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Production of *Loropetalum* and *Viburnum* with Capillary Mat and Sprinkler Irrigation

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Some container plants grown in Central Florida using overhead sprinkler irrigation exhibit shoot growth suppression during the summer, according to reports from commercial producers. We hypothesize that growth suppression is caused by suboptimal substrate moisture or heat induced stress. To test this, recently planted *Viburnum suspensum* Lindl. (Sandankwa Viburnum) and *Loropetalum chinense* (R. Br.) Oliv. Plum Delight® (Chinese Fringe Flower) in 2.5 L containers were grown during the summer of 2016 at the Gulf Coast Research and Education Center in Wimauma, FL. using either capillary mats or overhead sprinkler irrigation. Shoot biomass was measured 19 weeks after initiation of irrigation. *Viburnum* and *Loropetalum* grown in two of the five capillary mat blocks had similar shoot and root biomass compared to those grown with sprinkler irrigation. In contrast, the average shoot and root biomass for plants grown with capillary mats was smaller than for plants grown with sprinkler irrigation across all blocks. Our data indicated that experimental conditions for the sprinkler-irrigated *Viburnum* or *Loropetalum* did not result in discernable growth suppression. Further investigations are needed to determine the cause of growth suppression when growing woody plants using sprinkler irrigation.

Capillary mat irrigation has been available for more than 20 years and, in that time, the water saving utilities of this technology have been studied and realized (Beeson et al., 2004; Mathers et al., 2005). This type of irrigation has proven to reduce fertilizer leaching, use water efficiently (at a lesser cost), and to provide plants with a reservoir of water to draw from throughout the day (Bilderback, 2002; Haydu et al., 2002; Yeager and Henley, 2004). In contrast, the adoption of capillary mat irrigation on a large scale has not been widespread (Piatti et al., 2011). With conceivable climate change and water crises, the water savings alone would be able to justify this technology as water becomes more expensive and stringently regulated (Warsaw et al., 2009).

It has been noted by producers that some container-grown woody plants experience suppressed growth during the hot summer months in Florida. Therefore, our objective was to determine if plant growth suppression was caused by suboptimal irrigation that may be alleviated by capillary mat irrigation.

Materials and Methods

Experimental site. The experiment was performed at the Gulf Coast Research and Education Center in Wimauma, FL., (27°45'29.0"N 82°13'35.3"W). Ten blocks, measuring 6 ft x 8 ft (1.8 m x 2.4 m) were designated for the experiment based on existing infrastructure.

Experimental plants and design. *Viburnum* and *Loropetalum* were obtained from Harrell's Nursery (Plant City, FL) on 1 June 2016 and transported to the University of Florida Gulf Coast Research and Education Center in Wimauma, FL. Plants were grown in black containers (2.5 L) with trade size of 1 gal (Nursery Supplies Inc., Kissimmee, FL).

Substrate for *Viburnum* was 50% Florida peat, 25% pine bark, and 25% cypress/hardwood and was initially amended with 19 lb/yard^3 (11.3 kg·m^{-3}) of Harrell's (Harrell's Inc., Lakeland, FL.) 17N–2.2P–9.1K Polyon controlled-release fertilizer. Substrate for the *Loropetalum* was 35% Florida peat, 45% pine bark, and 20% Airlite and was initially amended with 22 lb/yard^3 (13.1 kg·m^{-3}) of Harrell's 17N–2.2P–9.1K Polyon controlled-release fertilizer.

Plants for each species were trimmed to uniform size and placed with containers touching in an offset pattern on 3 June 2016 in blocks (Fig. 1). Treatment blocks provided either mat or sprinkler irrigation. A total of ten, 6 ft x 8 ft (1.8 m x 2.4 m)

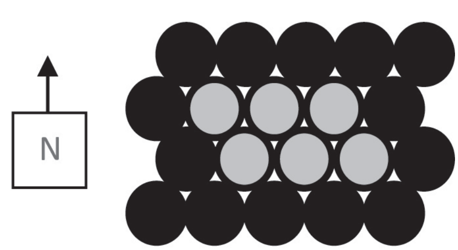

Fig. 1. *Viburnum suspensum* and *Loropetalum chinense* plants in the center of each block were sampled for growth measurements.

