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Managing Growth of *Hibiscus acetosella* by Controlling Substrate Moisture With Sensor-Controlled Irrigation©

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INTRODUCTION

Understanding how available water in the substrate affects plant growth and how much water plants use is important for effective irrigation management. A better understanding of plant water use will allow growers to irrigate more efficiently, increasing sustainability, reducing leaching and runoff, and decreasing disease incidence and severity. Precise control of irrigation can also provide growers the possibility to manipulate plant growth rate(s) by controlling substrate water content. The use of soil moisture sensors to successfully monitor substrate water content has been demonstrated in both greenhouse and nursery settings (Lea-Cox et al., 2008; van Iersel et al., 2009; van Iersel et al., 2010). Used in tandem with an automated irrigation system, soil moisture sensors can be used to monitor and control substrate water content (Nemali and van Iersel, 2006).

The ability to manage plant growth via control of substrate water content can be a valuable tool for growers, providing the possibility to increase or decrease the length of production cycles, foster or impede plant growth, or potentially help plants adapt to water-stressed environments. The objectives of this research were to understand how growth of *Hibiscus acetosella* 'Panama Red' (PP20121) was affected by maintaining various substrate water contents via soil moisture sensor-controlled automated irrigation and to quantify differences in growth due to variation in substrate water content.

MATERIALS AND METHODS

Experiments were conducted in Watkinsville, Georgia (USDA Zone 7b) and Tifton, Georgia (USDA Zone 8a) in order to address differences due to environmental factors. Rooted *H. acetosella* 'Panama Red' cuttings were planted in 3.8-L black plastic pots in summer 2010 in either a bark-and-peat-based substrate (Watkinsville) (Fafard nursery mix, Fafard, Agawam, Massachusetts) or a mix pine bark and sand (8 : 1, v/v) potting substrate (Tifton). At the beginning of the experiment, plants were pruned to 13 cm, top dressed with 18 g of controlled-release fertilizer (Harrell's 16N-6P-11K Professional Fertilizer, Harrell's, Lakeland, Florida), and irrigated thoroughly.

Throughout the experiment, plants were irrigated using a soil moisture controlled irrigation system as described by Nemali and van Iersel (2006). Two soil moisture sensors (10HS, Decagon Devices, Pullman, Washington) were used to monitor each plot. Sensors were inserted into the root zone of the plant at a 45° angle. Sensors were connected to a multiplexer (AM416; Campbell Scientific,

Logan, Utah) that was connected to a datalogger (CR10; Campbell Scientific). The datalogger recorded and stored voltage measurements from sensors every 20 min. Voltage readings were converted to substrate water contents (θ) using our own calibration [$\theta = -0.401 + 1.0124 \times$ output (V)]. The datalogger compared two sensor readings for each plot to a programmed set point (0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, or 0.45 $m^3 \cdot m^{-3}$) and initiated irrigation when both sensor readings were below the programmed set point.

When irrigation was needed the datalogger signaled a relay driver (SDM16AC/DC controller; Campbell Scientific) to open a solenoid valve (sprinkler valve; Orbit, Bountiful, Utah). Each irrigation event applied 60 ml of water over a period of 2 min using dribble rings connected to pressure-compensated drip emitters (Netafim USA, Fresno, California). Every 2 h, substrate moisture readings for each sensor were averaged and recorded. The number of daily irrigation events was also recorded allowing for calculation of daily irrigation volume. Environmental conditions were measured using a temperature and relative humidity sensor (HMP50, Vaisala), a quantum sensor (QSO-Sun, Apogee Instruments, Logan, Utah, and a rain gauge (ECRN-50; Decagon Devices) connected to the datalogger. Vapor pressure deficit was calculated by the datalogger using this information.

At the conclusion of the experiment, 10 plants from each plot were randomly selected for data collection. Plant heights were recorded. Shoots were cut off at the substrate surface and stem fresh weight was measured; stems were dried at 80 °C and stem dry weight was determined. Substrate water content was measured using a soil moisture sensor (ThetaProbe; Delta-T Devices, Cambridge, U.K).

The experiment was designed as a randomized complete block with eight treatments (substrate VWC set points) and two replications for a total of sixteen plots with 25 plants each. Data were analyzed using linear and nonlinear regression, with $P = 0.05$ considered to be statistically significant. Curve fitting was done using SigmaPlot (Systat, San Jose, California).

RESULTS AND DISCUSSION

Drying of substrates to programmed set points took longer than in our previous greenhouse experiment (Bayer et al., 2011) due to the influence of environmental factors. Frequent rain events occurred in both locations near the beginning of the experiments with setpoints not being reached until around Day 40 for the Tifton experiment and Day 34 for the Watkinsville experiment. After establishment of substrate water-content (θ) thresholds, restoration of setpoints was generally observed after subsequent rain events. The exception was in the Watkinsville experiment in which the 0.10 $m^3 \cdot m^{-3}$ threshold was unable to be reestablished after a 76-mm (3-in.) rain event near the end of the experiment (Fig. 1). This was most likely due to the volume of rain along with small size and low water use of the plants in the 0.10 $m^3 \cdot m^{-3}$ treatment.

