Performance of Rain Delay Features on Signal-Based Evapotranspiration Irrigation Controllers

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Abstract: Evapotranspiration-based irrigation controllers, also known as weather-based irrigation controllers, are a new water-saving technology that use evapotranspiration (ET) estimates to schedule irrigation. Many ET controllers have the ability to incorporate rainfall events into irrigation scheduling using onsite sensors attached to the controller or weather updates through weather-monitoring services. The Toro Intelli-Sense controller can use an onsite rain sensor (rain switch) that immediately interrupts irrigation or a weather service that causes the controller to enter a rain pause mode to incorporate rainfall into irrigation scheduling. Four treatments were created using the combination of rain delay features: no rain delay features (TN), rain pause (TRP), rain switch (TRS), and both rain delay features (TRP-RS). A fixed-time irrigation schedule with a rain switch and a fixed-time irrigation schedule without a rain switch were created for comparison: T, timer with a rain switch; and TWORS, timer without a rain switch. During relatively dry periods (72% below historical seasonal rainfall) neither rain pause nor the rain switch resulted in irrigation reduction. However, during periods of rainfall (84% of historically rainy days), both features resulted in significant irrigation savings. The combination of rain switch and rain pause reduced irrigation 41% compared with the use of no rain features, whereas the rain pause feature alone saved 25%. Because of the variability of rainfall in humid climates, using both a rain switch and the rain pause feature is recommended to delay irrigation on the Toro Intelli-Sense controller. **DOI: 10.1061/(ASCE)IR.1943-4774.0000499.**

CE Database subject headings: Evapotranspiration; Irrigation; Residential location; Water use; Rainfall.

Author keywords: Evapotranspiration; ET controller; Residential irrigation; Water conservation; Rain switch; Rain pause; Rain sensor.

Introduction

Public water supply demand in the United States has increased from 53 million m^3/day in 1950 to 167 million m^3/day in 2005. An estimated 58% of water from the public supply was allocated to 258 million people for household use in 2005 (USGS 2009).

Although residential water conservation has been achieved inside the home using low-flow fixtures and appliances, Mayer et al. (1999) reports that an average of 57% of residential water use is outside the home. Mayer et al. (1999) also found that residences with permanent irrigation systems controlled by a timer use 47% more water outside than homes with no permanent irrigation system. Among those that irrigated, only 15% were using water conservation techniques outside of the home. Substantial water savings could be realized with the incorporation of new "smart" irrigation technologies. Improved irrigation practices encompass improved scheduling where real-time monitoring of weather conditions is imperative to irrigation application (Carrow 2006). One of the emerging technologies to help accomplish this goal is evapotranspiration (ET) irrigation controllers, also known as weather-based irrigation controllers.

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Note. This manuscript was submitted on January 3, 2012; approved on April 25, 2012; published online on May 3, 2012. Discussion period open until April 1, 2013; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Irrigation and Drainage Engineering***, Vol. 138, No. 11, November 1, 2012. © ASCE, ISSN 0733-9437/2012/11-978-983/$25.00.

Toro's Intelli-Sense (Riverside, California) controller is a signal-based evapotranspiration controller. Daily reference evapotranspiration (ET_o) values are calculated by Hydropoint's WeatherTRAK (Riverside, California) system using the ASCE Penman-Monteith standardized reference evapotranspiration equation (Hydropoint 2003). These values are then sent to the controller using pager technology. Reference evapotranspiration is used to calculate crop evapotranspiration (ET_c) using plant-type settings entered into the controller for each zone. Crop evapotranspiration is calculated daily and summed from the last irrigation event. Once soil water depletion reaches the set point for the entered plant type of the irrigation zone, the controller will schedule an irrigation event and application depth. Although the controller can automate irrigation frequency on the basis of irrigation need, irrigation frequency can also be predetermined by setting specific irrigation days or schedules. Crop coefficients can be modified manually and rain pause features can also be enabled or disabled. Adjustable settings within the controller include usable rainfall, sprinkler type, precipitation rates, sprinkler efficiency, soil type, plant type, root depth, slope, and shade.

The Toro Intelli-Sense controller irrigates on the basis of daily water balance calculations. The controller estimates the amount of water in the soil and irrigates only when soil water depletion has reached the set value for a given irrigation zone. The settings input by the user are used by the controller to determine schedule and irrigation run times. Irrigation frequency and depth fluctuate on the basis of regional weather conditions.

