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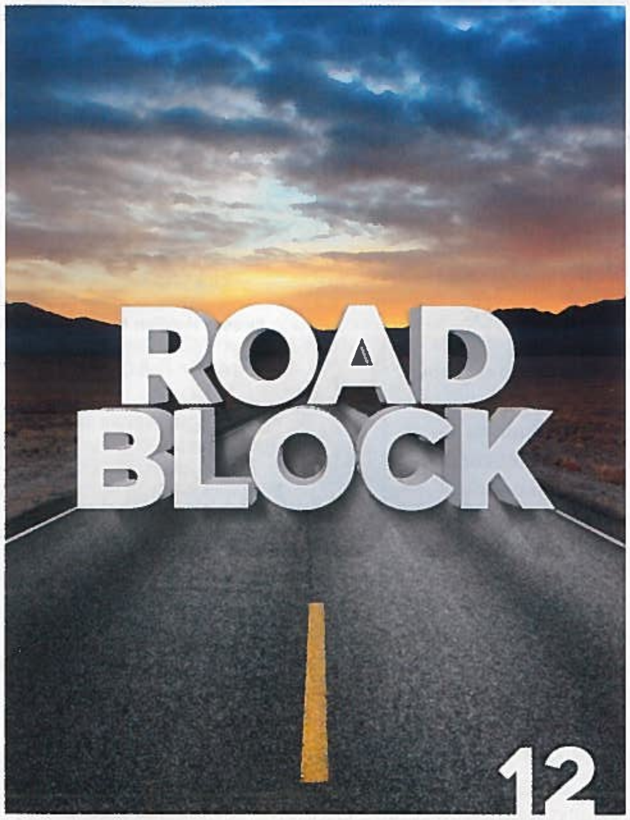

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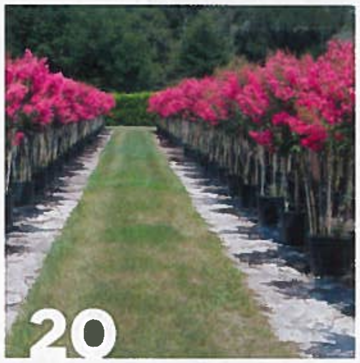
FEATURES



DEPARTMENTS

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BY JEFF MILLION AND TOM YEAGER

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Leaching fraction testing

The leaching fraction (LF) is defined as the amount of leachate divided by the amount of irrigation water applied to the container. If routinely measured, irrigation can be adjusted to maintain a target LF that will

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resupply substrate water loss by ET without excessive leaching. Based on results from several years of trials, we currently recommend a target LF of 10-15% for sprinkler-irrigated crops and 20-30% for micro-irrigated crops. These values may be lowered or raised as a nursery becomes experienced with LF testing and crop productivity.

The LF test requires two separate measurements — the amount of leachate or drainage and the amount of water applied to the container. The LF test procedure is different for sprinkler-irrigated crops than for micro-irrigated crops. For sprinkler-irrigated crops, the test container is placed in a tight-fitting pail leaving enough space below for collecting container leachate without the leachate being reabsorbed by the container substrate. The container and pail are weighed before and after irrigation with the difference in weight gain equal to the amount of water applied. The container is then removed from the pail and amount of leachate determined by weighing. The weight of leachate divided by the weight of water applied is the LF.

The LF test method for micro-irrigated crops is different than for sprinkler-irrigated crops. The test container is placed on an aluminum pizza pan while resting on two 1-foot pieces of 4-by-4 inch lumber. A one-half inch hole punched in the pizza pan near the rim allows collected leachate to drain into a lasagna pan for weighing. If needed, minimal slope can be created with shims to improve drainage from pizza pan. To measure the amount of water applied, an unused spray stake emitter is placed in a 4-gallon pail with a slot cut into the rim to prevent the tubing from being crimped when the lid is on the pail. Both leachate and water applied are collected over all irrigation cycles in a 24-hour period and LF calculated as described earlier. Unlike the sprinkler LF-test, the pizza pan setup remains in the field and the emitter used to determine the amount of water applied can be plugged and kept in the pail until the next LF test. This makes LF testing less labor-intensive in micro-irrigated areas than in sprinkler zones.

Routine LF tests are conducted approximately once every 2-4 weeks with more frequent testing during periods of rapid growth and/or seasonal changes in the weather. For example, LF testing frequency ramps up in spring and summer and declines in late fall and winter in Florida. To "stay ahead" during these periods, it is often recommended to increase irrigation rates 5-10% each week so that LF testing will not result in zero leachate. To account for variability (plant and irrigation delivery) in the field, it is recommended to test three to four plants per irrigated zone. To be conservative, we often choose larger plants and plants along the borders of the production area that may have higher water requirements. Also, plants along the border are easier to access.

