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Landscape irrigation by evapotranspiration-based irrigation controllers under dry conditions in Southwest Florida

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ABSTRACT

Due to high demand for aesthetically pleasing urban landscapes from continually increasing population in Florida, new methods must be explored for outdoor water conservation. Three brands of evapotranspiration (ET) controllers were selected based on positive water savings results in arid climates. ET controllers were evaluated on irrigation application compared to a time clock schedule intended to mimic homeowner irrigation schedules. Three ET controllers were tested: Toro Intelli-sense; ETwater Smart Controller 100; Weathermatic SL1600. Other time-based treatments were TIME, based on the historical net irrigation requirement and RTIME that was 60% of TIME. Each treatment was replicated four times for a total of twenty St. Augustinegrass plots which were irrigated through individual irrigation systems. Treatments were compared to each other and to a time-based schedule without rain sensor (TIME WORS) derived from TIME. The study period, August 2006 through November 2007, was dry compared to 30-year historical average rainfall. The ET controllers averaged 43% water savings compared to a time-based treatment without a rain sensor and were about twice as effective and reducing irrigation compared to a rain sensor alone. There were no differences in turfgrass quality across all treatments over the 15-month study. The controllers adjusted their irrigation schedules to the climatic demand effectively, with maximum savings of 60% during the winter 2006–2007 period and minimum savings of 9% during spring 2007 due to persistent dry conditions. RTIME had similar savings to the ET controllers compared to TIME WORS indicating that proper adjustment of time clocks could result in substantial irrigation savings. However, the ET controllers would offer consistent savings once programmed properly.

1. Introduction

Water is a limited resource as evidenced by water shortages seen in areas all over the world despite differences in climate. Water shortages in Florida have become more prevalent in the last few decades. Florida has the second largest withdrawal of groundwater used for public supply in the United States (Solley et al., 1998) and the largest net gain in population with an inflow of approximately 1100 people per day (United States Census Bureau, 2005). New home construction has increased to accommodate the large influx of people and most new homes include in-ground automated irrigation systems. However, homes with these systems have been shown to increase outdoor water use by 47% (Mayer et al., 1999). The need for landscape irrigation will continually grow with increased population and home construction if the demand for the current type of urban landscapes does not change.

Evapotranspiration (ET) is defined as the evaporation from the soil surface and the transpiration through plant canopies (Allen et al., 1998). ET is a part of a balanced energy budget that exchanges energy for outgoing water at the surface of the plant. The components of ET are solar radiation, air temperature, relative humidity, and wind speed (ASCE-EWRI, 2005). Reference ET (ET_o) is the evapotranspiration from a hypothetical reference crop assumed to be similar to an actively growing, well-watered, dense green grass of uniform height (ASCE-EWRI, 2005).

Evapotranspiration-based controllers, also known as ET controllers, are irrigation controllers that use an estimation of ET to schedule irrigation. Each controller works differently depending on manufacturer, but is typically programmed with landscape-specific conditions intended to make them more efficient (Riley, 2005). ET controllers receive ET_o information in three general ways, consequently dividing ET controllers into three main types: (1) standalone controllers, (2) signal-based controllers, and (3) historical-based controllers. Standalone controllers receive climatic data from on-site sensors and use calculations to determine ET_o whereas signal-based controllers receive ET_o calculated off-site

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from local weather stations. Historical-based controllers rely on historical ET_o information to adjust irrigation based on general climate patterns, but are not as efficient as other methods because actual changes in weather are not taken into account.

ET controllers have been used frequently over the last five years for studies performed by irrigation districts and other agencies in the western United States. Savings are usually reported in terms of actual or potential. Potential savings is defined by Hunt et al. (2001) as the "difference between actual outdoor water applied and what should have been applied taking weather into account." Actual savings is determined by comparing current use to some reference use which is usually based on water use history.

A study conducted in 2002 in west San Fernando Valley, California by the Los Angeles Department of Water and Power showed 17% actual savings by a WeatherTRAK enabled controller relative to a normalized weather year found through statistical modeling from the pre-retrofit time period and 78% of potential savings (Bamezai, 2004). A residential runoff reduction study was conducted using a modified Sterling irrigation controller to accept a broadcast signal from the WeatherTRAK ET Everywhere service in Irvine California; the ET controller group potentially reduced dry weather runoff 49% and saved 71% compared to the control groups (Diamond, 2003). Aquacraft Inc. performed an ET controller study in Colorado to determine savings compared to ET_o for the area and six sites were already irrigating below historical ET_o. The first year resulted in 94% of ET_o replacement by irrigation with $\pm$20% error between sites and achievement of 88% of the potential savings while the second year resulted in 71% of ET_o replacement and achievement of 92% of the potential savings (Aquacraft Inc., 2002, 2003). Devitt et al. (2008) found that using signal-based ET controllers in Las Vegas homeowner landscapes reduced water applied by 20% on average compared to sites without an ET-based controller. Results showed that 13 out of 16 ET controller sites reduced water applied compared to 4 of 10 sites without ET controllers. To date, results from ET controller studies generally have not been published in peer-reviewed journals. Additionally, these controllers have not been evaluated in a subtropical climate such as Florida.

