Tipping Bucket Rain Gauge for Measuring Leaching Fraction in Container Nurseries
Task 4: Initial Nursery Evaluation

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Abstract

It was proposed that instead of catching container drainage or leachate in a pan and measuring manually the amount of leachate, a mini tipping electronic rain gauge (tipper) will be placed under a container to measure the drainage. That drainage information or amount will be transferred to a microprocessor that has Bluetooth capability and an app will be developed to monitor the amount of drainage or leaching on a mobile device. Thus, personnel growing plants can quickly determine the amount of leaching as they move about the field. The information on the mobile device can then be used to establish the amount of time the irrigation system should be operated for the irrigation zone or plants where the information is collected. This will automate the process of conducting leaching fractions, a Best Management Practice, and provide a history needed for the future. A future where NHF made an idea a reality for Growing Forward!

Background

Container nursery personnel can routinely monitor the *Leaching Fraction* (LF = amount of leachate ÷ amount of water applied to the container) and adjust irrigation rates to maintain low LF (e.g., 15-30%). By adjusting irrigation to maintain low LF target values, economic plant production can be achieved while conserving water and agrichemical resources. We have found, however, a major issue for adopting routine LF testing is the hesitancy of nursery managers to dedicate labor for this practice. Currently, LF testing requires staff to set up several leachate collections in each of the irrigation zones in the nursery and measure leachate and irrigation amounts by weighing with a portable scale. Our proposed project tests a new technology for measuring leachate volumes that would replace the more labor-intensive, weighing method. The new technology would include a small rain gauge and a data acquisition/communication system that could be left in the field. The tipping bucket rain gauge would be used for both micro-irrigated (≥ trade 7-gallon containers) and sprinkler-irrigated (< trade 7-gallon containers) nursery crops. By placing a tipping rain gauge under the container, the amount of leachate or drainage could be automatically determined. For deployment in a commercial nursery, a data acquisition system using Bluetooth or similar wireless communication will be needed for nursery staff to gather the LF data. Fortunately, microprocessor technology has become very cost-effective so that a battery-powered system could be assembled and tested for this important task.

Methods

An Arduino or data acquisition/communication device connected to a small tipping gauge was used to measure container leachate. The device used Bluetooth communication to transfer daily tip counts to an application (WaterTips) on a mobile device. In the first report we described the assemblage of components and their functions. In the second report we described the development of the WaterTips' app. In the third report, we described the initial testing of the system at the University of Florida (UF) and noted the changes needed to make WaterTips reliable and easier to navigate. We also described the use of a small solar panel to keep the Arduino powered indefinitely.

For this fourth task, we engaged two nurseries to evaluate the WaterTips' technology. For Hibernia, located near Webster in Sumter County Florida, one Arduino was used to monitor leachate from four trade #7-gallon containers of Burford holly (*Ilex cornuta* 'Burfordii Nana') in a spray-stake irrigated irrigation zone. A second Arduino was used to monitor leachate from four trade #3-gallon containers of Loropetalum (*Loropetalum chinense* 'Ruby') in a sprinkler-irrigated zone. Photos of these two zones at Hibernia nursery are given in Figs. 1-2 and additional details of the setup are given in Figs. 3-5.

The other nursery engaged to evaluate the technology was 1-D, located near Brandon in Hillsborough County Florida. Unlike Hibernia, there was no sprinkler-irrigated plant production, so both Arduinos were set up in a spray-stake-irrigated zone. One Arduino was set up to monitor leachate from four trade #15-gallon containers of 'Little Gem' Magnolia (*Magnolia grandiflora*) trees and a second Arduino was set up to monitor leachate from four trade #15-gallon containers of Japanese Blueberry (*Elaeocarpus decipiens*) trees. Photos of these two locations at 1-D nursery are given in Fig. 6.

Tipper systems or gauges were initially set up in February 2022 at each nursery. UF personnel worked with nursery personnel to set up the leachate collectors, tippers, and Arduinos. Each nursery had an Android phone with the WaterTips' app downloaded. Nursery personnel were shown how to set up WaterTips for each location within the nursery. This included entering zone names, descriptions, irrigation rates, target leaching fraction values, and container diameter (for sprinkler zone only). UF personnel also demonstrated how to test the tippers by manually tipping the gauge and refreshing the tip count to ensure the manual tips were being registered. Personnel were instructed to contact UF if one or more tippers were not working.