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blocks were selected in a polypropylene covered nursery production area. Half of the blocks (5 blocks/irrigation method) were used in each treatment. Blocks contained 10 plants of each species totaling 20 plants in a randomized design. Empty containers were weighed down with rocks and used to form a perimeter around the blocks to act as a heat/radiation shield and protect the roots from heat damage. On 15 June 2016, *Viburnum* plants measured approximately 8.2 in × 11.6 in × 10.1 in (height × width × width) (20.8 cm × 29.5 cm × 25.7 cm) and *Loropetalum* at 9.3 in × 10.7 in 9.3 in (23.6 cm × 27.2 cm × 23.6 cm). Containers were spaced 1 in (2.54 cm) apart at 4 weeks, 3 in (7.6 cm) at 6 weeks, and 5 in (12.7 cm) at 9 weeks. At the final 5 in (12.7 cm) spacing, containers were placed in a net that was cut to accommodate each container to stabilize the plants. Empty containers were inverted and placed between the planted containers to secure them in place. Blocks were exposed to rainfall events throughout the experiment. All plants were fertilized at 10 weeks with approximately 8 g of 18N–2.6P–6.6K Nutricote® Total Type 180 fertilizer (Florikan ESA LLC, Sarasota, FL.).

Irrigation Systems. Capillary mats measuring 4 ft × 8 ft (1.2 m × 2.4 m) (WaterPulse Technologies, Denver, CO) were composed of a thick plastic backing, capillary material, 2 drip tapes (8 emitters each with pressure relief valves at ends), a pervious polypropylene layer to cover, and a header. Mats were placed in the center of the 8 ft × 6 ft (2.4 m × 1.8 m) blocks. Plumbing was placed above ground for ease of setup. PVC pipe (3/4 in; 1.9 cm) was used to provide water to each of the mat blocks. A spigot was placed at the end of the pipe for ease of supplemental overhead irrigation of capillary mat blocks (to ensure capillarity between mat and container). Capillary mats provided 0.15 gal·min^{-1} (0.57 L·min^{-1}) and 0.5 gal (1.9 L) was needed per mat per irrigation event to provide approximately 70 mL (2.5 oz) per plant. With three irrigation events daily, at 3 min each, the application rate provided a total of 210 mL (0.39 in) per plant per day (Table 1). Changes to irrigation run times and frequencies occurred due to electrical/storm outages and visual inspection.

Sprinkler irrigation blocks were fitted with four Pro Fixed Arc nozzles with an 8 ft (2.4 m) radius and 90° arc (#8Q; Hunter Industries, San Marcos, CA) attached to Pro-Spray® heads (#PROS-03; Hunter Industries, San Marcos, CA) on 18 in (45.7 cm) risers. Block sizes were defined by the irrigation nozzles, spaced approximately 8 ft × 6 ft (2.4 m × 1.8 m). Irrigation ran daily for 10 min to achieve a minimum of 1.28 gal (4.84 L) over the irrigated area. Irrigation times and frequency increased later in the experiment (Table 1).

Distribution uniformity (DU) of sprinkler irrigation was performed using the twelve-cup method outlined in Million and Yeager, 2012. Twelve cups, with an opening area of 95.2 cm^2, were evenly spaced in the blocks to cover an approximately 4 ft × 6 ft (1.2 m × 1.8 m) area (space to be occupied by the total plants). Sprinkler irrigation was run for 20 min and then each cup's water content was measured with a graduated cylinder and the volumes recorded. Average DU% for the 12 cup calculations resulted in 77% (Table 2). Average DU% was 84% when only examining the interior 6 cups (where the plants used for growth measurements were located) (Table 3).

Average irrigation application rate was determined for sprinkler irrigation using the volumes recorded from the DU test, resulting

Table 1. Irrigation run times for sprinklers and mats used to grow *Viburnum suspensum a*nd *Loropetalum chinense* in Central Florida in 2016.