According to Hydropoint, ET_o values are calculated to a resolution of 1 km^2 (a "microzone"). Weather data are gathered from public databases such as the National Oceanic and Atmospheric Administration (NOAA) to collect weather information for regional areas. In addition, other sources such as cities, states, water districts, and private organizations help to provide greater coverage resolution. Weather data collected from these weather stations then undergo quality control in which both human and automated system verifications are performed. Data are used with the ASCE standardized evapotranspiration methodology (ASCE-EWRI 2005) to calculate ET_o. Once daily ET_o is calculated for a microzone, the values are transmitted to the controller (Hydropoint 2003). In addition to daily ET_o values, Hydropoint sends rain pause information to controllers in response to rainfall events. The rain pause feature pauses irrigation for a length of time determined by Hydropoint.

The Toro Intelli-Sense rain pause feature works in addition to a rain switch that may be added to the controller. A rain switch is also called a rain sensor and refers to a device that immediately interrupts irrigation in response to a predetermined amount of rainfall. Cardenas-Lailhacar and Dukes (2008) evaluated new expanding disk rain switches and found them to be relatively accurate and with less than a year payback period in a rainy climate. In a follow-up study, Meeks et al. (2012) found that over time erratic behavior of these devices increased and recommended replacement of expanding disk material at least annually for best performance. When rainfall is recorded by the weather network, a set number of days is determined that the controller should not irrigate on the basis of depth, intensity, duration of the rainfall event or events, and evapotranspiration. Details of this determination are proprietary. The number of days of rain pause is then sent to the controller wirelessly along with the ET_o signal.

The Toro Intelli-Sense controller does not bypass irrigation in the same manner as a time clock and rain switch combination, which simply opens the valve control circuit as long as the rain switch is in interrupt mode because of wet conditions. The Toro Intelli-Sense cannot interrupt irrigation events because it does not have a set schedule. Instead, it delays irrigation by not updating the soil water balance within the controller when the rain pause or rain switch is active. In other words, the controller assumes that there is no soil water depletion during the rainy periods. The rain pause feature can be updated by the weather service from the initial pause sent to the controller. Changes to the rain pause duration are likely the result of reevaluation of rainfall and ET_o by the weather service. In addition, the controller prioritizes the rain pause feature over that of the rain switch. If both features are activated, the controller will only show the use of the rain pause event, even though zones that do not have the rain pause feature activated are using the rain switch for delay. Thus, recording a rain switch event during a rain pause event is impossible.

Many evapotranspiration (ET) irrigation controllers have the capability to use rain features such as rain shutoff devices to bypass or delay irrigation during and after rain events. Cardenas-Lailhacar and Dukes (2008) investigated the possible savings that could be achieved by a rain switch. Two expanding disk rain switches were used for comparison in the test, the Hunter Mini-Click and wireless Rain-Click (Hunter Industries, San Marcos, California). It was shown that the mini-clicks responded close to their set points (3, 13, and 25 mm). Theoretical water savings estimates ranged from 3% at a 25-mm set point to 44% at a 3-mm set point. Meeks et al. (2012) found that some brands of expanding disk rain switches required disk replacement annually for optimum performance.

McCready et al. (2009) compared ET controller performance with that of a regular homeowner time-based irrigation schedule without a rain switch. One of the evapotranspiration controllers used was the Toro Intelli-Sense controller. A rain switch was not added to the controller; however, the useable rainfall percentage was set at 100%, which allowed for full use of the rain pause feature. Despite low rainfall amounts compared with historical averages, the Toro controller saved 59% of water compared with an irrigation system without an ET controller.

Davis et al. (2009) compared ET controller performance with that of a regular homeowner time-based irrigation schedule without a rain switch. ET controllers used in the study were the Weathermatic SL1600 (Dallas, TX), Toro Intelli-Sense, and ET Water Smart Controller (Corte Madera, CA). The Weathermatic SL1600 has a rain switch incorporated into its weather monitor, and a rain switch was attached to the Toro Intelli-Sense for rainfall measurement. The ET Water controller sends both ET_o and rainfall data to the controller from weather station measurements. Even during dry conditions, overall the ET controllers saved an average of 43% with respect to timed irrigation system with no rain switch.