The objective of this study was to evaluate the ability of three brands of ET-based controllers to schedule irrigation by comparing irrigation application to a time clock schedule intended to mimic homeowner irrigation schedules, while maintaining acceptable turfgrass quality.

2. Materials and methods

This study was conducted at the University of Florida Gulf Coast Research and Education Center (GCREC) in Wimauma, Florida and at the University of Florida Agricultural and Biological Engineering Department in Gainesville, Florida. There were a total of twenty plots at the GCREC that measured 7.62 m $\times$ 12.2 m, with 3.05 m buffer zones between adjacent plots. Each plot consisted of 65% St. Augustinegrass (*Stenotaphrum secundatum* cv. 'Floratam') and 35% mixed ornamentals to represent a typical residential landscape in Florida. This research focuses only on the turfgrass. Landscapes were maintained through mowing, pruning, edging, mulching, fertilization, and pest and weed control according to current University of Florida Institute of Food and Agricultural Sciences (UF-IFAS) recommendations (Sartain, 1991; Black and Ruppert, 1998). The controllers set up in Gainesville were connected only to a CR10X data logger (Campbell Scientific, Logan, UT) to record run times to study the variability in water application between ET controllers of the same brand.

Weather data available on site included rainfall, solar radiation, wind speed, air temperature and relative humidity at 15 min intervals from a Florida Automated Weather Network (FAWN) station. The FAWN station was located within 100 m of the test site.

Five treatments were established at the GCREC that were replicated four times for a total of twenty plots in a completely randomized block design. The irrigation treatments were as follows: Weathermatic SL1600 controller with SLW15 weather monitor (Dallas, TX); Toro Intelli-sense (Riverside, CA) utilizing the WeatherTRAK ET Everywhere service (Hydropoint Datasystems Inc., Petaluma, CA); ETwater Smart Controller 100 (Corte Madera, CA); TIME, a time-based treatment determined by UF-IFAS recommendations (Dukes and Haman, 2002); and RTIME, a time-based treatment that was 60% of TIME. All treatments utilized rain sensors to bypass irrigation after 6 mm of rainfall.

Individual valve and flow meter combinations were used to supply and monitor irrigation to each zone (separate irrigation zones for turfgrass and ornamentals) of each plot. The flow meters (15.9 mm V100 w/Pulse Output, AMCO Water Metering Systems, Ocala, FL) used to monitor irrigation water application were connected to five Campbell Scientific SDM-SW8A switch closure input modules that in turn were connected to a CR10X data logger. The CR10X data logger monitored switch closures every 18.9 l from the water meters. The meters were also read manually each week.

Irrigation sprinklers specified for the turfgrass portions of the plots consisted of Rain Bird (Glendora, CA) 1806 15 cm pop up spray bodies and Rain Bird R13-18 black rotary nozzles. In each plot, there were four sprinklers with a 180° arc (R13-18H) and a center sprinkler with a 360° arc (R13-18F). The application rate of the sprinklers was specified by the manufacturer as 15.5 mm/h.

Thirty-year historical rainfall averages were calculated from monthly rainfall data collected by the National Oceanic and Atmospheric Administration (NOAA, 2005) from 1975 through 2005. The closest NOAA weather station from the project site with available rainfall data was located approximately 28 km away, in Parrish, FL.

There were five periods of data collection: 13 August 2006 through 30 November 2006 as fall 2006; 1 December 2006 through 26 February 2007 as winter 2006–2007; 27 February 2007 through 31 May 2007 as spring 2007; 1 June 2007 through 31 August 2007 as summer 2007; and 1 September 2007 through 30 November 2007 as fall 2007. All five treatments were set up with two days per week watering restrictions during fall 2006 and winter 2006–2007, Wednesday and Saturday, and no watering between 10 am and 4 pm. Also, the ET controller treatments were established based on the site location without accounting for system efficiency (Table 1). The Weathermatic controller was set to apply 100% of the calculated water requirement while the Toro and ETwater controllers were set to the maximum controller efficiency of 95%. The monthly irrigation depth for TIME was 60% of the net irrigation requirement derived from historical ET and effective rainfall specific to south Florida (Dukes and Haman, 2002) and RTIME was a reduced treatment, applying 60% of the irrigation depth calculated from TIME equaling 36% of the net irrigation requirement (Table 2). Spring, summer, and fall 2007 differed from the previous two periods in that the ET controller treatments could irrigate any day of the week and up to everyday instead of two days per week and were updated with a system efficiency of 80% determined from irrigation uniformity testing instead of 100% or 95% as described above (Table 1). TIME was increased to apply irrigation to replace 100% of the net irrigation requirement instead of 60% used during the first three periods (Table 2). Once again, RTIME applied 60% of TIME resulting in the reduced treatment applying 60% of the net irrigation requirement. The first two testing periods were meant to simulate a worst-case scenario of minimal irrigation; whereas, the last three testing periods were intended to simulate typical ET controller settings and a reasonable homeowner time clock schedule.