	Sprinkler			Capillary Mat		
Date (2016)	Start time (HR)	Run Time (min)	Daily water per block (gal/L)	Start time (HR)	Run Time (min)	Daily water per block (gal/L)
				08:15	3	
				14:30	3	
3 June	08:00	10	1.28/4.84	18:30	3	1.35/5.11
				09:15	3	
				12:30	3	
8 June	09:00	10	1.28/4.84	16:30	3	1.35/5.11
				05:15	3	
				12:00	3	
21 June	05:00	10	1.28/4.84	18:00	3	1.35/5.11
				06:15	3	
				11:00	3	
				15:00	3	
28 June	06:00	10	1.28/4.84	19:00	3	1.80/6.81
				09:15	3	
				12:30	3	
30 June	09:00	10	1.28/4.84	16:30	3	1.35/5.11
				06:15	3	
				09:00	3	
				13:00	3	
				16:00	3	
6 July	06:00	10	1.28/4.84	19:00	3	2.25/8.52
				06:15	3	
				09:00	3	
				13:00	3	
	06:00	10		15:00	3	
				17:00	3	
19 Aug.	12:00	10	2.56/9.68	19:00	3	2.70/10.22

Table 2. Distribution uniformity (DU) of irrigation systems used to grow *Viburnum suspensum* and *Loropetalum chinense* in Central Florida in 2016. DU was calculated for 12 collection cups per block.

Block	Average (mL)	Low quarter (mL)	DU (%)	Application rate (in/h)	**Application rate (cm/h)**
1	148	120	81	1.8	4.7
2	152	130	86	1.9	4.8
3	150	127	85	1.9	4.7
4	150	95	63	1.9	4.7
5	168	120	71	2.1	5.3
	Average DU and application rate:		77	1.9	4.8

Table 3. Distribution uniformity (DU) of irrigation systems used to grow *Viburnum suspensum* and *Loropetalum chinense* in Central Florida in 2016. The DU was calculated for six interior collection cups per block.

Block	Average (mL)	Low quarter (mL)	DU (%)	Application rate (in/h)	Application rate (cm/h)
1	150	128	85	1.9	4.7
2	158	146	92	2.0	5.0
3	149	124	83	1.8	4.7
4	156	124	80	1.9	4.9
5	178	138	78	2.2	5.6
	Average DU and application rate		84	1.9	4.9

in an average of 1.91 inches/hour (4.85 $cm \cdot h^{-1}$), or 0.032 $in \cdot min^{-1}$ (0.08 $cm \cdot min^{-1}$). The irrigation was initially set to 0.32 in (0.8 cm) per day (Million et al., 2007) so the irrigation run time was set at 10 min for the sprinkler irrigation treatment. The irrigation supply pipe for both sprinklers and mats was fitted with a water meter. Meter readings at the beginning and the end of the experiment were recorded.

Data Collected. Six plants were used for data collection from the inside of the block; 3 of each species (Fig. 1). Growth index (GI) data were determined, where height (H) and width (W) were used to determine growth index from the equation: $[H \times (W1 + W2)/2]$. GI was measured on 15 June 2016, and at two-week intervals thereafter.

Electrical conductivity (EC) measurements were taken monthly from the growing substrate of a *Viburnum* in the center of the north outside row. Plants were irrigated (10 min for sprinkler and 3 min for capillary mat) and after 30–60 min, EC was measured using the Pour-Through method (Yeager et al., 1983). Two-hundred milliliters of deionized water were supplied to each container and leachate EC was measured using the Myron L Agri-Meter (Model # AG6/PH; Carlsbad, CA).

Substrate temperatures were recorded for both species in all blocks. The westernmost plant substrate of each species was measured on 22 July, 25 July, 28 July, and 19 Aug. 2016, at approximately 15:00 HR on sunny days using an Ertco soil thermometer (#BK3006005; Dubuque, IA). The thermometer tip was placed 1 in (2.54 cm) from the westernmost container sidewall and inserted downward 3 in (7.6 cm) from the bottom of the container.

Containers were weighed 17 June, 22 June, and 11 Aug. 2016 to evaluate the substrate moisture retention that occurred with periodic irrigation events. Measurements were used to guide changes in irrigation frequency and/or timing.