Vasanth et al. (2007) found that the Toro Intelli-Sense controller overirrigated compared with other smart irrigation technologies. In addition, the Toro controller was not fitted with a rain switch and only used the rain pause system for water budget modification. Overirrigation was attributed to the controller using regional rainfall data from the weather service rather than site-specific rainfall data.

Although savings are seen from rainshut off devices with respect to time-based controllers, ET controllers may have variable irrigation frequencies and depths. On the basis of previous research, the rain delay features of the Toro Intelli-Sense should enhance the water-saving capabilities of the controller; however, this capability has not been specifically documented. Use of the Toro Intelli-Sense controller in rainy climates heightens the need for better understanding of its integrated rainfall features. The objective of this study was to determine the effectiveness of the rainfall features of the Toro Intelli-Sense controller by determining the water savings achieved compared with the controller without those features.

Materials and Methods

This research was conducted at the University of Florida Gulf Coast Research and Education Center (GCREC), Wimauma, Florida, on 20 existing plots of established St. Augustinegrass (*Stenotaphrum secundatum,* "Floratam") bordered on one side by mixed ornamentals. The turfgrass and mixed ornamentals area of each plot measured 60 m^2 by 33 m^2, respectively. All 20 plots were bordered by a 15-cm-tall black metal barrier. Each plot was separated by a buffer zone of 3 m covered with a plastic weed barrier on all sides.

Each plot received a separate irrigation line for turfgrass and mixed ornamentals. Hunter (San Marcos, CA) SRV solenoid valves and Elster AMCO Water (Ocala, FL) V100 flow meters were used in combination to operate and monitor the irrigation system. This experiment used only the irrigated turfgrass portions of the plots. Digital collection of the flow meter data was accomplished by wiring each flow meter to one of five Campbell Scientific (Logan, UT) SDM-SW8A switch closure input modules that were monitored by a Campbell Scientific CR-10x datalogger. Each reading had a resolution of 18.9 L and was totaled hourly by the datalogger. Manual readings were taken weekly to verify logged data. Data from the Toro Intelli-Sense ET controllers were manually collected Monday through Friday. This data consisted of daily ET_o, weekly ET_o, time of signal reception, percent water depletion, and status of the rain pause and rain switch features.

Rain Bird R13-18 (Glendora, CA) rotary nozzles on model 1806 15-cm popup spray bodies were used for the turfgrass irrigation system on all plots. Each plot contained four half-circle nozzles (R13-18H) located at the midpoint of the borders and one full-circle nozzle (R13-18F) located in the center. All heads have a documented application rate of 15-mm/hr at pressures of 206 to 380 kPa. Microirrigation spray heads from Maxijet (Dundee, FL) were installed in the ornamental section of the plots. A 138-kPa pressure regulator was installed for the microirrigation in each plot. Pressure regulators at the manifold maintained approximately 380 kPa.

Five irrigation treatments were established as follows: TN, Toro Intelli-Sense with no rain switch and the rain pause feature set at 0% usable rainfall; TRP, Toro Intelli-Sense with no rain switch and 100% usable rainfall; TRS, Toro Intelli-Sense with Hunter Mini-Clik rain switch set at a 6-mm threshold and 0% usable rainfall; TRP-RS, Toro Intelli-Sense with Hunter Mini-Clik rain switch set at a 6-mm threshold and 100% usable rainfall (Table 1); *T*, time schedule using a recommended irrigation schedule for the region (Dukes and Haman 2002) using a Rainbird timer with a Hunter Mini-Clik rain switch set at 6 mm. TRS and TN treatments used the microirrigation spray heads for water application. These treatments used a modified application rate in the controller to match the application rate on the turfgrass zones of the other experimental treatments. The *T* treatment was implemented using a traditional irrigation time clock. A theoretical time-based treatment without a rain switch (Time WORS) was created to determine water savings created by the attached rain shutoff device. Time WORS was created by substituting bypassed irrigation events that occurred on the *T* treatment because of activation of the rain switch in response to rainfall.

Historical rainfall depth and frequency were calculated using a 30-year average from a weather station in Parrish, Florida, operated by the National Oceanic and Atmospheric Administration (NOAA) approximately 20 km southwest of the project site (27°37′N; 82°21′W).