The new irrigation system

The irrigation system has two components that can function independently but work best in tandem. One component is a web-based irrigation scheduling program called CIRRIG (Container IRRIGation) that outputs real-time irrigation run times based on weather and grower inputs for each irrigation zone. The second component is an automated irrigation control system that interfaces with CIRRIG to implement the output run times by automatically controlling solenoid valves in the field. Each will be briefly described before we get into how the new system was evaluated at the nursery.

CIRRIG (www.bmptoolbox.org/cirrig) is a web-based, irrigation scheduling program for container nurseries in the Southeast United States – its use in other regions of the U.S. has not been tested. One function of CIRRIG is to collect and manage weather data from one or more weather stations on site. At Hibernia, two weather stations were installed, one at each pump house. Both stations were the cabled (not wireless) version of the Vantage Pro 2 Plus (Davis Instruments), which has a solar radiation sensor and a day-time aspirated fan for accurate temperature readings. An optional data-logger (Weatherlink USB Data Logger; Davis Instruments) with a USB output was programmed to record weather data at 5-minute intervals. The USB output of the data-logging console was connected to a microcomputer (Raspberry Pi 3 Model B; Adafruit Industries) that uploaded the data to the CIRRIG server located at the University of Florida, Gainesville. Besides being used for real-time irrigation calculations as described later, historical weather data are available to be viewed on an hourly or daily basis.

A second function of CIRRIG is to output real-time irrigation run times for each irrigation zone created by the user. Each valve in the nursery has a corresponding CIRRIG zone. The user inputs certain parameters that remain constant or are infrequently changed such as zone type (LF sprinkler or LF micro-irrigation), crop name/identification, container diameter, irrigation rate and uniformity, number of irrigation cycles per day and minimum run time. A second section of inputs is for inputting the results of LF tests conducted routinely. LF-related inputs include LF test date and time, LF test run time (minute), average measured LF (%), and target LF (%).

Here is how CIRRIG uses LF tests and real-time weather to make real-time irrigation decisions. When the results of a LF test are input for a given zone, CIRRIG calculates two reference values that remain constant until the next LF test is input. One reference value is an LF test irrigation run time, which is the LF test run time adjusted to give the target LF (see box at the bottom of this page). A second reference is an ET value (inch/

MAKING A SIGNIFICANT change in an irrigation practice is no easy task for a nursery. Visit https://vimeo.com/357888673 and hear from Hibernia Nursery about their experience with CIRRIG. We believe that directly working with the staff of Hibernia Nursery during this two-year project was crucial to properly evaluate how the CIRRIG technology worked. The visual nature of the LF test was also an important aspect of the technology that helped staff appreciate how LF testing could provide an alternative indication of irrigation efficiency.

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day) calculated using the past 24-hours of weather data. Essentially this provides a reference ET value associated with the first reference value. For each subsequent day, a new ET value is calculated just prior to irrigation and compared to the ET reference value. Based on this comparison, the reference irrigation run time is adjusted upwards or downwards accordingly to give the present day's irrigation amount. Rain can reduce the irrigation amount depending on the amount and time of the day the rain occurred relative to the last irrigation cycle.

The output from CIRRIG could be manually entered into a traditional irrigation controller, but this becomes very labor-intensive if done daily. An automated system is needed to take advantage of the real-time technology. For our system, we used programmable logic controllers (PLC) commonly used in non-agricultural industries. These brick-sized, specialized computers can receive digital information to control switches that can activate irrigation solenoid valves in the field. In our case, the PLC receives run time information from CIRRIG and sets timer values for each valve controlled by the PLC. Each PLC (Direct Logic D0-06; Automation Direct) can control 16-64 valves depending on the optional output modules used. The PLC has a communications module that allows the PLC to be controlled and monitored remotely if the PLC is on a local network connected to the internet. At Hibernia, we established a local network at each pump station using a router (MBR95; Cradlepoint) and USB cellular modem with a static IP address for the internet connection. We found a "1-bar" cellular signal was sufficient for running the irrigation system. The microcomputer described previously that served to upload weather data to CIRRIG also ran programs that allowed the user to manage and monitor one or more PLCs on the local network. A program was developed that allowed the user to create zone groups for each PLC and add one or more zones to each group. The program allows the user to select a maximum number of valves to run at one time. Because each zone in a group will have a different run time and run times will change from cycle to cycle, a queue is established so that as one zone turns off a new zone in the queue is automatically turned on. Certain features that you find on a traditional time clock are also available such as

Adjusted run time (minutes) = (100% - LF_{test}) ÷ (100% - LF_{target}) × run time (minutes)

Example: LF_{test} = 40%, LF_{target} = 15%, and LF test run time = 30 minutes

Adjusted run time = (60 ÷ 85) × 30 = 21 minutes

Table 1. Plant growth and irrigation water applied during seven side-by-side trials comparing CIRRIG with Hibernia Nursery's traditional irrigation practice.

