Automated Irrigation Control for Improved Growth and Quality of *Gardenia jasminoides*©

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INTRODUCTION

As global water consumption increases in the coming years, available water for agriculture will decrease (Jury and Vaux, 2005). This will necessitate that growers use irrigation scheduling with an alternative focus other than what has been traditionally used. Generally irrigation scheduling has been aimed at maintaining substrate water content near container capacity to maximize plant growth (Beeson, 1992). However, the growing number of laws and regulations regarding water use and runoff are requiring growers to reassess their irrigation practices (Lea-Cox and Ross, 2001; Beeson et al., 2004).

Researchers related growth to total daily water use (DWU) as well as reduced replacement of DWU (50, 75% of measured DWU) (Welsh et al., 1991; Warsaw et al., 2009). These studies showed that reduced irrigation volumes can produce high quality plants with little to no reductions in growth. Other studies have looked to relate plant growth to substrate volumetric water content (θ) (van Iersel et al., 2010; Fulcher et al., 2012; Garland et al., 2012). Automated irrigation using soil moisture sensor control allows for precise control of irrigation, allowing for maintenance of θ close to a programmed threshold (van Iersel et al., 2010). This precise irrigation application method allows us to relate θ to irrigation volume and plant growth.

The objectives of our research were to quantify root and shoot growth of two gardenia cultivars, *Gardenia jasminoides* 'August Beauty' and 'Radicans', maintained at various substrate volumetric water content thresholds.

MATERIALS AND METHODS

Research was conducted at the University of Georgia Horticulture Farm in Watkinsville, Georgia and at the University of Georgia Tifton Campus from April - November, 2011. The studies were conducted at two locations in different USDA hardiness Zones (Tifton 8b, Watkinsville 8a; USDA, 2012) to compare plant responses under different environmental conditions.

Gardenia jasminoides 'August Beauty' and 'Radicans' in #1 black plastic containers were obtained from McCorkle's Nurseries (Dearing, Georgia) on 5 April 2011. Plants were grown in a pine bark-based substrate with Osmocote incorporated. Plants were kept well watered for 2-4 weeks to allow for root establishment. Irrigation treatments were initiated in Tifton on 18 April 2011 and in Watkinsville on 4 May 2011.

Irrigation was applied using a soil moisture sensor-controlled irrigation system based on that described by Nemali and van Iersel (2006). Soil moisture sensors (10HS; Decagon Devices, Pullman Washington) were inserted into two pots in each of the 16 plots at approximately a 45° angle into the center of the substrate. The 32 sensors were connected to a datalogger (CR10; Campbell Scientific, Logan, Utah) for automated data collection. Sensor readings were taken every 20 min.

The voltage output from the sensors were converted to substrate water contents using our own calibration [$\theta = -0.401 + 1.0124 \times \text{output (V)}$]. When the maximum reading from the two sensors measurements was less than the θ threshold for that plot (20, 30, 40, or 50%), the datalogger signaled the relay driver (SDM16AC/DC controller; Campbell Scientific) to open the appropriate solenoid valve (sprinkler valve; Orbit, Bountiful, Utah). Plants were irrigated with 60 ml of water over a period of 2 min using dribble rings (Dramm; Manitowoc, Wisconsin) connected to pressure-compensated drip emitters (Netafim USA, Fresno, California).

Soil moisture readings from each sensor were averaged and stored every 2 h and the number of irrigation events per plot was recorded daily. The total irrigation volume for a plot was calculated from the number of irrigation events and the volume of water applied per irrigation event. Water use per acre was estimated by multiplying irrigation volume per plant by 43,560 (estimating 1 plant per square foot). Height of all plants was measured at the conclusion of the experiment. Shoots were cut off at the substrate surface and shoot fresh mass was measured; shoots were dried at 80°C and shoot dry mass was determined. Five (Tifton) or six (Watkinsville) root systems were randomly selected from each plot, root systems were washed to remove substrate, dried at 80°C and root dry mass was determined. The experiment was designed as a randomized complete block with four treatments (substrate VWC set points) and two replications of each cultivar for a total of sixteen plots with approximately 18 plants each.

RESULTS AND DISCUSSION

Using substrate water content to control growth requires an understanding of how growth relates to θ threshold and irrigation volume. This knowledge can help growers make irrigation decisions based on their specific needs for plant growth while using water more efficiently. Production of high quality plants with the lowest inputs is a goal of many growers. However, consumer demand, or lack thereof, may necessitate that a grower alter their standard production cycle. To do this effectively the relationship between plant growth and θ threshold and irrigation volume is needed.

In our study substrate volumetric water content was generally maintained at or close to the threshold by the automated irrigation system. Rain events increased θ; however, drying of substrates to the θ threshold generally occurred within a few days. The total irrigation volume increased with increasing θ threshold; with patterns of increasing volume similar for both cultivars and locations (Table 1). Height and shoot and root dry mass also increased with increasing θ threshold with similar patterns of growth for both cultivars and locations (Tables 2 and 3).

Table 1. Estimated water use (gallons/acre) of *Gardenia jasminoides* ‘August Beauty’ and ‘Radicans’ at the substrate water content thresholds (20, 30, 40, and 50%). Differences in water use between the two locations (Watkinsville and Tifton, Georgia) can be explained by variation in environmental conditions as well as growth rates between the two locations.