Dry biomass for shoot and root growth was determined at the end of the experiment on 12 Oct. 2016, when plants were taken to the Plant Science Facility at University of Florida, Gainesville for drying and determination of shoot and root biomass. Plants were clipped at the uppermost root and shoots were individually bagged for each plant. Roots were washed to remove substrate, and then bagged individually. All samples were placed into forced air dryers set to 70 °C, allowed to dry for 80 hours, and then weighed.

Statistical significance was determined using Monte Carlo mean comparison tests and standard errors. Due to the slope of the land, the data could not be analyzed using typical linear models because our data broke the assumptions of normality and homogeneity. Monte Carlo statistical analysis allows for significance to be tested with data that has an abnormal distribution and heterogeneous variance.

Results

In this experiment, mats 3 and 5 were on the lower side of a slope. It is likely that water drained through the system after the irrigation run time ended and placed excess water on those two mats at each irrigation event. For this reason, data have been separated in the following figures and tables to show the differences for those two blocks and Monte Carlo statistical analysis was used to determine statistical significance. The slope of the plumbing and the capillary mats is important when attempting to increase the efficiency of this type of system (Piatti et al., 2011; Schuch et al., 2008).

Biomass and Growth Index. Shoot and root biomass and growth indices were larger for plants that received sprinkler irrigation compared with plants that were irrigated with mats (Table 4, Figs. 2, 3, 4, 5, and 6). However, *Viburnum* and *Lorop-*

Table 4. *P*-values from Monte Carlo statistical analysis for final growth index and biomass of *Viburnum suspensum* and *Loropetalum chinense* grown under sprinkler vs. mat blocks and sprinkler vs. mat blocks 3 and 5 are given for experiment termination.

Plant	Parameter	Sprinkler vs. Mat blocks	Sprinkler vs. Mat blocks 3 and 5
Viburnum	Growth index	0.0001	0.696
	Shoot biomass	0.0001	0.951
	Root biomass	0.0010	0.889
Loropetalum	Growth index	0.0001	0.962
	Shoot biomass	0.0001	0.960
	Root biomass	0.0001	0.947

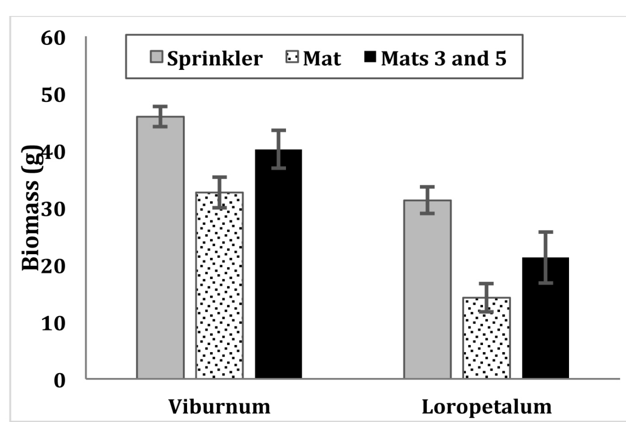

Fig. 2. Shoot biomass (±SE) of *Viburnum suspensum* and *Loropetalum chinense* grown under 2 irrigation systems.

etalum plants grown in blocks 3 and 5 with mats had shoot and root biomass and growth indices (Table 4) that were similar to sprinkler irrigated plants at experiment termination.

Electrical Conductivity (EC). The EC values at weeks 8 and 12 were below acceptable ranges for container-grown woody plants (Florida Department of Agriculture and Consumer Services, 2014). The EC values for the mat plants were low initially and elevated to 0.48 mmhos·cm^{-1} for mat 3 and 5 at week 12 (Fig. 7). The EC values for the plants from mats 3 and 5 ranged from 0.15–0.48 mmhos·cm^{-1}. The sprinkler irrigated plant's EC ranged from 0.30–0.37 mmhos·cm^{-1} (Fig. 7).

Substrate Temperature. Substrate temperatures were not excessively high compared to temperatures measured previously in exposed black plastic containers. Ingram (1981) reported container substrate temperatures of approximately 133° F (45° C) in Florida in September. In our experiment, substrate temperatures for plants irrigated with mats or sprinklers were similar (considering standard errors) (Fig. 8).

