Commercial Evaluation of Automated Irrigation Control for Overhead Irrigation Based on Daily Weather

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Abstract

A weather station capable of calculating reference evapotranspiration (ETo) was assembled in late Spring 2009 at the Mid-Florida Research and Education Center (MREC). The computer (data logger) was programed to calculate ETo each midnight and open a solenoid on a water valve for the amount of irrigation required. Irrigation requirements were calculated from a canopy closure algorithm successfully tested in 2005-07 in research plots at MREC. Irrigation applications were sensed using a second rain gauge mounted 3 ft above ground level. In late May 2009, the system was installed in a nursery bed at Jon's Nursery near Eustis, Fla. Several unexpected issues emerged over the following months that required program modification and evaluation. Hardware issues also hampered automated control. By the end of August 2009, all issues appear to have been resolved. No data from automated control had been collected. The project will continue into 2010 and a summary report will be submitted in August 2010.

Introduction and Objectives

As water allocations to nurseries have declined over the past 17 years, irrigation managers have had to become more precise in their timing and in the quantity of irrigation applied. This includes taking advantage of rainfall to delay supplemental irrigation. With the ban on daytime overhead irrigation imposed in the 1990's, many if not most nurseries producing small containers have moved to time clock-based irrigation systems to apply overhead irrigation at night. The best of these systems are adjusted daily and have rain shutoff devices to interrupt irrigation if sufficient rainfall occurs.

Irrigation managers know that plant water use changes on a day to day basis with weather conditions and across seasons. The amount is usually estimated subjectively and applications scheduled based on previous experience or calibration(s) preformed at some point in the past, which may or may not be accurate now, or for other nursery sections.

Research conducted at the Mid-Florida Research and Education Center (MREC) since 1993 led to the development of an algorithm based on reference evapotranspiration (ETo), percent canopy closure and plant size. ETo is derived from a complex mathematical equation that has inputs of solar radiation, wind speed, temperature and relative humidity. It outputs a depth of water transpired from a well-irrigated short grass crop and evaporated from the soil surface. The equation is called the Penman-Monteith equation and has been used in agronomy and vegetable production for 40+ years. The Canopy Closure algorithm uses ETo to quantify these daily changes in evaporative demand that account for day to day changes plant water use. The algorithm was evaluated during production of *Ligustrum japoncia* and *Viburnum odoratissimum* from liners to marketable 3 gal plants at MREC. For both species, the algorithm produced marketable quality plants with reduced supplemental irrigation compared to regularly adjusted time clock controlled irrigation, that targeted 70 inches annually.

The objective of this project was to evaluate this algorithm in a commercial nursery. This included determining how it compared in regards to plant quality and irrigation quantities to irrigation managed by the nursery, and if the programing was sufficiently robust to successfully mange irrigation outside the more controlled research setting.

Material and Methods

In March 2009, components of a commercial grade weather station were purchased. These included an anemometer, temperature/relative humidity sensor, solar pyranometer, a data logger enclosure, mounting hardware, solar panel, deep cycle battery and 2 tipping bucket rain gauges. The data logger (computer, CR10X, Campbell Scientific Inc., Logan, UT) was available from a previous project. In early-May, components were mounted on a twelve ft, 1½ inch galvanized pipe for initial testing at MREC. One tipping bucket gauge was mounted at the top of the pole to measure rainfall. The second gauge was mounted with the top 3 ft above ground level to measure overhead irrigation.

A program was written to calculate a Water Needs Index (WNI) daily for representative plants. The WNI was based container upper diameter, average canopy width and spacing (on center) between containers. The program also calculated ETo hourly based on App. Note 4D (Campbell Scientific Inc). With these values, the algorithm estimated the daily water use of plants at midnight and initiated irrigation (opened a 24 VAC solenoid valve). To initiate irrigation, the data logger closed a mechanical relay between a 12 V deep cycle marine battery and an inverter that changed the electricity from 12 VDC to 110 VAC. A transformer stepped the voltage down to 24 VAC, the standard voltage for most irrigation valve solenoids. The solenoid valve remained open until the depth of irrigation required was counted by the lower tipping bucket gauge, or a time limit expired. An elapsed time clock was connected in parallel with the solenoid to determine if and how long the solenoid valve was held open. The system was evaluated without irrigation at MREC for 3 weeks. During this time the program was adjusted until it was functioning properly.

