indicating that water was released from DRiWATER. It is interesting to note that the gradient of soil moisture with depth is quite large in the drier treatments (0, 6, 12 and 18% soil moisture). The disappearance of this gradient in the 24% soil moisture treatment is probably due to the rapid rate at which water moves and therefore can equilibrate at these higher soil moisture contents. It is interesting to note that the soil moisture gradient reverses in the 30% treatment which indicates water is draining to the bottom of the container at this moisture level -- a clear indication that 30% volumetric soil moisture exceeds field capacity in this soil.
The core samples also provided an opportunity to view the DRiWATER-soil interface. The interface of the higher soil moisture treatments contained a black layer which often extended into the soil to a depth of 3-7 mm. The layer was not subjected to chemical evaluation, but appeared to be a dense mixture of organic material and soil particles. The layer appeared cemented or plugged to the point where the layer would restrict water flow in the higher soil moisture treatments (24 and 30%). It is also important to note that this zone emitted an odor akin to hydrogen sulfide -- a gas often associated with an anaerobic environment. These observations suggest the possibility that lack of soil oxygen was a factor in reducing water release from DRiWATER in the high soil moisture treatments.
Data collected in this study provide an opportunity to compare water release from DRiWATER with values stated in the product literature. Product literature suggests the rate is about 1 ounce (28.4 g) every three days or ~9.5 g/day. The average rates of water release from this study were far lower and ranged from 0.37 g/day to 0.66 g/day. However, assuming water release is a function of the amount of soil area in contact with DRiWATER, the data set collected in this study must be adjusted before making comparison regarding water release rates. DRiWATER is commonly sold in a square carton that measures approximately 7.3 cm on each side. Users of the product are instructed to cut off the bottom of the container and place the exposed DRiWATER in contact with the soil/root ball (of plant). The surface area of DRiWATER in contact with the soil is 53.32 cm^2. The DRiWATER reservoirs used in the study were made of 2.54 cm diameter pipe which produces a potential DRiWATER surface contact area of 5.06 cm^2. The DRiWATER reservoirs also utilized window screen to help retain DRiWATER in the reservoir during measurements. This window screen reduced the effective reservoir surface area by 20% to 4.05 cm^2. Assuming water release is related to surface area, then one should multiply the release rates obtained in this study by the ratio of the surface areas (53.32/4.05) to obtain a fair estimate of the water release rate expected from a standard DRiWATER carton. This ratio comes to 13.16 which would generate water release rates ranging from 4.9 to 8.7 g/day. The peak rate of water use obtained in this study (0.66 g/day), when properly adjusted for surface area contact, falls within 9% of the values indicated in the product literature.

Conclusions

Soil moisture did impact the rate of water release from DRiWATER. Water release was reduced when soil moisture was either very wet or very dry. The current product recommendation to thoroughly wet the soil surrounding transplants would therefore seem appropriate. Failure to water would lower the rate of water release and possibly result in severe water stress or plant death. If watering produces excessive soil moisture for a few days, the results of this study indicate water release from DRiWATER will simply be reduced.

The results of this study also indicate that water release may accelerate over time. This acceleration may simply reflect the population dynamics of the soil microbes, or it may be an artifact of the study that is not particularly relevant to the intended use of the product. One can assume that the microbes responsible for breakdown of DRiWATER must develop in sufficient numbers to make the product work effectively. Presumably, water release should increase as the microbial populations grow and develop near the zone of DRiWATER-soil contact. However, the soil used in this study was oven dried and then rewetted to establish treatments. The process of oven drying the soil may have reduced and/or inhibited microbial populations, resulting in a longer period of reduced microbial activity (water release) than might be expected if the product were placed directly into soil in the natural environment. It is also important to note that the recommended procedure for using the product is to place the exposed end of an DRiWATER container on the root ball of the transplant. Presumably, the microbial activity would be quite high around the root ball which should result in high rates of water release in very short order.

The maximum rates of water release approached the levels indicated in the product literature after adjustments were made for differences in DRiWATER-soil surface contact area. The slightly lower peak rate of water release obtained in this study is probably due to a variety of factors, including: 1) regular removal of the reservoir from soil contact (for measurement); 2) presence of window screen at the DRiWATER-soil interface; and 3) failure to have an active plant root system in the soil containers. Lack of oxygen in the soil atmosphere may also have played a role in reducing water release from DRiWATER. The results of this study suggest that water release is reduced when soil oxygen is limited by high levels of soil moisture. The soil containers used in this study were not sealed to prevent gas exchange with the atmosphere; however, the container lids certainly did not promote rapid gas exchange. It is therefore possible that reduced levels of soil oxygen could have limited water release from all treatments.

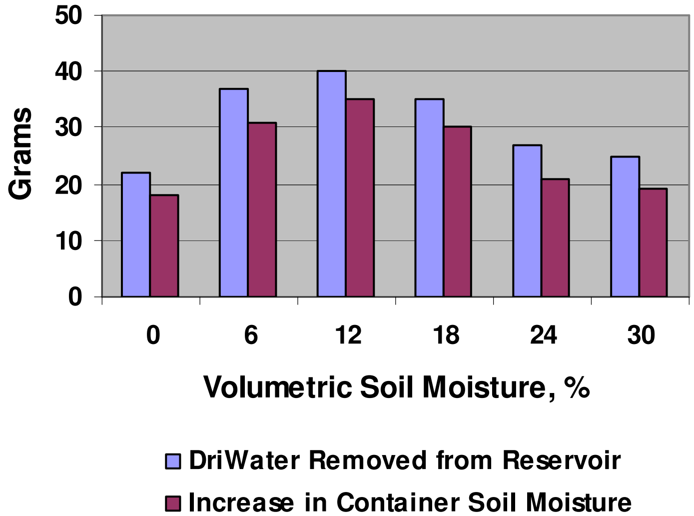

Figure 1. Total amount of DRiWATER removed from reservoirs and the increase in container soil moisture content for each soil moisture treatment over the 61-day period of study.

