Comparing Conventional to On-Demand Gravimetric Based Irrigation Scheduling for Containerized Nursery Crops

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Significance to Industry: On-demand irrigation scheduling increased water application efficiency while growing an equivalent size plant when compared to conventional irrigation scheduling applied cyclically at 1200, 1500 and 1800 HR with a 0.2 leaching fraction. The on-demand system successfully used weight to maintain adequate substrate moisture content throughout the day, efficiently and frequently replacing water lost from evapotranspiration. A gravimetric means of irrigation scheduling holds promise to accurately provide water to containerized crops.

Nature of Work: Water management is at the core of container nursery production (9). Currently, leaching fraction (LF = volume leached ÷ volume applied) is the recommended method to assure adequate irrigation volume is applied to hydrate the substrate and prevent salt build-up. The current LF recommendation is ≤ 0.20 or ≥ 80% water application efficiency {WAE = [(volume applied - volume leached) ÷ volume applied] x 100} (11). Ruter (7) and others have found that cyclic application of irrigation increased WUE, improved substrate rewetting, and decreased leachate volume. Research has demonstrated irrigation applied in the afternoon reduces substrate temperature and plant water stress presumably by maintaining adequate available water (AW) which leads to increased growth (2, 7). Irrigation applied at 1200, 1500, and 1800 HR resulted in 63% greater total plant dry weight compared to plants irrigated at 0300, 0500, and 0700 HR (8). Therefore, the ideal time to irrigate is before water becomes limiting and the plant begins to experience mild water stress, reducing growth. Both irrigation volume and time of application should be considered when developing a water management plan.

Lysimeters have long been used in field crop irrigation to determine rates of water loss via evapotransporation (5). Gravimetric techniques have been used by researchers to determine water content in a container and to detect points at which plant water stress may occur (3, 6). Beeson (1) successfully used a suspension lysimeter in a nursery setting to measure substrate AW. However, little work has been done using this system in a container nursery to *control* irrigation scheduling. Irrigation scheduling includes determining both irrigation volume and timing of water application.

An irrigation control system has been devised for containerized nursery crops which uses the gravitational method of irrigation via a load cell/computer interface (load cell). The load cell, equivalent to a scale, acts as a transducer, converting force [weight] into a measurable electrical output which can be monitored continuously, providing real-time feedback from crops within a grower's nursery. With this system, the irrigation scheduling can be automated based on weight (1 g = 1 mL); a direct measure of water added via irrigation and water lost via evapotranspiration. Therefore, the system can be used to apply precise amounts of water when substrate water content is depleted avoiding crop stress and subsequent reduction in crop growth. In addition, the precision of returning only the water lost results in little water leaching from the container and increases crop water use efficiency. This directly decreases agrochemical (nutrient and pesticide) losses from container crops decreasing environmental impact and increasing nutrient-use efficiency/pesticide efficacy.

The objective of this experiment was to compare two methods of irrigation scheduling: conventional, in which the crop was cyclically irrigated at 1200, 1500, and 1800 HR to maintain a 0.2 LF, and on-demand, in which plants were irrigated, regardless of time, to remain between maximum (98% to 94%; by weight) and minimum (94% to 90%) soilless substrate container capacity thresholds. Thresholds were adjusted within given ranges to maintain a 0.15 LF. Therefore, the upper and lower threshold were decreased, maintaining 4% range, when ≈ 15% water applied via irrigation was being leached per day. The experiment was conducted on a gravel pad at the North Carolina State University Horticulture Field Lab, Raleigh, NC (lat. 35°47'37", long. -78°41'59") in a randomized complete block design with four blocks, seven containers per replication, and 14 containers per block. Plants were irrigated via pressure compensated spray stakes [Acu-Spray Stick; Wade Mfg. Co., Fresno, CA (200 mL min^{-1})]. Simulated container nursery plots were used to collect and quantify water applied and effluent which were used to determine and adjust leaching fraction daily. In addition, this data was used to calculate time averaged application rates [TAAR = water applied (mL) ÷ application duration time (min)].

Uniform rooted stem cuttings of *Cotoneaster dammeri* C.K. Schneid. 'Skogholm' were potted on 19 April 2007 into 14 L (#5) containers (C-2000, Nursery Supplies Inc., Chambersburg, PA) using an 8:1 pine bark:sand (by vol.) substrate. Containers were top-dressed with 71.2 g (0.16 lb) 16N-2.6P-9.0K (16-6-11 six month controlled-release fertilizer, Harrell's Inc., Lakeland, FL). Electrical conductivity and pH of the substrate solution were measured every 3 weeks. The substrate solution was collected via the pour-through nutrient extraction procedure (10).

