Smart Water Application Technologies™ SWAT™

Turf and Landscape Irrigation Equipment

Rain Sensors

Phase 1: Equipment Functionality Tests

1st Draft Testing Protocol (April 1, 2007)

Developed by

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1. PROTOCOL SUMMARY

Rain sensors (RSs) appear to be a useful tool for water conservation at a relatively low cost. However, little evidence related to RS performance and/or reliability exists. This protocol provides a standard procedure for evaluating the performance and reliability of RSs, with respect to the rainfall depth before RSs switch to bypass mode, and the accuracy, precision, and variability of their set points. It is proposed that a Phase II testing scenario would serve to quantify potential water savings, evaluate the effects of these devices on turfgrass under natural conditions, as well as to test other RS features such as the dry out period and their behavior under different rainfall events.

2. STATEMENT OF WORK

2.1. Relevance and Importance

A rain sensor (RS), also called rain shut-off device or rain switch, is a device designed to interrupt a scheduled cycle of an automatic irrigation system controller (i.e. timer) when a certain amount of rainfall has occurred. By eliminating unnecessary irrigation, RSs can improve irrigation efficiency, conserve water, reduce wear on the irrigation system, reduce disease and weed pressure on turfgrass/landscapes, and reduce the runoff and/or deep percolation that carry pollutants–such as fertilizers and pesticides–into storm drains and groundwater. In addition, RSs could reduce utility bills and turf maintenance costs by minimizing over-watering.

Several types and models of RSs, which differ in method of operation, have been developed by the irrigation industry. Some of them have a receptacle to weigh the amount of water. Other models also use a receptacle but, instead of weight, they detect the water level with a set of electrodes. However, the most widely used method employs a hygroscopic expanding material to sense the amount of rainfall. A recent development of these devices is a radio-controlled or wireless rain sensor, which comprises a sensor and a receiver unit. In some new versions, the receiver unit also acts as a controller, where different settings are allowed (delay time, soil type, custom bypass, etc.).

2.2. Problem Statement and Project Need

Florida is the only state in the nation with an overall RS statute. Florida law states: *"Any person who purchases and installs an automatic lawn sprinkler system after May 1, 1991, shall install, and must maintain and operate, a rain sensor device or switch that will override the irrigation cycle of the sprinkler system when adequate rainfall has occurred."* (Florida Statutes, 2006), and some municipalities require older systems to be retrofitted with rain shut-off switches (St. John's River Water Management District, 2006). Moreover, there are mandates for the use of RSs in various municipalities in New Jersey, North and South Carolina, Georgia, Texas, Minnesota and Connecticut (Dewey 2003). In spite of these mandates and laws, little scientific evidence related to RS performance and/or reliability existed until Cardenas-Lailhacar and Dukes (2007) conducted a study on two expanding-disk RS models.

2.3. Scope and Objectives of the Protocol

The scope and objectives of this protocol are to provide a standardized procedure for evaluating the performance and/or reliability of commercially available RSs. As a standard from which to judge the RSs' performance, the following parameters will be quantified: a) rainfall depth before RSs switch to bypass mode, and b) accuracy, precision, and variation of their set points. This protocol does not consider RSs connected to an actual automatic irrigation system. Therefore, some features that could impact their market acceptance will be out of the scope of this protocol; like the adequacy of the RSs to maintain an acceptable turfgrass/landscape quality, or the improvement on the irrigation system's efficiency to conserve water, among other features.

3. METHODS, PROCEDURES, EQUIPMENT AND TASKS

Different RS models differ in their method of measuring the amount of rainfall (weight, electrodes, hygroscopic expanding discs, etc.). Also, RSs typically have some type of adjustment so that they can be set to react after a specific amount of rainfall. For example, some of the hygroscopic expanding disk-types have five different settings that are intended to bypass an irrigation cycle after rainfall quantities of 3, 6, 13, 19, or 25 mm. However, this is not the case of some wireless models, where a quick shut down of the irrigation system occurs after rain begins (without preset adjustments for a certain precipitation amount). Therefore, different approaches must be taken to test singular models/set points.

3.1.Test Set-Up

The units to be tested will be purchased by the University of Florida (UF) from an irrigation dealer, and installed and set by UF personnel. Every sensor will be placed in the testing area at the Agricultural and Biological Engineering Department research facilities in Gainesville, Florida. Each RS model test will require eight identical devices[1], which will be connected to a datalogger.

3.2. Rainfall

The standard test will use a rainfall simulator, because natural rain:

- Has different intensities during the same event. Sometimes it drizzles for a long time and sometimes it rains at high intensities for short periods of time.

[1] Due to variability observed in current testing.

- Instruments (RSs and/or rainfall measurement devices) could be affected by rain intensity associated with wind.
- Sometimes during a rain event, rain stops for some time, and then continues again. Depending on the elapsed time during the break, it could be considered one rain event or two separate events (e.g. 2 hr apart or more than 5 hr apart, respectively). During the break, part of the rain that fell is evaporated, increasing the testing error.
- Based on past experience testing rain sensors in Florida, the 25 mm set point probably could not be tested under natural rain conditions in less than a year. Also, it is desirable to achieve replicate storm events to test the repeatability of the results and doing so with real rain events would be unlikely in a reasonable amount of time.