Follow-up trips by UF personnel were made to get feedback on using WaterTips. In May, partly due to erratic use and monitoring of the systems by nursery personnel, we created a daily irrigation-leachate log form for each nursery to fill out for a 2-3-week period. The daily form was designed to make sure each nursery would focus on using WaterTips and provide us with some evidence that it was being used. The results of our experiences with each nursery are given in the results section along with some considerations for improving WaterTips.

Fig. 1. Leachate from Dwarf Burford holly grown in trade #7-gallon containers with spray-stake irrigation was monitored at Hibernia nursery in central Florida. The Arduino housed in the plastic tote with white lid (lower center) was connected to four tippers to monitor container leachate using WaterTips' app. The site was initially set up in February 2022 (above) when Burford hollies were recently planted. The bottom photo was taken in May 2022 when Hibernia nursery staff recorded leachate data.

Fig. 2. Loropetalum grown in trade #3-gallon containers with sprinkler irrigation at Hibernia nursery in central Florida. The Arduino housed in the plastic tote was connected to four tippers to monitor container leachate. The above photo was taken in February 2022 when tippers were initially set up. These spaced plants were sold in March and replaced with a new Loropetalum planting that was pot-to-pot (bottom photo).

Fig. 3. Double pans were used to collect leachate and direct it to a tipping bucket rain gauge under hole in bottom pan. The bottom pan (top left) angled downward to the tipper has a handful of sand located above and around the drain hole to slow the leachate and filter out debris. The top pan (top right) is angled in the opposite direction using small wood pieces (placed on bottom pan) so that the leachate from top pan drains near the elevated edge of the bottom pan. Lower photo of Dwarf Burford holly at Hibernia nursery shows the double pans.

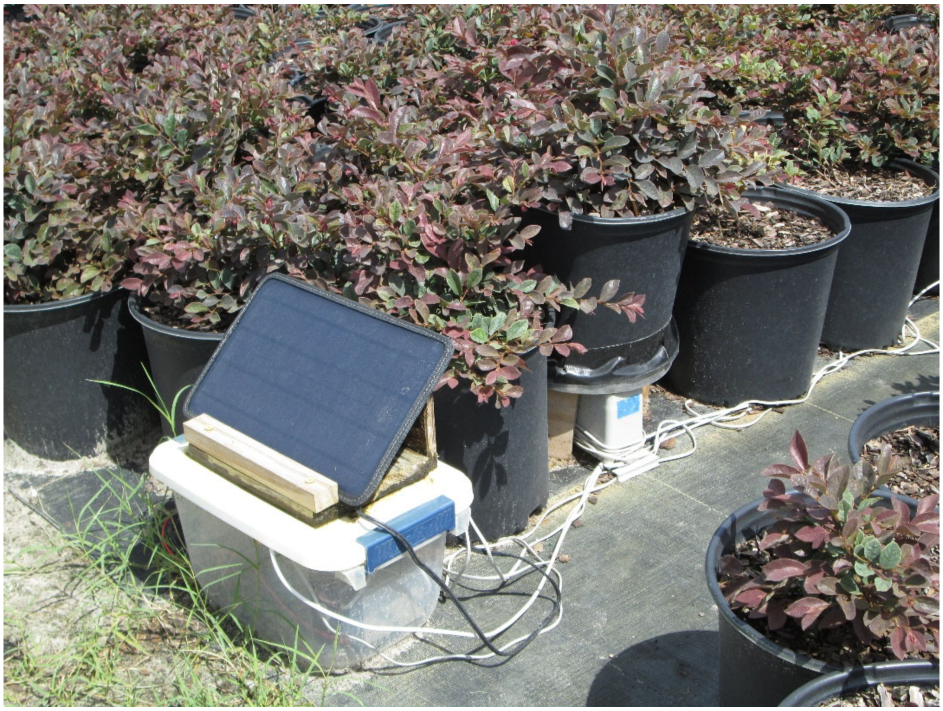

Fig. 4. Loropetalum in trade #3-gallon containers with sprinkler irrigation at Hibernia nursery during recording of WaterTips' data (June 2022).