A total of five periods of data collection were used: summer 2008, June 25, 2008, to August 31, 2008; fall 2008, September 1, 2008, to November 30, 2008; winter 2008–2009, December 1, 2008, to February 28, 2009; spring 2009, March 1, 2009 to May 31, 2009; and summer 2009, June 1, 2009, to August 31, 2009. All ET controller treatments were allowed to irrigate any day of the week and at any frequency automatically determined by the controller. The treatments using the rain pause feature had usable rainfall settings adjusted to 100%, whereas TRS and TN had the usable rainfall settings adjusted to 0%. For summer 2009, the usable rainfall settings for TRS and TN were changed to 25%. The timer treatments were scheduled for two irrigation events per week (Table 1).

The total weekly irrigation was compared across treatments. Delay days were quantified by number of recorded days with a rain pause or rain switch event active on the controller. Statistical analysis was performed with SAS statistical software (SAS Institute, Cary, NC) with weeks as a repeated measure. The general linear model (GLM) was used assuming a 95% confidence interval. Least square means separation was conducted using Tukey's procedure for pairwise comparison. All data were confirmed to be normal before conducting the comparative analysis.

Results and Discussion

Every month in the 14-month study period was drier than the historical average except for two months: July 2008 (9% higher than historical rainfall) and May 2009 (156% higher than historical rainfall). All seasons received less than historical average rainfall. Rainfall between July 2008 and August 2009 totaled 1,175 mm, which is 35% less than the historical rainfall value of 1,806 mm (Fig. 1). There were 51 days of rainfall totaling 6 mm or more, leaving 88% of the 427 days without rainfall above 6 mm, the rain switch threshold (Fig. 2).

The TRP-RS treatment encountered 114 days during which irrigation was delayed because of either the rain pause or the rain switch. Using just the rain pause feature (TRP) resulted in 72 recorded rain pauses over the course of the monitoring period.

TRS and TN treatments were created to compare and contrast the effects of a rain switch when not using the rain pause feature of the controller. The Toro Intelli-Sense does not have a method for directly turning off the rain pause feature. The Toro technical staff relayed that by turning the usable rainfall setting to 0% that the controller would not use the rain pause feature. During spring 2009 it was discovered that TRS was not bypassing irrigation during rain switch events. It was determined that if the usable rainfall setting is entered as 0%, the controller will not use the rain shutoff device as a means of irrigation bypass during or after rainfall events even when the controller displays that the rain shutoff device is in bypass mode. To counter this effect, the TRS treatment was set to 25% (values increment by 25%) for summer 2009 (Table 1); thus, the TRS results are only reported for this period. The new setting

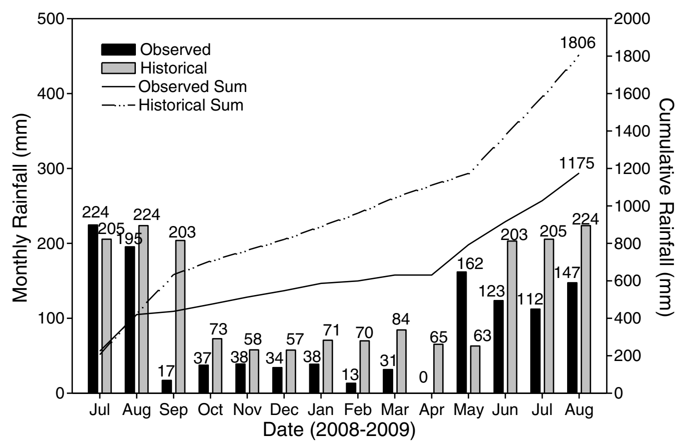

Fig. 1. Monthly and cumulative historical (1979–2009) and observed rainfall for duration of study period (July 1, 2008–August 31, 2009)

Table 1. Toro Intelli-Sense Controller and Treatment Settings for Study Period

	TN	TRP	TRS	TRP-RS
Controller input	No rain features	Rain pause only	Rain switch only	Rain pause and rain switch
Application rate (mm/h)	15.4	15.4	15.4	15.4
Root depth (cm)	30.5	30.5	30.5	30.5
Plant type	Warm season turf	Warm season turf	Warm season turf	Warm season turf
Soil type	Sand	Sand	Sand	Sand
Shade	Sunny all day	Sunny all day	Sunny all day	Sunny all day
Slope (°)	0	0	0	0
Usable rainfall (%)	0	100	0[a]	100
Irrigation efficiency (%)	80	80	80	80
Rain switch	No	No	Yes	Yes
Days	Any day	Any day	Any day	Any day

[a]Value was changed to 25% for summer 2009.