Plant height generally increased with increasing θ thresholds (Fig. 2). In the Tifton experiment height increased from an average of 27 cm for the 0.10 $m^3 \cdot m^{-3}$ treatment to 90 cm for the 0.45 $m^3 \cdot m^{-3}$ treatment (Fig. 3). In the Watkinsville experiment, height increased from an average of 28 cm in the 0.10 $m^3 \cdot m^{-3}$ treatment to 69 cm in the 0.45 $m^3 \cdot m^{-3}$ treatment (Fig. 4). Shoot dry mass also increased (data not shown). The linear relationship between plant height and θ threshold (Tifton: $r = 0.88$, $p<0.001$; Watkinsville: $r = 0.90$, $p<0.001$) demonstrate that controlling

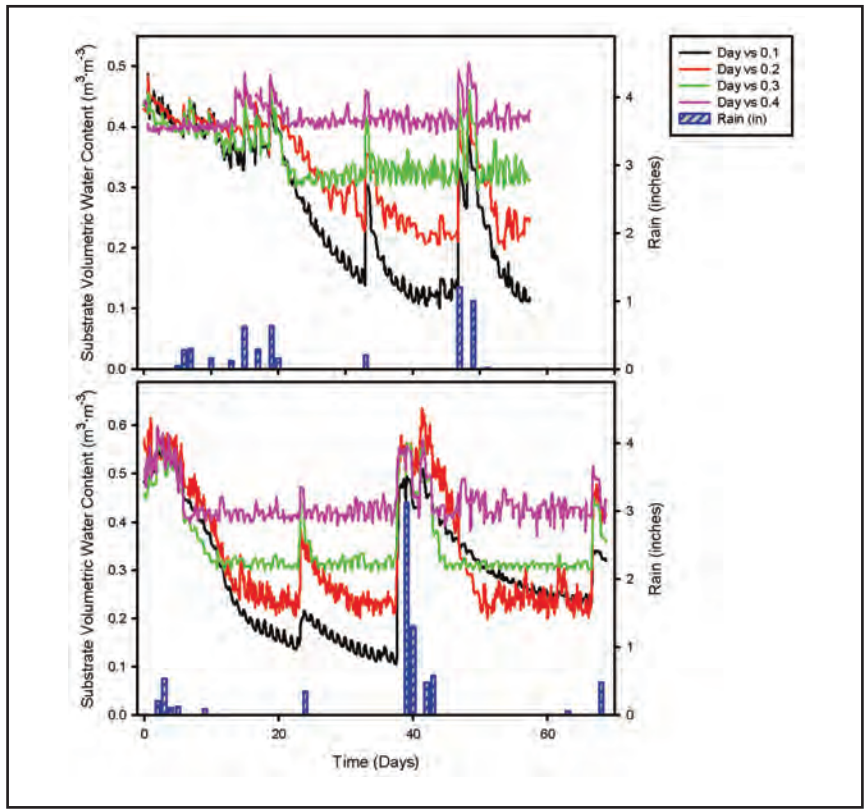

Figure 1. Substrate volumetric water contents over the course of the experiment. The θ thresholds were 0.10,0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45 $m^3 \cdot m^{-3}$, but only the 0.10, 0.20, 0.30, and 0.40 $m^3 \cdot m^{-3}$ treatments are represented for clarity (line graphs). Rain events are shown as blue bars. Nine rain events occurred during the first 20 days of the Tifton experiment (top) causing thresholds to not be reached until around Day 40 of the experiment. Five rain events occurred during the first 10 days of the Watkinsville experiment (bottom) causing thresholds to not be reached until around Day 34 of the experiment. A 76-mm (3-in.) rain event on Day 39 of the Watkinsville experiment prevented the reestablishment of the 0.10 $m^3 \cdot m^{-3}$ by the conclusion of the experiment.

substrate water content can be used to regulate plant growth. As has been observed in previous experiments (Burnett and van Iersel, 2008; Kim and van Iersel, 2009; van Iersel et al., 2010), total irrigation volume increased with increasing θ thresholds. Irrigation volumes over the entire production cycle increased from 0.24 L per plant for the 0.10 $m^3 \cdot m^{-3}$ treatment to 33.6 L per plant for the 0.45 $m^3 \cdot m^{-3}$ treatment in Tifton, and from 0.06 L per plant for the 0.10 $m^3 \cdot m^{-3}$ treatment to 23.0 L per plant for the 0.45 $m^3 \cdot m^{-3}$ treatment in Watkinsville. Similar plant heights can be achieved with a range of θ thresholds. For example in Watkinsville, the 0.35 $m^3 \cdot m^{-3}$, 0.40 $m^3 \cdot m^{-3}$, 0.45 $m^3 \cdot m^{-3}$ treatments all produced plants with similar heights, while height was reduced at lower θ thresholds. There was a