Fig. 5. For sprinkler irrigated Loropetalum at Hibernia nursery, a "skirt" taped around the pan was used to keep irrigation from directly entering the collection pan (left). A wood stand was used so the tipper could be situated inside the stand below the pan, and thus not directly intercept sprinkler irrigation water.

Fig. 6. Leachate from Japanese Blueberry trees (below) and Magnolia trees (above) grown in trade #15-gallon containers with spray-stake irrigation was monitored at 1-D nursery in central Florida. The Arduino housed in the plastic tote and powered with battery and solar charger was connected to four tippers to monitor container leachate using WaterTips' app. The site was initially set up in February 2022.

Results

1-D Nursery

After setting up the tippers in February, UF revisited on March 6 to show 1-D manager how to use the app to acquire tip data and save LF data. During the first session reviewing the data and saving LF test, 1-D manager was impressed to know he was irrigating with an amount of water on March 6 near the target LF of 25%. However, we were able to show him that the results were variable, and that one tipper was not functioning. He wanted to know why on March 3 the values were higher, and we figured out that it was their irrigation check day when they apply and extra cycle of water. He then wanted to know why there was no leachate on March 2 and March 4. Turned out that the nursery was installing irrigation equipment in a new field and water was off. He had to ask employees to get this information as he assumed everything was being watered. We repaired the one tipper giving zeroes. The tipper was working fine but sand had washed into tipper and knocked it over.

We also looked at tipper data for the Blueberry trees. All tippers were functioning and the LF saved for March 6 was higher (36%) than the target of 25%. The plants were in the same irrigation zone as the Magnolia, so the irrigation schedule was not changed despite a WaterTips' recommendation to reduce irrigation 1 minute. This brings up an important point, many nurseries have minimum cycle run time of 1 minute so that if two cycles are scheduled, the minimum run time change would be 2 minutes. WaterTips calculates to the nearest 0.1 minute so the user would need to decide to round up or down when considering a run time change. This might warrant a settings option to round off to a given resolution e.g., 0.1 min, 1 min, 2 min, or 3 min. In 1-D nursery's case, a resolution of 3 minutes would have simplified the output as they were scheduling 3 cycles per day.

After reviewing everything, we left thinking that 1-D's manager saw the value in the tipper information and would continue to monitor leachate with WaterTips. Unfortunately, during subsequent visits it became very apparent that the manager was too busy to keep up with the monitoring (Fig. 7). Most of the tipper setups were not functioning so UF reset all containers in working order and left hoping better monitoring during next visit. The magnolia trees were sold and replaced with a new magnolia tree crop in April. Following this change, all tipper setups were again found to be not functioning. Blueberry plants were similarly in disarray and not functioning. A decision was made to remove the Blueberry setups and focus solely on the Magnolia trees. Again, we reset the Magnolia trees setups back to working order and asked the manager to monitor the LF daily for two weeks using the form mentioned in the methods section. Our hope was that this would encourage him to monitor the results daily and write down the results. During a final visit, the manager had not been using the app and was not recording WaterTips' data on the form provided. We saw no further value for the nursery to continue this evaluation. UF downloaded some of June's WaterTips' data to document that the app was working but the setups were not being maintained. Selected screenshots are provided in Fig. 8 and Fig. 9.

Fig. 7. Collector setups in Magnolia tree location at 1-D in June 2022 showing the lack of routine checking of the components.