Substrate water content (%)	‘August Beauty’		‘Radicans’	
	Watkinsville gal/acre	Tifton gal/acre	Watkinsville gal/acre	Tifton gal/acre
20	21,735	11,040	15,870	15,180
30	172,498	177,725	162,838	72,449
40	551,647	1,241,460	385,360	182,503
50	1,010,491	2,753,438	3,003,873	1,444,150

Table 2. Growth measurements of *Gardenia jasminoides* ‘August Beauty’ and ‘Radicans’ for the Watkinsville experiment. Height, shoot dry mass, and root dry mass of all plants were measured at the conclusion of the experiment.

Substrate water content (%)	‘August Beauty’			‘Radicans’		
	Height (mm)	Shoot dry mass (g)	Root dry mass (g)	Height (mm)	Shoot dry mass (g)	Root dry mass (g)
20	139.9	4.4	2.0	105.3	2.6	1.0
30	221.6	15.5	7.7	128.3	5.8	2.3
40	397.4	37.2	26.7	203.6	24.6	13.5
50	416.6	44.1	35.5	214.8	26.3	16.4

Table 3. Growth measurements of *Gardenia jasminoides* 'August Beauty' and 'Radicans' for the Tifton experiment. Height, shoot dry mass and root dry mass of all plants were measured at the conclusion of the experiment.

Substrate	'August Beauty'			'Radicans'		
water content (%)	Height (mm)	Shoot dry mass (g)	Root dry mass (g)	Height (mm)	Shoot dry mass (g)	Root dry mass (g)
20	125.8	1.9	1.0	122.7	2.7	1.2
30	168.0	5.9	2.6	129.9	8.3	2.6
40	406.7	47.6	32.8	205.0	20.0	8.4
50	470.0	65.0	38.0	259.9	39.1	15.0

The 20% θ threshold was insufficient for root establishment, with 79% mortality in Watkinsville and 72% mortality in Tifton. Plants grown with a 30% θ threshold generally survived but did not grow well and their flowering was delayed. Visually plants were very similar at the 40% and 50% θ thresholds (Figs. 1-3). The extra irrigation water applied with the 50% θ threshold (Table 1) did not result in substantially more growth (Tables 2 and 3) and resulted in reduced flower bud development for 'Radicans' (data not presented). Plants at the 50% threshold began to show signs of nutrient deficiency before the 40% threshold, suggesting increased fertilizer use and loss through leaching. Observations of the root systems (Fig. 3) made it clear that θ thresholds of 20% and 30% were inadequate for the development of a vigorous system. A relatively high θ threshold (i.e., 40%) is needed for the establishment of a strong root system. The reduced growth at lower θ suggests that alteration of thresholds over the course of a production cycle could be used as a tool for controlling growth; lowering the θ threshold after a strong root system has developed could slow down growth, if needed.

Fig. 1. Shoot growth of *Gardenia jasminoides* 'August Beauty' and 'Radicans' in the Watkinsville experiment. 'August Beauty' is on the top and 'Radicans' on the bottom'. Substrate water content thresholds for irrigation increase from 20% on the left to 50% for plants on the right for both cultivars.

Fig. 2. Shoot growth of *Gardenia jasminoides* ‘August Beauty’ and ‘Radicans’ in the Tifton experiment. ‘August Beauty’ is on the top and ‘Radicans on the bottom’. Substrate water content thresholds for irrigation increase from 20% on the left to 50% for plants on the right for both cultivars.

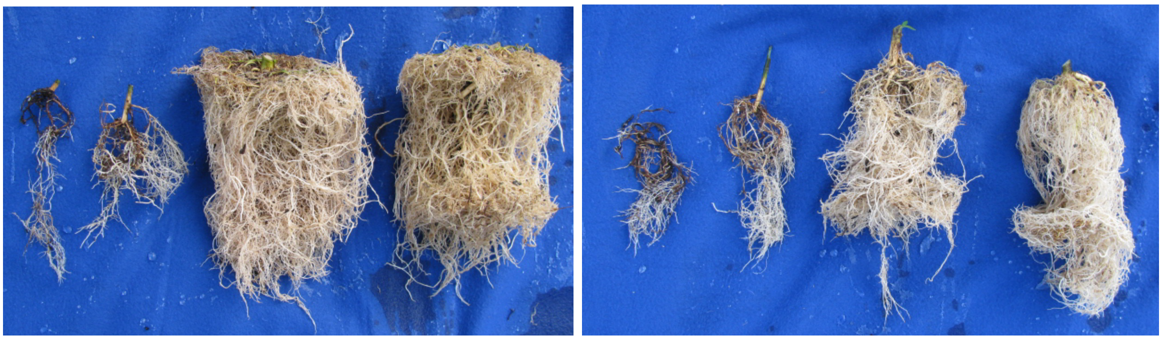

Fig. 3. Root growth of *Gardenia jasminoides* ‘August Beauty’ and ‘Radicans’ in the Tifton experiment. ‘August Beauty’ is on the left and ‘Radicans’ on the right. Substrate water content thresholds for irrigation increase from 20% on the left to 50% for plants on the right for both cultivars.

Controlling growth in this manner could reduce inputs needed for production including reduced irrigation, labor inputs, fertilizer, and pesticide and fungicide applications.

This study shows that by monitoring and controlling substrate water content, growers can improve plant quality by irrigation control to maintain substrate water content as needed to support growth. Differences in growth among the 30%, 40%, and 50% thresholds suggest that alteration of substrate water content during the production cycle would provide growers with the ability to control crop growth. This can increase production efficiency as crop timing could be altered to meet production needs.

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