One plant per replication (4 per treatment) was positioned on a load cell (total of 8). Real time monitoring of container weight (plant + substrate + container) was performed using a low profile, two-beam, single aluminum point load cell with a 30 kg capacity (± 0.02% error) (Model RL 1042, Tedea-Huntleigh Inc, Covina, CA). The load cell was mounted between two 15 cm x 15 cm (5.9 in), 0.06 cm (0.2 in) thick square aluminum plates. One aluminum spacer 0.6 cm (0.25 in) inch thick was attached between the top and bottom plates and the load cell to keep debris out. The top surface area was expanded with a 23 x 23 cm (9.1 in) square, 3 mm (0.12 in) thick aluminum plate. The load cells were connected to a CR3000 Micrologger® via an AM32 multiplexer (Campbell Scientific, Logan, UT). Weight was recorded every 15 minutes, and every 10 seconds when the water was running. Container capacity was determined by placing the container from the load cell into a 20 L (5 gal) water-filled bucket. Containers were removed after ≈ 2 hr when the substrate was fully saturated (as evidenced by a glossy sheen of water at the substrate surface), placed on the load cells, and allowed to drain until 0000 HR (12 AM) the following morning at which time weight was automatically recorded for each individual replication.

The experiment was initiated on 7 June 2007. Plants were harvested 65 days after experiment initiation. Tops (aerial tissue) were removed from two plants per replication (total of 8 containers per treatment). Plant roots were placed over a screen and washed with a high pressure water stream to remove substrate. Tops and roots were dried at 65C (150F) for 5 days and weighed. All data were subjected to analysis of variance and means were separated with Fisher's Protected Least Significant Difference, $P = 0.05$ when appropriate.

Results and Discussion: On-demand irrigation was able to grow an equivalent plant (mean = 104.5g ± 6.5) when compared to conventional irrigation scheduling method. Root:top ratio (mean = 0.12 ± 0.004) was unaffected by irrigation treatment. Leaching fraction was reduced from 0.14 to 0.06 when irrigated on-demand as opposed to conventionally. The on-demand system initially (June) had only 2.0 cycles occurring over a 2.0 hr time duration and by August required 7.5 cycles occurring over 13.5 hrs; whereas cycle number (3 cycles) and duration (min) were fixed by the conventional irrigation schedule (Table 1). This dynamic irrigation system resulted in maintaining a lower TAAR throughout the study than the conventional method of irrigation scheduling. Lamack and Niemiera (4) reported a reduction in TAAR, increased water application efficiency and decreased leaching. The increased leaching under the conventional irrigation schedule resulted in a 28% decrease in electrical conductivity after 64 days. This reduction in nutrient leaching may be the reason for the 36% (0.5 $mg \cdot g^{-1}$ P) phosphorus concentration increase in tops of Skogholm cotoneaster when irrigated on-demand versus the conventional method (Data not shown).

On-demand irrigation scheduling can effectively apply water via micro-irrigation to containerized crops without decreasing crop growth. On-demand irrigation scheduling decreased water and nutrient leaching when compared to conventional irrigation scheduling. More research needs to be conducted to determine dynamics of container capacity in overhead and micro-irrigated systems and its effect on gravimetric based irrigation control. In addition, feasibility of on-demand irrigation scheduling application in commercial nurseries needs to be assessed.

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Table 1. Cycle duration and number, water use and time averaged application rate for Skogholm cotoneaster grown in 8:1 pine bark:sand (by vol.) under two irrigation regimes.

Irrigation Treatments	Cycle duration[z] (hr)	Number of cycles	Water applied per day (L)	TAAR[y] (mL min^{-1})
		June		
Conventional	6.0[x]	3.0[x]	0.9 a[w]	2.7 a
On-demand	4.9	2.0	0.5 b	1.6 b
		July		
Conventional	6.0[x]	3.0[x]	1.5 a	4.1 a
On-demand	10.2	3.5	1.1 b	2.2 b
		August		
Conventional	6.0[x]	3.0[x]	2.3	5.4 a
On-demand	13.5	7.5	2.0	3.3 b

[z]Duration of time from beginning of first daily cycle to end of last daily cycle
[y]Time averaged application rate (TAAR) = total water applied daily (mL) ÷ total run time (min)
[x]Dictated by treatment selection.
[w]Means within a column and variable not followed by the same letter are significantly different as determined by Fishers Protected LSD $P = 0.05$.