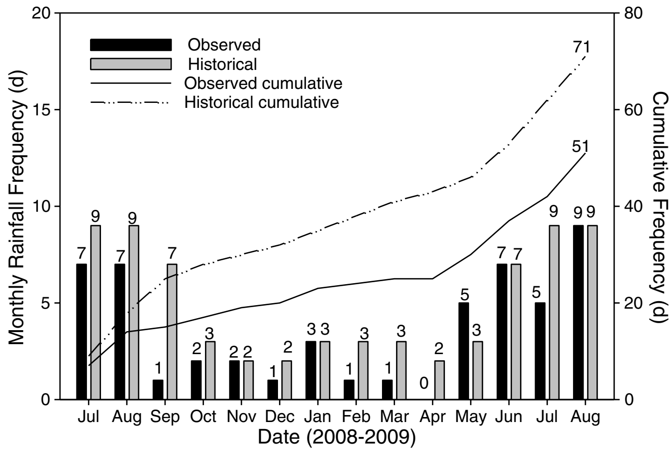

Fig. 2. Monthly and cumulative historical (1979–2009) and observed rainfall frequency events at or above 6 mm for study period (July 1, 2008–August 31, 2009)

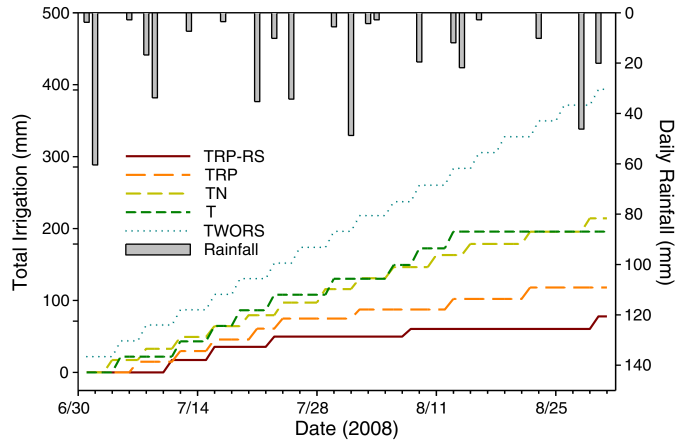

Fig. 3. Cumulative daily irrigation application and rainfall for summer 2008 (July 1, 2008–August 31, 2008): TRP-RS, rain pause and rain switch; TRP, rain pause only; TN, no rain pause or rain switch; T, fixed-time treatment with a rain switch; and TWORS, fixed-time treatment without a rain switch

Table 2. Average Weekly Irrigation Application (mm/Week) during Study Period (September 1, 2008–August 31, 2009)

Treatment	Summer 2008	Fall 2008	Winter 2008–2009	Spring 2009	Summer 2009
TN	23.8 b[b]	11.0 b	8.7 b	23.8 b	20.1 b
TRP	12.9 c	10.4 b	7.3 b	18.4 c	15.4 ab
TRS	—[c]	—	—	—	8.5 c
TRP-RS	8.6 c	10.2 b	5.6 b	15.3 c	9.3 bc
T[a]	21.7 b	26.2 a	17.4 a	22.2 b	20.5 b
TWORS	43.7 a	29.6 a	19.1 a	27.1 a	33.8 a

[a]T is a 2 days/week time-based irrigation schedule with a rain switch set at 6 mm; TWORS is the same irrigation schedule without a rain switch.
[b]Numbers with different letters in columns indicate difference at the 95% confidence level using Tukey's pairwise comparison.
[c]TRS was not functional until later in 2009.

Table 3. Total Number of Days of Irrigation Delay during Study Period (September 1, 2008–August 31, 2009)

Treatment	Summer 2008	Fall 2008	Winter 2008–2009	Spring 2009	Summer 2009
TN	0 c[a]	0 c	0 b	0 c	0 c
TRP	21 b	9 a	14 a	15 b	13 b
TRS	—[b]	—	—	—	18 b
TRP-RS	30 a	8 b	14 a	22 a	32 a

[a]Numbers with different letters in columns indicate difference at the 95% confidence level using Tukey's pairwise comparison.
[b]TRS was not functional until later in 2009.

allowed rain switch events to occur when using the minimum amount of the rain pause feature.