Trial[z]	Plant species	Start date	Days[y]	Growth[x] (inch)			Water use[w] (gal/ac/day)		
				HIB	CIRR	CIRR/HIB	HIB	CIRR	CIRR/HIB
S1	*Ilex cornuta* 'Burfordii Nana'	3/1/2016	106	10.4	9.9	0.95	5870	5640	0.96
S2	*Loropetalum chinense* 'Plum'	7/5/2016	139	10.6	10.1	0.95	5900	5860	0.99
S3	*Ilex cornuta* 'Burfordii Nana'	8/10/2017	370	13.5	16.6	1.23	4850	6020	1.24
M1	*Ilex* x 'Nellie R. Stevens'	3/1/2016	141	23.0	25.2	1.10	4720	4150	0.88
M2	*Cupressus x leylandii*	10/4/2016	148	27.6	27.3	0.99	2980	2890	0.97
M3	*Ilex* x 'Nellie R. Stevens'	3/27/2017	322	42.1	40.9	0.97	6716	4690	0.70
M4	*Lagerstroemia* spp. 'Natchez'	4/13/2017	130	10.3	9.6	0.93	7800	5410	0.69

[z] Trial designation: S=sprinkler-irrigated trade 3-gallon containers, M=micro-irrigated trade 15-gallon containers
[y] Days until trial was ended when plants began being sold out of one or both test areas
[x] Change in plant height + change in plant width or stem caliper for *Lagerstroemia* (average of 20 plants per irrigation practice)
[w] Measured with flowmeters

a manual on/off with or without a timer and a system water check that will run each valve for a specific time to allow staff to check irrigation systems in a methodical manner. The program outputs run times (RT) in an HTML table for checking locally or remotely and output is also uploaded to CIRRIG where the irrigation history and accompanying input data are stored for historical record-keeping.

Evaluating Hibernia's new irrigation system

Seven side-by-side trials were conducted comparing automated CIRRIG technology with the nursery's traditional irrigation practice **(Table 1)**. The same crop was grown in each of the two irrigation zones being compared in the side-by-side trials. Overhead irrigation was applied with Wobbler (Senninger) sprinklers that were on 5-foot risers with 25 feet between sprinklers down the production bed in an offset pattern. Micro-irrigation was applied with spray stake emitters (Spot-Spitter Black High Flow or Green Medium Flow; Primerus Products, LLC). The container substrate was either a 60% pine bark: 40% compost mix (Trials S1, S2, M1, M2) or a 70% pine bark: 30% sedge peat mix (Trials S3, M3, M4) both with incorporated controlled-release fertilizer. Additional fertilizer was top-dress applied as needed. All production activities were conducted by Hibernia staff.

Hibernia's traditional irrigation practice was intensive. Twice each week staff took cores of substrate from containers in each zone and rated soil moisture on a numerical scale. As a group, staff decided on necessary changes to irrigation run times which were then manually entered into their traditional irrigation controller (Sterling 8 Station; Buckner Superior). We were surprised to find that for sprinkler irrigation, times were adjusted to the nearest 5 minutes several times per week, if not daily. Micro-irrigated areas were irrigated 2-3 times per day and sprinkler-irrigated areas once a day predawn. CIRRIG zones were managed by Hibernia staff. Staff conducted LF tests and entered results into CIRRIG. Start times for CIRRIG-controlled zones were the same as for Hibernia's traditional practice.

For evaluating each trial, we measured irrigation water use with flowmeters and monitored plant growth by measuring the height and width of 20 plants at the start and every 2-3 weeks throughout each trial. For *Lagerstroemia* (crape myrtle), we measured stem caliper 6 inches above substrate (five stems per plant). We considered growth to be the change in height and width from the beginning to the end of each trial. Each trial was ended when plants were being sold out of one or both of the test zones.

Trial results

Hibernia staff quickly learned how to conduct LF tests and became familiar with some of the glitches that can occur during testing. For example, it was important to have an easy-to-use weighing method to eliminate taring mistakes that can give erroneous results. Another example was to plan ahead and conduct

Table 2. List of hardware required to implement automatic irrigation via CIRRIG.