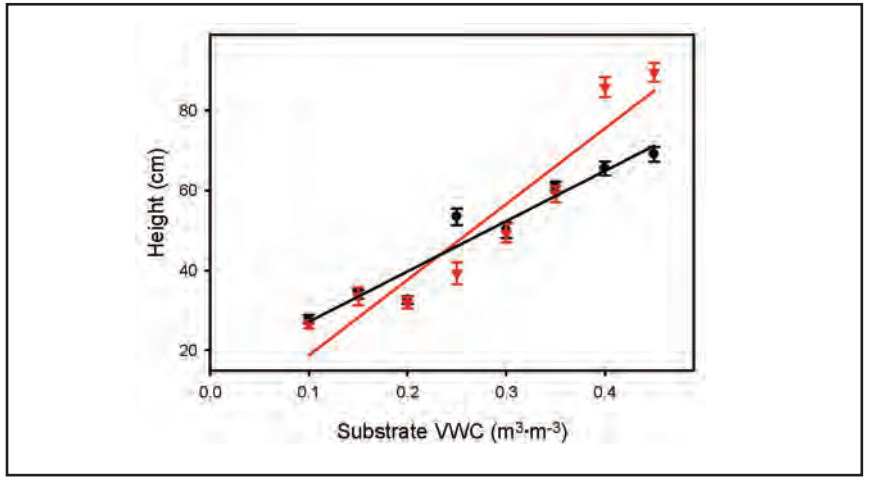

Figure 2. Plant height vs. substrate volumetric water content (θ threshold) for both the Tifton and Watkinsville experiments. Height and θ threshold had a linear relationship (Tifton: r = 0.88, $p < 0.001$; Watkinsville: $r = 0.90$, $p < 0.001$). Watkinsville data is represented by the black circles, Tifton data is represented by the red triangles.

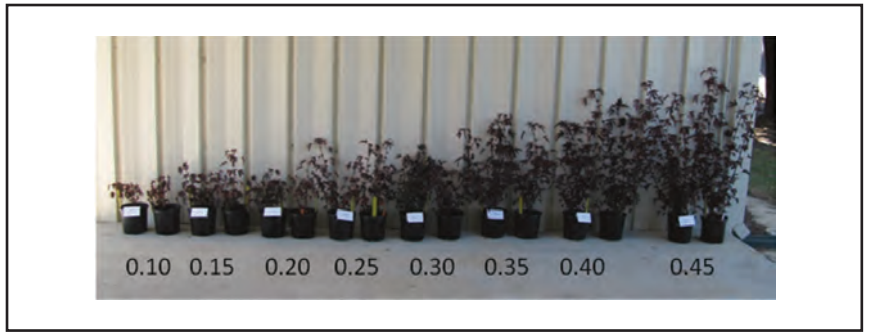

Figure 3. *Hibiscus acetosella* 'Panama Red' grown with increasing substrate volumetric water content (moving from 0.10 $m^3 \cdot m^{-3}$ on the left to from 0.45 $m^3 \cdot m^{-3}$ on the right). Tifton experiment.

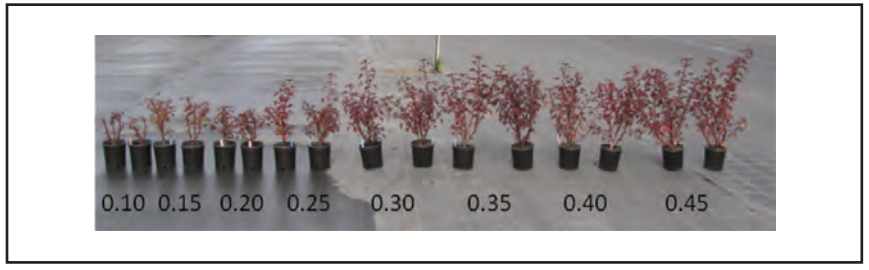

Figure 4. *Hibiscus acetosella* 'Panama Red' grown with increasing substrate volumetric water content (moving from 0.10 $m^3 \cdot m^{-3}$ on the left to from 0.45 $m^3 \cdot m^{-3}$ on the right). Watkinsville experiment.

7.65 L/plant saving in the 0.35 $m^3 \cdot m^{-3}$ compared to the 0.45 $m^3 \cdot m^{-3}$ treatments with only an 8 cm difference in plant height. This 33% savings in irrigation volume with minimal loss in plant height demonstrates that substantial water savings are possible.

Effects of θ thresholds on plant height and shoot dry weight suggest that growth can be controlled via control of substrate volumetric water content. This can provide growers the opportunity to alter production cycles by altering water availability and thereby controlling growth rate. Along with controlling growth, control of substrate volumetric water content can allow for substantial savings in irrigation and fertilizer. Reduced leaching through control of substrate volumetric water content can allow for a reduction in fertilizer application. An experiment in 2012 will look to quantify fertilizer savings.

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