Summer 2008

This period received the most rainfall at 419 mm, compared with the historical average of 429 mm, despite being the shortest period at 62 days (Fig. 1). There were 14 days of rainfall totaling 6 mm or more, compared with the historical average of 18 days (Fig. 2). The Toro controller without the rain switch or rain pause features (TN) resulted in similar irrigation application as the fixed-time treatment (T) with a rain switch (21.7–23.8 mm/week; Table 2); however, both Toro controllers using RP applied significantly less irrigation (8.6–12.9 mm/week) than the fixed-time treatments and Toro controller without rain delay features (Fig. 3). The addition of a rain switch to a Toro controller with rain pause (TRP-RS) did not increase irrigation savings for this period (Table 2) compared with rain pause alone (TRP). The addition of a rain switch to a controller with rain pause (TRP-RS) delayed irrigation significantly more than using the rain pause feature alone (TRP); however, the increase of delay days did not significantly affect the weekly irrigation applied (Table 3). This result was because although the rain switch did increase delay time, these times did not coincide with needed irrigation events. All treatments with rain features significantly reduced weekly irrigation compared with the fixed-time treatment without a rain switch (TWORS).

Fall 2008

A total of 93 mm of rain fell during the entire 91-day period, which was 72% less than the historical average of 334 mm (Fig. 1). Similarly, there were 5 days of rainfall totaling 6 mm or more, which was less than half the historical average of 12 days (Fig. 2). As a result of the dry weather, the use of rain features did not save a significant amount of water during this period. All rain-savings experimental treatments resulted in between 10.2 mm and 11.0 mm/week of irrigation (Table 2). Despite the low rainfall, the TRP-RS and TRP treatments recorded rain pause events (Table 3); however, these events did not save significant amounts of water compared with the TN treatment, which did not use rainfall features (Fig. 4). The reduction in ET during the fall season lowered the irrigation frequency and reduced the disparity between irrigation-delay periods. In contrast, all ET controller combinations significantly reduced water application compared with the time schedule, similar to the results reported by Davis et al. (2009). Adding a rain switch to the timer did not result in significant irrigation reduction, again because of dry conditions.

Winter 2008–2009

This season received the least amount of total rainfall at 86 mm (Fig. 1). There were 5 days of rainfall totaling 6 mm or more compared with the historical average of 8 days (Fig. 2). The use of rain features did not save a significant amount of irrigation during this period similar to the fall. All Toro controllers applied between

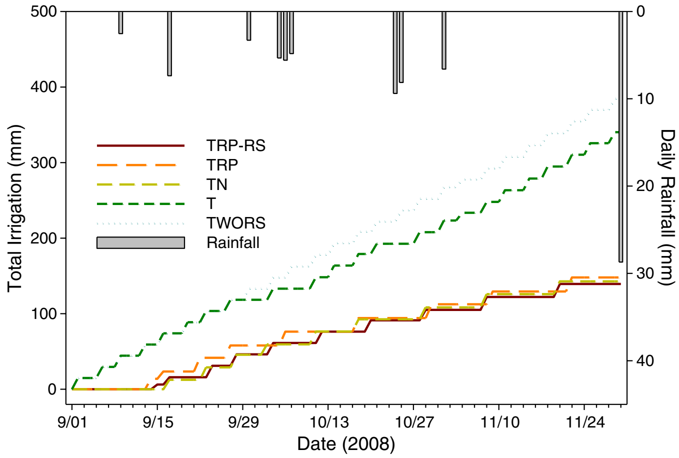

Fig. 4. Cumulative daily irrigation application and rainfall for fall 2008 (September 1, 2008–November 30, 2008): TRP-RS, rain pause and rain switch; TRP, rain pause only; TN, no rain pause or rain switch; T, fixed-time treatment with a rain switch; and TWORS, fixed-time treatment without a rain switch