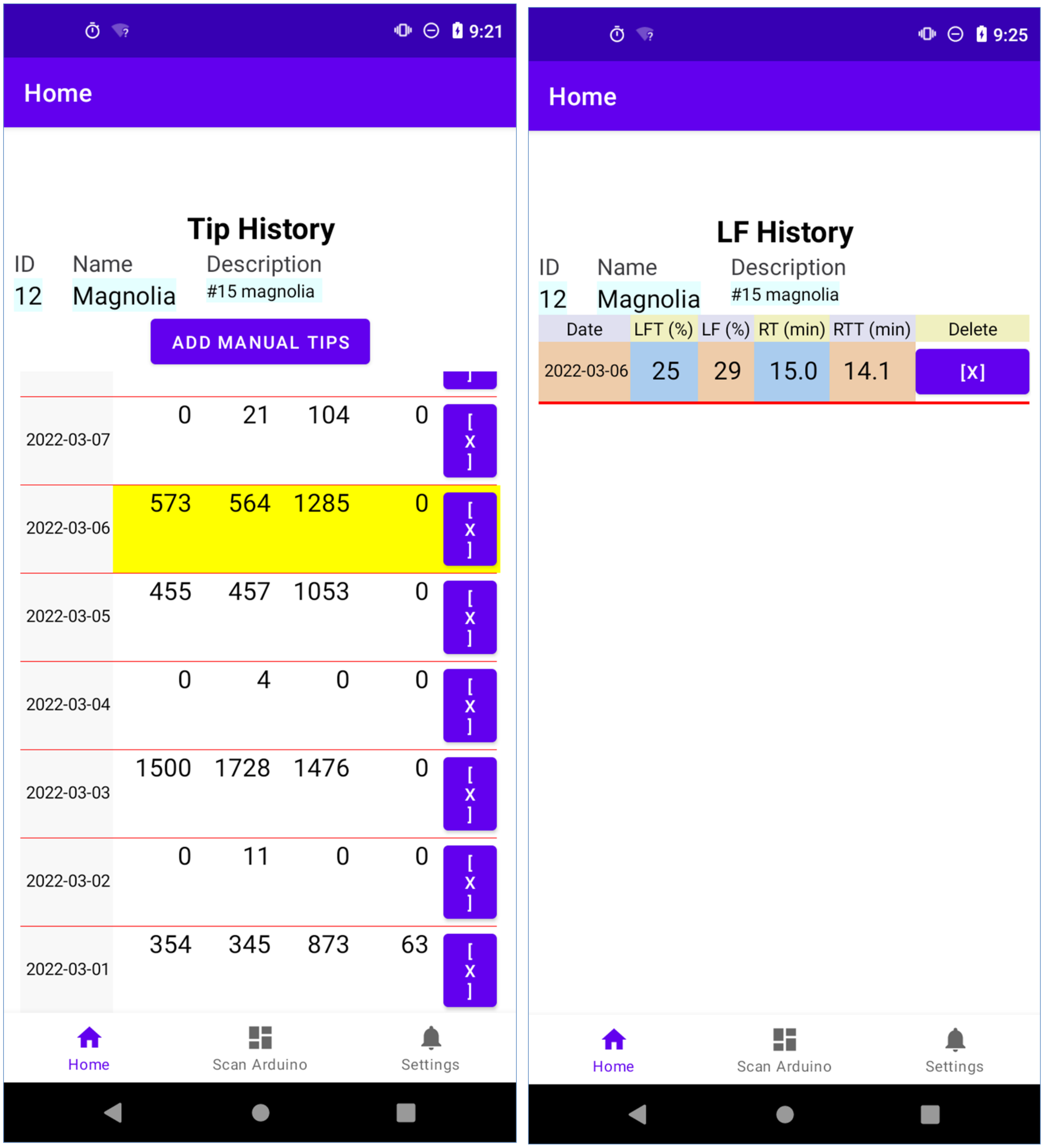

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Fig. 8. Screenshot of WaterTips' app during early evaluation at 1-D nursery in Brandon, FL. Yellow (left) highlights a saved LF test that was saved into WaterTips' LF History (right). The desired run time (RTT) for this day should be used as the irrigation run time going forward until another desired run time is selected.