3.3. Rainfall Simulator

A rain simulator will be constructed to allow faster data collection under controlled and uniform (standardized[2]) rain events. The frame and hydraulic design will be similar to that recommended by the Agricultural Research Service (ARS) of the USDA, following the design of Miller (1987), and as described by Humphry et al. (2002). The device will be calibrated and pressure regulated at 138 kPa (20 psi) to produce uniform rainfall events. The nozzle commonly used in rain simulation experiments is the Spraying Systems square full cone nozzle TeeJet™ ½ HH-SS50WSQ. However, a nozzle with a spinning deflector, made by Water Whizzer, and previously tested by the University of Florida, will be used instead. This is because they produce a good drop diameter (1.44 mm, on average), excellent CU (0.92) and, most importantly, a lower intensity rainfall can be simulated (60 mm/hr compared to 20 mm/hr).

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[2] The accuracy and precision of a measurement process is usually established by repeatedly measuring some traceable reference standard.

The amount of rainfall applied per test will be checked against a calibrated tipping bucket rain gauge, which will be connected to a data logger. Precipitation data will be recorded at intervals of 0.25 mm of rainfall; and day, hour, minute and second will be logged.

3.4. Sensor Dry-Out

The time that it takes RSs to reset for normal sprinkler operation after the rain has stopped–dry out period–is determined by weather conditions (temperature, wind, sunlight, relative humidity, etc.). Since the primary goal of this Phase I protocol is to test the accuracy and precision of the RS set points, the dry-out period will be normalized. The natural dry-out period will be accelerated by using heat lamps under indoor conditions and will reduce the total testing time. Under Phase II testing, the dry-out period will be evaluated under natural conditions of the testing site.

3.5. Data

Each time a rain sensor changes status (from allowing irrigation, to bypass mode, or vice versa), the date and time will be automatically recorded, at a one-second sampling interval, by means of a datalogger. Each set point test will be repeated 8 times to determine the variation inherent in individual sensors.

3.5.1. Rainfall before bypass mode

The depth (mm) of rain applied before each RS unit switches to bypass mode will be calculated. This will characterize the sensitivity of RS models with no explicit set point. The rain applied to the RS models with specific set points will be, at least, three times the amount needed to meet each set point.

3.5.2. Accuracy

The accuracy of an instrument refers to its ability to indicate an exact true value. Accuracy is related to absolute error, ε, which is defined as the difference between the true value of a measurement and the indicated value of the instrument:

$$\varepsilon = \text{true value} - \text{indicated value} \qquad [1]$$

from which the percent accuracy, A, is found by (Figliola and Beasley, 2000):

$$A = \left(1 - \frac{|\varepsilon|}{true\ value}\right) \times 100 \qquad [2]$$

3.5.3. Precision

Precision, also called reproducibility or repeatability, is the degree to which further measurements or calculations will show the same or similar results. Precision is usually characterized in terms of the standard deviation of the measurements, and it is defined as the square root of the variance. In other words, the standard deviation is the root mean square (RMS) deviation of values from their arithmetic mean as follows:

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2} \qquad [3]$$

where σ is standard deviation, N is the number of samples taken, x is the value of each sample, i is the number of the sample, and $\bar{x}$ is the mean value of the samples.

The reported standard deviation of a group of repeated measurements should give the precision of those measurements. A large standard deviation indicates that the data points are far from the mean and a small standard deviation indicates that they are clustered closely around the mean.

3.5.4 Coefficient of variation

The coefficient of variation (CV) for each device tested will be calculated for each set point. The CV is a measure of dispersion of a probability distribution, and it is defined as the ratio of the standard deviation σ to the mean, μ.

$$CV = \frac{\sigma}{\mu} \qquad [4]$$

The CV is a dimensionless number that allows comparison of the variation of populations that have significantly different mean values, with the standard deviation significantly less than the mean.

3.6. Test Duration

A minimum of 8 shut-off/allow irrigation cycles will be considered for a valid RS evaluation, at one rain intensity. Thus, for a sensor with 5 thresholds testing would be performed along the following timeline: 5 thresholds * 8 replications / 2 tests per week = 20 weeks + 4 weeks for report preparation. Under this scenario, the total testing period would be 24 weeks per sensor brand/type; however, multiple brand/types can be tested concurrently. On the other hand, for RSs with no specific set point, the timeline should be 4 weeks for the test + 2 weeks for the report preparation.

4. TEST REPORT

A test report will be completed for each brand/model/set point. The test report is not meant to criticize the different brands, models or set points; neither to compare them. If some specific values are adopted as the minimum accepted by the industry, the final report may mention whether or not these values were achieved by the tested units.

The test report will include the following:

- Depth of rainfall before shut off (mm), average
- Accuracy (%), average and standard deviation
- Depth of rainfall precision (σ from the mean)
- Coefficient of variation (%), average
- Rainfall events not detected (#, and %), if any[1]
- Shut off in absence of rainfall (#, and %), if any[1]

5. REFERENCES

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[1] Cardenas-Lailhacar and Dukes (2007) reported this behavior for some hygroscopic expanding disk models.

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