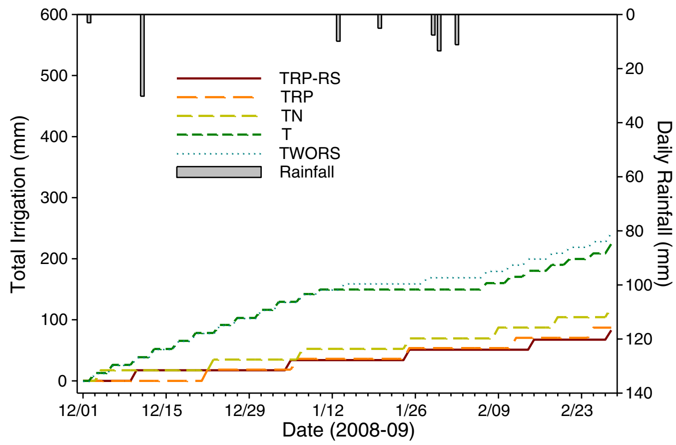

Fig. 5. Cumulative daily irrigation application and rainfall for winter 2008–2009 (December 1, 2008–February 28, 2009): TRP-RS, rain pause and rain switch; TRP, rain pause only; TRS, rain switch only; TN, no rain pause or rain switch; T, fixed-time treatment with a rain switch; and TWORS, fixed-time treatment without a rain switch

5.6 and 8.7 mm of irrigation (Table 2). As in the fall 2008 season, the rain pause and rain switch events that were recorded (Table 3) failed to save water because of lower irrigation frequency and rainfall (Fig. 5).

Spring 2009

Rainfall in this season totaled 193 mm, with no rainfall in April and 161 mm of rainfall occurring in the last two weeks of May (Fig. 1). Six days of rainfall totaled 6 mm or more compared with the historical average of 8 days (Fig. 2). The controller with no rain delay features (TN) resulted in similar irrigation application to the fixed-time treatment with a rain switch (T) (Table 2). The combination of rain pause and rain switch (TRP-RS) saved more water than the treatment with no rain features active (TN) and the fixed-time treatments with and without a rain switch (34–44%) (Fig. 6); however, the addition of a rain switch to a controller using the rain pause feature (TRP-RS) did not save a significant amount of water for

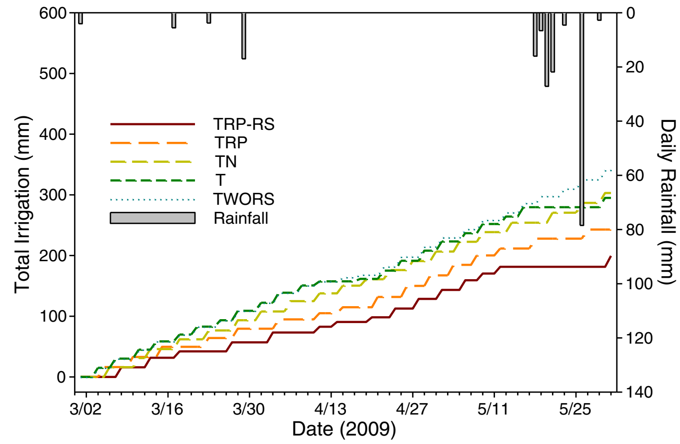

Fig. 6. Cumulative daily irrigation application and rainfall for spring 2009 (March 1, 2009–May 31, 2009): TRP-RS, rain pause and rain switch; TRP, rain pause only; TN, no rain pause or rain switch; T, fixed-time treatment with a rain switch; and TWORS, fixed-time treatment without a rain switch

this period (Table 2) compared with a controller using rain pause feature alone (TRP). The fixed-time treatment with a rain switch (T, 22.2 mm/week) applied a similar amount of weekly irrigation to the Toro controller with no rain features enabled (TN, 23.8 mm/week).

Summer 2009

Although this period did not receive the least amount of precipitation, a difference of 249 mm between cumulative recorded rainfall and cumulative historical rainfall shows the greatest deficit to historical rainfall out of the five seasons (Fig. 1). A total of 21 days of recorded rainfall of 6 mm or greater, the most out of all seasons during the study period, compared with the historical average of 25 days (Fig. 2). In this season the addition of a rain switch (TRP-RS) did not save a significant amount of irrigation (9.3 vs. 15.4 mm/week, respectively) when compared with using the rain pause feature alone (TRP), although there was a trend for less irrigation using both the rain pause feature and a rain switch. The Toro controller using only the rain switch (TRS) saved more water (45%) than the Toro controller using only the rain pause feature (TRP) but did not save a significant amount of water when compared with the Toro controller using both rain delay features (TRP-RS) (Table 2). The Toro controller with no rain features enabled (TN) applied similar weekly irrigation to the fixed-time treatment with a rain switch (T), approximately 20 mm/week. The similarity in TN and T treatments could possibly be the result of the Toro controller balancing the soil water balance as effectively as a timed treatment with a rain sensor attached. The fixed-time treatment without a rain switch (TWORS) applied significantly more water (33.8 mm/week) than all treatments during this period. This season had the greatest rainfall frequency out of all of the seasons. The higher rainfall frequency increased the number of days irrigation was delayed for treatments with rain features enabled compared with the treatment with no rain features enabled (Fig. 7). Although the Toro controller with both rain features enabled (TRP-RS) delayed irrigation significantly more than the TRS and TRP Toro treatments, the number of days of delay were not directly related to water savings (Table 3). The irrigation delay was recorded on the controllers for a particular experimental treatment; although irrigation delay was reported by the controller and in some cases the