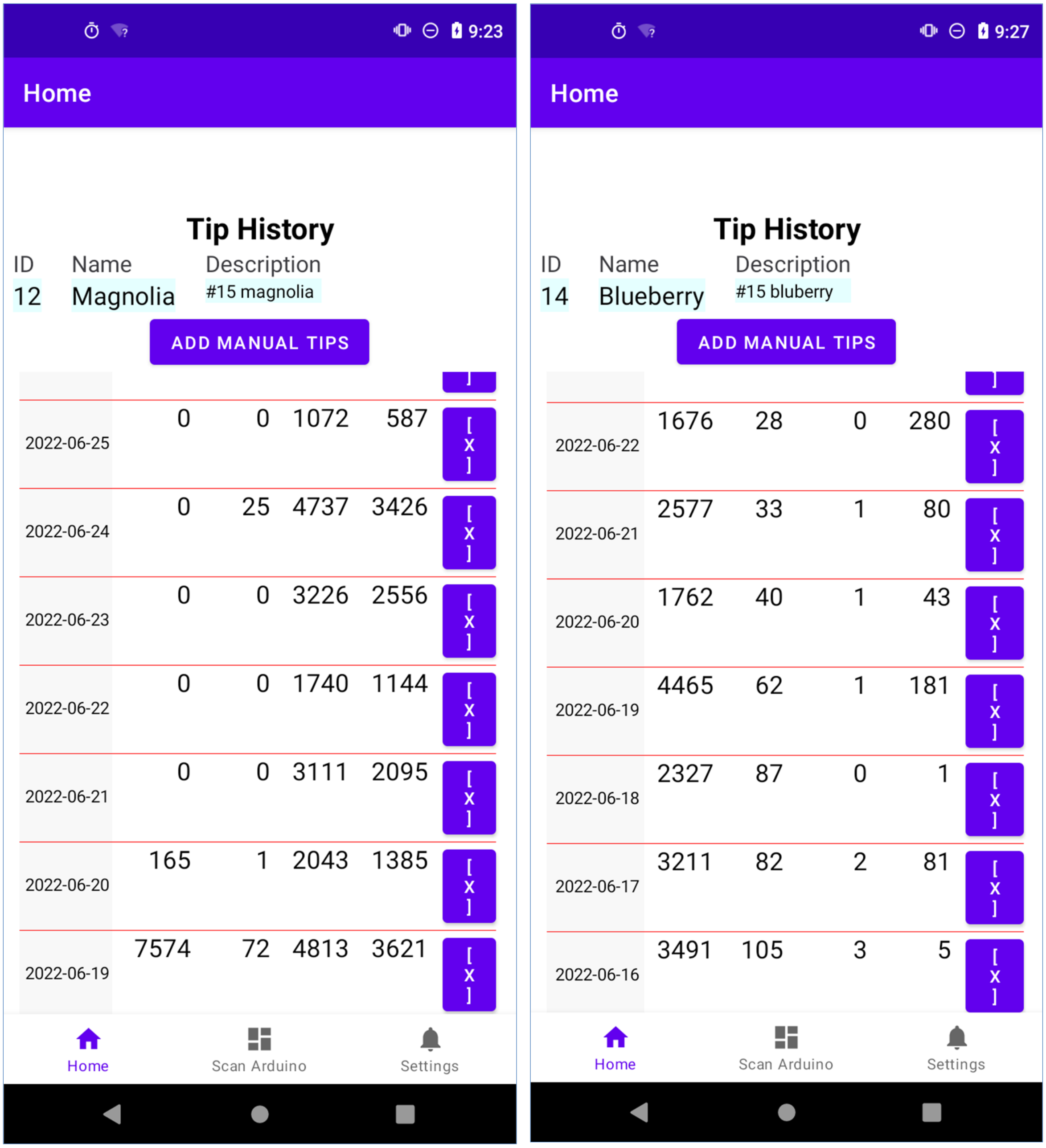

Fig. 9. WaterTips' screenshots during evaluation at 1-D nursery in Brandon, FL. At this point, tipper setups were not being maintained. The low tip values indicate the tippers or gauges that need maintenance.

Hibernia Nursery

Arduinos were installed at the nursery in February with the help of Hibernia staff. Two Arduinos, one in a sprinkler irrigated Loropetalum crop and one in a spray-stake-irrigated holly crop, were successfully added to WaterTips. Hibernia staff were shown how to manually tip the rain gauge tippers to ensure all were functioning. Target LF values and current irrigation run times were entered into WaterTips for each crop area. After allowing tip data collection for a week, UF returned to show Hibernia personnel how to view the tip data and save any LF values. A senior high school student working every afternoon at the nursery was assigned by the production manager the task of using WaterTips to acquire tip data and report to the water manager about the results. Connecting WaterTips to the Arduinos and downloading tip data was easy for the student. Entering the actual daily irrigation run time (needed to output a correct LF and adjusted run time) seemed to be a stumbling block for using the WaterTips' information for adjusting future irrigation run times. A second factor that was overlooked was accounting for weather conditions. The WaterTips' user only needed to use results for days that were "normal" e.g., no rain and normal evapotranspiration rates, if the WaterTips' output would be useful for adjusting irrigation. For example, if irrigation water was not applied due to rain, then the user would need to disregard that day's LF and RTT results. To be useful, the user needs to not only be in communication with the actual irrigation scheduler or water manager, but also consider weather when deciding if a particular day's LF results from WaterTips warrant an irrigation adjustment. The apparent disconnect between the WaterTips' user and the water manager seemed to be a stumbling block at Hibernia.