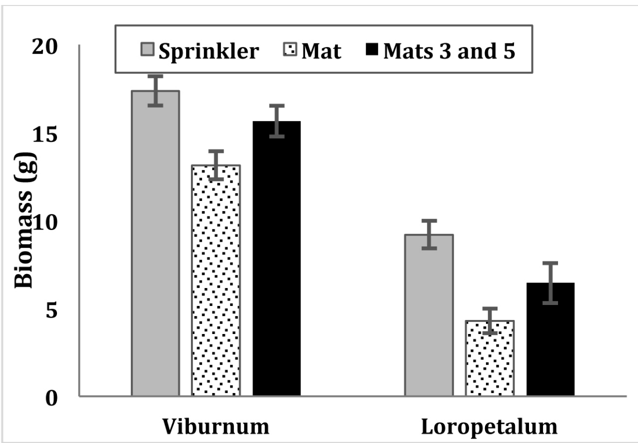

Fig. 3. Root biomass (±SE) of *Viburnum suspensum* and *Loropetalum chinense* grown under 2 irrigation systems

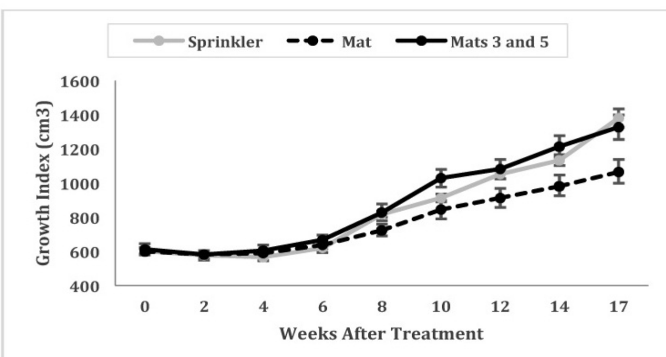

Fig. 4. Growth index (±SE) is given for *Viburnum suspensum* (scale smaller than Fig. 5).

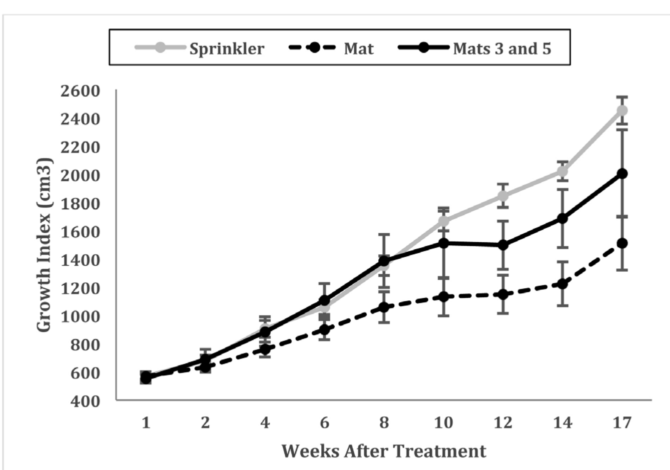

Fig. 5. Growth index is (± SE) given for *Loropetalum chinense* (scale larger than Fig. 4).

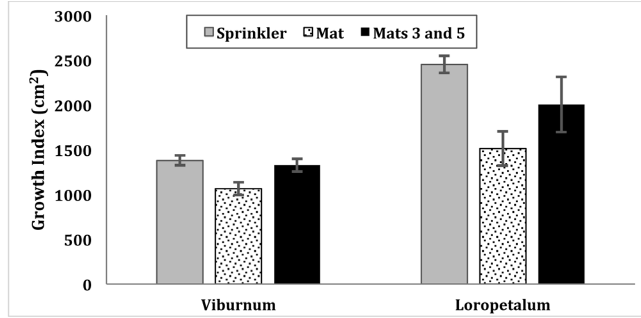

Fig. 6. Final growth index (± SE) for *Viburnum suspensum* and *Loropetalum chinense* at experiment termination.