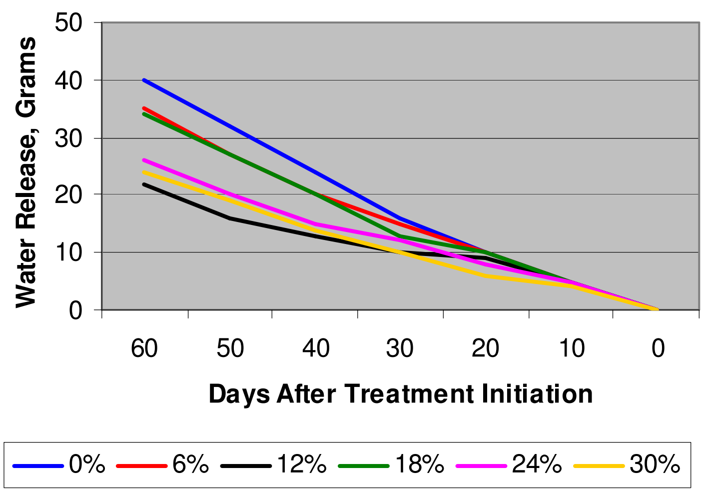

Figure 2. Water release from DRiWATER as a function of time for each soil moisture treatment.

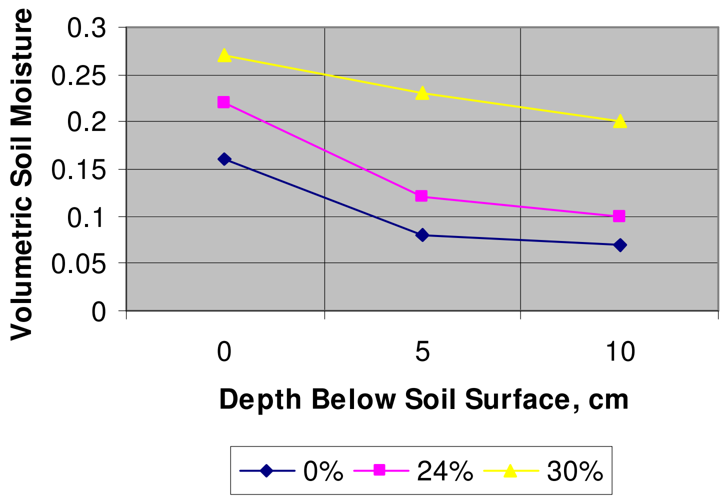

Figure 3. Volumetric soil moisture content in the 0-5 cm, 5-10 cm, and 10-15 cm depth increments directly below the DRiWATER reservoirs for the 0, 6, and 12% soil moisture treatments. Data are plotted at the mid-point of each depth increment.

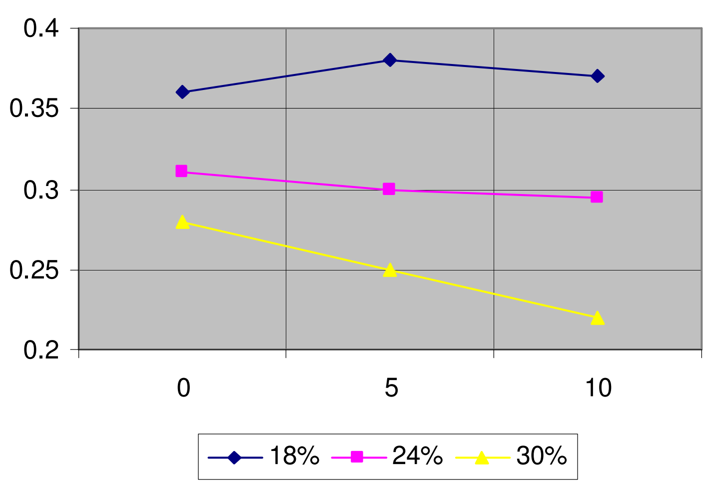

Figure 4. Volumetric soil moisture content in the 0-5 cm, 5-10 cm, and 10-15 cm depth increments directly below the DRiWATER reservoirs for the 18, 24, and 30% soil moisture treatments. Data are plotted at the mid-point of each depth increment.

Table 1. Results of the analysis of variance used to evaluate the study data set.

ANOVA TABLE			
Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Between Moisture Levels	5	1557.1	311.4
Within Moisture Levels	30	887.8	29.6
Total	35	2445.9	
Critical F value (p = 0.05) = 2.53			
Actual F Value = 311.4/29.6 = 10.51*			

* F value is significant at p<0.05

ASSESSMENT OF TREATMENT MEANS USING LSD PROCEDURE	
Soil Moisture Treatment	Water Released*
12%	40.4 g a
6%	36.5 g a
18%	34.3 g a
24%	26.3 g b
30%	24.9 g b
0%	22.6 g b

- Means followed by different letters are significantly different at p<0.05.

Table 2. Mean water release from DRiWATER in g/day from the first 33 days and the last 28 days of the study for the six soil moisture treatments.

TIME	Volumetric Soil Moisture Content					
	0%	6%	12%	18%	24%	30%
Days 1-33	0.033	0.49	0.53	0.47	0.4	0.32
Days 33-61	0.42	0.72	0.82	0.68	0.47	0.51