By the end of May 2009, the nursery hosting the experiment (Jon's Nursery, Eustis, FL) had installed the pole base and two water meters designed for 2-inch water mains. One meter was installed in the bed to be controlled by the weather station, the other in an adjacent bed to serve as the nursery managed control. The pole and associated sensors were installed in the middle of the nursery bed which was 30 ft wide by 500 ft long. The weather station controlled bed contained green ligustrum in 3 gal containers of three sizes. After discussions with the production manager, it was decided to irrigate for the largest size. Ten plants near the weather station were randomly selected, tagged and measured. Measurements consisted of the widest canopy width, canopy width perpendicular, height and distance between containers on center. Mean canopy width and distance on center between the containers were in input into the program. The irrigation valve was connected to the 24 VAC transformer in the data logger enclosure and the algorithm control was initiated.

Results

As of the end of August 2009, no reportable data had been collected. Throughout the summer, the project was beset with both software and hardware issues. Since access to the equipment was limited to weekday nursery hours, any changes to the system, either software and hardware, could be made only Monday through Friday. Due to the number and value of the plants under automated control, handing off control of the irrigation to the data logger was done conservatively only after several days of evaluation after each change. Even though Jon's Nursery was on the normal travel route to MREC, and the system was checked most weekday mornings, debugging the unexpected problems was time consuming. Out of state trips on four separate occasions since installation augmented the delays in debugging. No plants were measured in the control bed since the system was not operating satisfactory.

Software issues. A major issue noted early on was that the irrigation rate calculated by the algorithm exceeded the amount normally applied by the irrigation manager. Since plants were not irrigated every day, it took a couple of weeks to scale back the estimated nightly irrigation rate to be inline with what was traditionally applied by the nursery. Eventually this was set at 45% of the algorithm calculated rate. This may have been the result of having less leaf area per plant than those plants used to develop the model, and/or a more prominent "island" effect at MREC from the relatively small (1100 sq. ft) production beds in which the plants for the modeling were grown.

Other software issues were principally related to enhancing the control portion of the program to handle unexpected events. One such issue was the nursery practice of cyclic irrigating in several sets from at 7 pm until 6 am Daylight Saving Time (DST) the following morning. Exact times when water pressure would be available at the data logger-controlled bed was somewhat random and the length of time of each set could vary from night to night. ETo is normally calculated from midnight to midnight. Thus two sets of ETo were required, one accumulated at midnight for comparison to previous research, the other at 7 pm DST for irrigation control. Two concurrent running totals of rainfall were also required. Rainfall totaled at 7 pm had to additionally discount any rainfall occurring during irrigation the previous night.

Another issue was irrigation outside of the 7 pm to 6 am time frame. For example, when a primary pump failed, or the data logger system was malfunctioning and plants were severely wilted, the bed was irrigated manually during normal work hours. The program had to be enhanced to recognize these daytime irrigation events, and account for them by reducing irrigation that would be applied at the next irrigation event.

Hardware issues. Hardware issues were easier to fix, but actually took longer to uncover than software issues. All hardware issues were initially believed to be software issues since the hardware was new and assumed to be infallible. The first two hardware issues were the result of a power transformer with too high a wattage. While it performed flawlessly for several weeks during evaluation at MREC, after a few weeks in the field the transformer caused both blown fuses and the failure of the12 VDC relay. This was solved by replacing it with a transformer of lower wattage in late June.

The most time consuming hardware issue was determined only the third week of August to be intermittent conversion of 12 VDC to 110 VAC. This began on July 17th and was not uncovered and corrected until August 21st. During this time period the inverter only functioned from a few minutes to less than 2 hr per night on an erratic schedule. Replacing the new inverter with another one solved the problem.

Conclusions and Recommendations

The data logger system preformed well in the research setting where irrigation would run immediately on demand at midnight for as long as was needed, and 120 VAC power was readily available. In the real world commercial nursery, several issues of both software and hardware arose and had to be solved. This was anticipated, and was the reason this project was proposed in 2008. Without real-world testing and improvement, this technology would not have a chance to be successful.

Controlling irrigation as is tested here has several benefits for the nursery industry. Basing irrigation on prevailing weather conditions more accurately reflects daily changes in cloud cover, temperature and relative humidity. ETo can fluctuate as much as 50% from one day to the next, which changes plant water use proportionally. Automating irrigation as done here would make more efficient use of rainfall, particularly the evening thunderstorms during the summer, and reduce weekend changes in timed irrigation. Finally the system is scalable, with the cost per bed declining as the number controlled is increased.

It is believe that most, if not all issue have now been encountered and resolved. Both myself and Jon's Nursery are committed to continuing this technology transfer until it is successful or proven impossible.