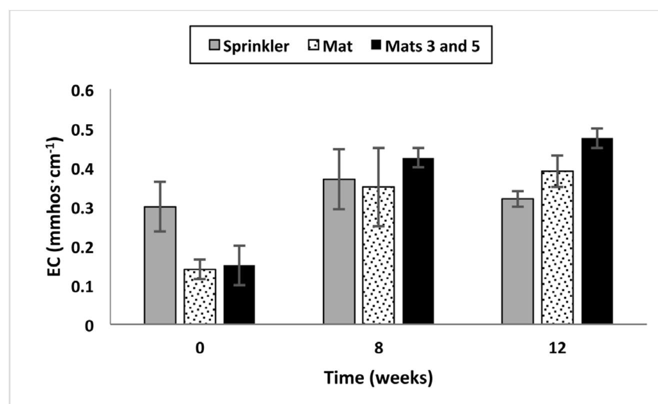

Fig. 7. Electrical conductivity (EC) data (± SE) for substrate used to grow *Viburnum suspensum* at 3 times during the experiment.

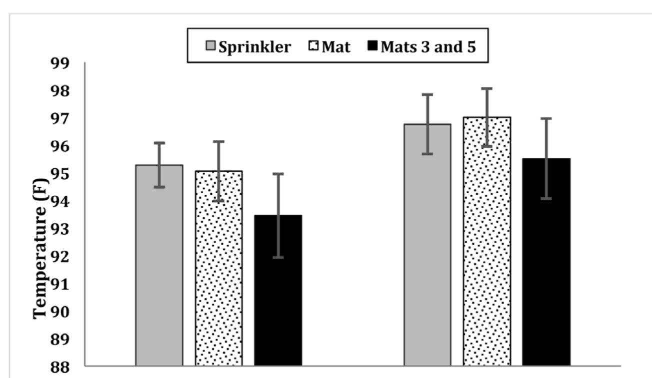

Fig. 8. Substrate temperature data (± SE) for all blocks was measured 22 July, 25 July, 28 July, and 19 Aug. 2016. Average air temperature at 2 feet was 91.22 F ± 1.33 SE [Florida Automated Weather Network (FAWN)].

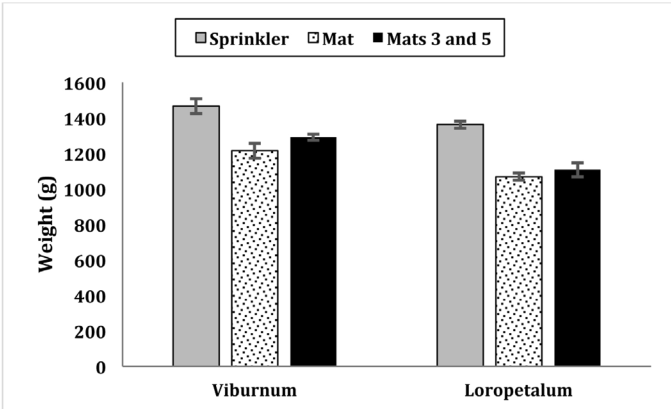

Fig. 9. Average plant weight (± SE) is given for *Viburnum suspensum* and *Loropetalum chinense* measured on 17 June and 22 June 2016.

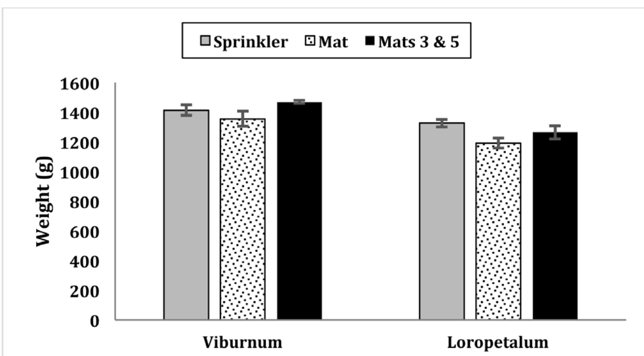

Fig. 10. Average plant weight (± SE) for *Viburnum suspensum* and *Loropetalum chinense* is given for 4 days of consecutive rain (2.3 in; 5.8 cm) preceding 11 Aug. 2016.