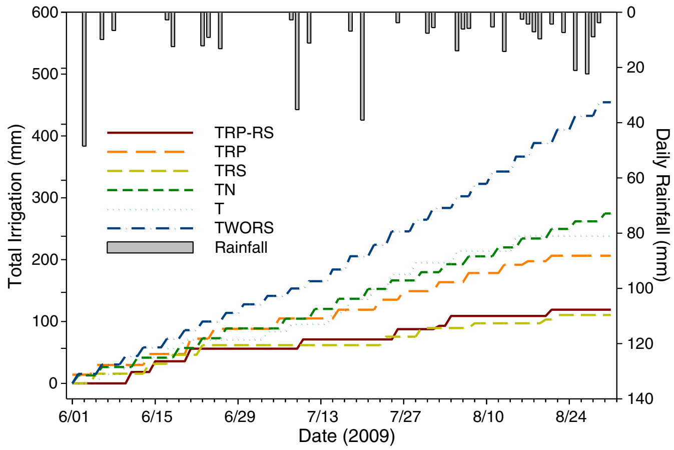

Fig. 7. Cumulative daily irrigation application and rainfall for summer 2009 (June 1, 2009–August 31, 2009): TRP-RS, rain pause and rain switch; TRP, pause only; TRS, rain switch only; TN, no rain pause or rain switch; T, fixed-time treatment with a rain switch; and TWORS, fixed-time treatment without a rain switch

average irrigation amount was reduced, it is possible that irrigation events are not computed as necessary by the controller even during a delay period because the calculated soil water deficit may not be enough to schedule an irrigation event.

Summary and Conclusions

The fall 2008 and winter 2008–2009 periods did not have significant rainfall events in enough frequency to affect irrigation application between treatments. However, during these two seasons, the frequency of irrigation was less because of reduced ET rates relative to spring and summer. Reduction in irrigation frequency reduces the chances of irrigation delay resulting from controller rainfall features. Although there were still rainfall events significant enough to cause rain features to delay irrigation, water application was not significantly reduced because of lower ET rates and lower irrigation frequency.

The spring 2009 period experienced less rainfall frequency but had similar total rainfall to cumulative historical averages, thereby showing a trend in which a rain switch in combination with the rain pause feature can reduce irrigation on a Toro Intelli-Sense controller during average periods of cumulative rainfall. The cumulative rainfall for the summer 2009 period was less than the historical average; however, rainfall frequency was near the historical average, which shows that the addition of a rain switch significantly improved water savings during times of average rainfall frequency when using only the rain pause feature did not. Overall, the use of a rain switch in addition to the rain pause feature reduced irrigation 41% when compared with the use of no rain features, whereas the use of the rain pause feature alone reduced irrigation by 25%. During periods of rainfall, a properly scheduled irrigation timer working with a rain switch applied a similar amount of water compared with a Toro Intelli-Sense ET controller without active rain features.

One advantage of an ET controller is its ability to remove any homeowner error from irrigation of the home lawn. Rain switches require maintenance and proper installation to function correctly. When working properly, the attached rain shutoff device set at a 6-mm threshold saved more water than the rain pause events sent out by the weather service. The weather service attempts to remove homeowner errors by removing homeowners from regular responsibilities associated with irrigation timer adjustments. Because of the spatial variability of rainfall in humid climates, weather stations would likely miss rainfall events that occur in the immediate area of the controller. On the basis of the savings shown in this study, it is recommended that a rain switch be installed on a Toro Intelli-Sense ET irrigation controller in addition to proper use of the rain pause feature.

Acknowledgments

The authors recognize the support staff of the Agricultural and Biological Engineering Department and the Gulf Coast Research and Education Center for the success of this research.

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