Component	Item/Model	Website	Cost ($)
Weather station	Cabled Vantage Pro2 Plus (#6162C)	www.davisnet.com	1040
	WeatherLink® USB (6510USB)	"	165
	Fan Aspirated Radiation Shield Kit (#7747)	"	135
	Subtotal		1340
Internet/network	MBR1200b	www.cradlepoint.com	250
	USB620L 4G LTE Cellular Modem		160
	Subtotal		410
PLC	D0-06DA PLC	www.automationdirect.com	300
	H0-ECOM100 Communications module		220
	D0-06LCD Display		80
	24VAC Transformer 90-T40F3		30
	Subtotal		630
Microprocessor	Raspberry Pi 3-Model B-ARMv8 with 1G RAM	www.adafruit.com	50
	Raspberry Pi 3 Case	"	10
	16GB Ultra Micro SDHC UHS-I/Class 10 Card	www.sandisk.com	10
	Subtotal		70
Misc	Ethernet/USB cables		20
	Battery Backup (BE550G)		60
	Subtotal		80
		Weather station	1340
		Internet	410
		PLC	630
		Microprocessor	70
		Misc	80
		Total	**2530**

LF tests on days unaffected by cloudy or rainy weather. This can be frustrating in summer months when frequent afternoon rains can spoil a prepared test. A third example was to increase irrigation rates 5-10% prior to running a test to ensure that leachate will be collected. In general, this is especially true during the spring months when plants are rapidly growing and ET rates increasing with longer days and warmer temperatures.

CIRRIG had less effect on water use and plant growth in sprinkler-irrigated trials than with micro-irrigated trials (**Table 1**). In two of the three trials (S1, S2), plant growth and water use were similar for the two irrigation practices. In the third trial, CIRRIG applied 24% more water than Hibernia. The finding that CIRRIG increased plant growth 23% and LF tests during the crop averaged 15% and never exceeded 27% throughout the 370-day trial indicated that Hibernia was likely under-watering this crop.

CIRRIG reduced irrigation water applied by an average of 19% in the four micro-irrigated trials. For the holly (M1) and Leyland cypress (M2) crops, water use was reduced by only 12% and 3%, respectively, with similar growth and plant quality. Greater irrigation water savings (30%) were observed with the second holly (M3) and crape myrtle (M4) crops. Plant growth in these two trials was reduced 3% and 7%, respectively, with CIRRIG even though plants were marketable-sized and of similar quality as plants produced with Hibernia's traditional irrigation practice.

Cost/savings – are the economics there to make a change?

Potential water savings from using CIRRIG at Hibernia Nursery can be estimated from the trials. If it is assumed that CIRRIG was not over-watering the S3 trial, then CIRRIG had little effect on irrigation water use in sprinkler-irrigated crops. The average reduction in water use in the four micro-irrigated trials was 1,270 gal/acre/day or 464,000 gal/ac/year. Hibernia's pumping cost rate based on electric bills and flowmeter readings at each of their two pumps was $0.20 per 1,000 gallons. At this cost rate, the potential pumping cost savings for 35 acres of micro-irrigated production would be $3250/year which was equivalent to $0.03 per container at a plant density of 3,000 containers per acre. Clearly there was little monetary incentive to conserve water with CIRRIG when each plant in a trade 15-gallon container was selling for $45-$65.

For Hibernia Nursery, potential pumping cost savings using CIRRIG were not as important as the potential labor cost savings of substituting a LF testing program for the traditional substrate moisture sampling practice. Hibernia staff estimated that implementing an automated CIRRIG system including an LF testing program in their nursery will save them in labor alone approximately $35,000-$40,000 per year, which was equivalent of reducing their water staff from four to three with one staff assuming other duties at their labor-challenged nursery. Hibernia noted that the new irrigation technology also improved the quality and skill level of the employee's managing irrigation. Towards the end of our cooperative project with Hibernia, the nursery installed PLCs to control all 156 valves for their 70 acres of production. The hardware cost for installing the system at two pump locations was $8,000, which included two weather stations, two router/cell modems, two microprocessors, six PLCs and miscellaneous cable and electrical accessories **(Table 2)**. The cost associated with LF testing materials is approximately $15 per setup in micro-irrigated production. For 80 micro-irrigated zones at Hibernia and four LF setups per zone, this fixed cost would be $4,800. As this is a new technology that to date has been supported with research funding, we are unsure how the CIRRIG system and service will be monetarily supported in the future. Our best estimate is that a contract for service would be entered into between the nursery and the University that would initially include installation of hardware (provided by nursery), training and service at $10,000 per year and decrease over time. NM

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