Irrigated Plant Weight. Irrigated plant weight was calculated by weighing one container of each species per block after an irrigation event. Plants were weighed 30 min after the first irrigation event of the day. This data shows that overall, the substrate for *Viburnum* retained more water than that of *Loropetalum* (Fig. 9). Both species showed highest irrigated weights for sprinkler irrigated plants, and the lowest for capillary mats, but neither of the capillary mat plant groups achieved the water status of the sprinkler plants. Data taken on 11 Aug. 2016, after multiple days of rain (Fig. 10), shows that irrigation provided by the capillary mats was not providing the optimal amount of water (Fig. 9) because similar weights were obtained for the *Viburnum* capillary mat treatments and the sprinkler irrigated weight measurements after rain (Fig. 10).

Discussion and Conclusions

An important outcome from this experiment is that substrate composition is a factor when using capillary mat technology. Although this technology has shown major water savings through efficiency of the system (Haydu et al., 2002; Mathers et al., 2005), it is less known that substrates can be problematic for the plant producer (Schuch et al., 2008). It is imperative to understand the basics of capillary mat use prior to assuming irrigation expectations and setting schedules.

Capillary mats were installed using the manufacturer's specifications for flow and pressure but due to a very hot and dry June, plants were showing stress, hence irrigation frequency was adjusted. During the study, the variable frequency drive (VFD) pump was damaged from an electrical storm and a diesel pump operated at odd hours, changing irrigation frequency and run times. This occurred once more during the experimental period. Due to an irregular rain schedule, irrigation run times and frequency changed often (Table 1). Once the substrate water column was broken between the bottom of the container and the capillary mat, it had to be replaced before water could be pulled through capillary action into the substrate. Overhead irrigation of the capillary mats with hose and water breaker was performed when needed to re-establish mat contact with substrate. Overall water use for each treatment was 13,446 gal for the sprinkler irrigation blocks and 7,751 gal for the capillary mat blocks.

The *Loropetalum* on mats 3 and 5 did not have the amount of shoot and root biomass relative to the plants grown with sprinkler irrigation. The differences in shoot and root biomass for *Viburnum* grown with sprinkler irrigation or with mats 3 and 5 were 5.8 g and 1.7 g, respectively. Differences in shoot and root biomass for *Loropetalum* grown with sprinkler irrigation or with mats 3 and 5 were 10.0 g and 2.8 g, respectively. The larger differences for *Loropetalum* were assumed to be due to the substrate that was too porous to create the continuous link in capillarity needed to provide the plant with available water (Piatti et al., 2011). The substrate for *Loropetalum* is made specifically porous, as this species is susceptible to root rot (a common threat in nursery production). It can be reasoned that this species is not suitable for capillary mat technology due to these substrate limitations and perhaps another method, such as micro-irrigation, would work better. A high EC value can also limit plant growth but did not seem to be an issue for plants in this study (Fig. 7).

The irrigated plant weight data showed that sprinklers applied an optimal amount of water for the substrate. Plants irrigated by capillary mats weighed less than that of sprinkler irrigated plants for both species, regardless of substrate. The substrate for *Viburnum* seemed to be effective in maintaining capillarity and providing plant water throughout the day. However, plants on mats 1, 2, and 4 were stunted at the time their vegetative stage was to be most active. It would be advisable to test this species again with the capillary mats using a daily irrigation frequency of 4 times or more with the substrate that was used in this study. This plant is also effective in shading the substrate surface so that evaporation could be reduced due to the moderation in substrate temperatures (Fig. 8).

Additionally, elevated temperatures for *Loropetalum* substrates could be due to sparse foliage because these plants have elongated branches, unlike *Viburnum*. Radiant energy reached the substrate surface relatively unabated and temperatures were not buffered with moisture due to the porous substrate. The substrate used for *Viburnum* contained more peat and bark which absorbed moisture and buffered temperature.

In our experiment, we were not able to determine if *Viburnum* or *Loropetalum* exhibited growth suppression as reported by the producers because sprinkler irrigated plants were larger than plants irrigated with mats. The average size of *Viburnum* and *Loropetalum* plants irrigated with sprinklers was 30% and 62% larger, respectively, than plants irrigated with capillary mats. A possible explanation for the plant size difference for *Loropetalum* is inadequate moisture capillarity from the mat due to a porous substrate and inadequate plant water availability. Further investigation is needed to determine the cause of growth suppression when growing woody plants with sprinkler irrigation.

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