After several months of use, we gave Hibernia personnel the data log form to fill out hoping that would encourage that the daily WaterTips' output was being monitored routinely. Hibernia was good about filling this information out for a period in May and June (Tables 1 and 2).

For the spray stake irrigated holly crop (Table 1), the irrigation schedule changed from 2X/day (2x4 = 8 min) to 3X/day (3x4=12 min) starting in June. LF output from WaterTips showed that LF values were generally higher (30-60%) than the target LF of 25%. WaterTips' output of run times to target an LF of 25% (RTT) were in the general range of 7-11 minutes. Because actual run times were 12 min/day, WaterTips' output indicated that the nursery could have potentially saved 1-2 minutes of run time per day for this crop. It should be noted that Hibernia staff correctly unchecked tipper #4 that was apparently not functioning for June dates.

For the sprinkler irrigated Loropetalum crop (Table 2), WaterTips' output showed very little leachate during early May prior to rain. Hibernia personnel initially thought the tippers were not working. After checking them by manually tipping each one, they found them to be working fine. Based on the low LF values, starting May 21 the water manager increased the run time from 45 to 60 min/day. This change brought subsequent LF values up so that lowest daily values were in the 10-25% range. Other days with higher LF values were likely due to afternoon rains that were frequent in June.

Table 1. WaterTips' output data recorded by Hibernia personnel for spray-stake irrigated trade #7-gallon Dwarf Burford holly.

Zone name	W14
Description	7 gal Burford Holly
Irr type	Micro
Irr rate	10 GPH
Desired LF	25%

Irrig. date	Irrig. day	Tip_1		Tip_2		Tip_3		Tip_4		Avg. Tips	LF (%)	RT (min)	RTT (min)	Nursery comment	UF comment
		Tips	✓	Tips	✓	Tips	✓	Tips	✓						
17-May	Tue	1246		854		1052		834		1009	33	8	7.0		
18-May	Wed	2335		1564		1872		894		1666	56	8	4.6		
19-May	Thu	4026		3914		3568		2047		3388	114	8			rain or pm irrig?
20-May	Fri	4585		6503		4917		1764		4442	149	8		rain	
2-Jun	Thu	2511		1886		1969		0	x	2122	47	12	8.3		did not communicate or fix tipper prob
3-Jun	Fri	2482		1851		1956		1	x	2096	47	12	8.4		
4-Jun	Sat	3332		2605		2318		22	x	2751	61	12	6.1		
5-Jun	Sun	2787		2136		2564		14	x	2495	56	12	7.0		
6-Jun	Mon	2021		1682		1534		0	x	1745	39	12	9.7		
7-Jun	Tue	2970		2716		2230		26	x	2638	59	12	6.5		
8-Jun	Wed	1813		1892		3004		0	x	2236	50	12	7.9		
9-Jun	Thu	406		332		337		0	x	358	8	12	14.7		one or more cycles likely missed?
10-Jun	Fri	1734		1439		1441		2	x	1539	34	12	10.4		
11-Jun	Sat	2819		2325		2053		24	x	2399	53	12	7.3		
12-Jun	Sun	2327		1975		1711		1	x	2004	45	12	8.7		rain recorded so irrig may have been turned off?
13-Jun	Mon	2450		2060		1593		1	x	2034	45	12	8.6		rain recorded so irrig may have been turned off?
14-Jun	Tue	2250		1564		1830		0	x	1714	38	12	9.8		rain recorded so irrig may have been turned off?
15-Jun	Wed	1420		1412		1158		0	x	1496	33	12	10.6		rain recorded so irrig may have been turned off?
16-Jun	Thu	2051		1625		1236		0	x	1637	36	12	10.1		
17-Jun	Fri	2585		2120		871		0	x	1858	41	12	9.3		
18-Jun	Sat	2891		2026		848		0	x	1921	43	12	9.0		
19-Jun	Sun	5041		4686		925		51	x	3550	79	12	3.2		water check?

✓=good tipper value; X = bad tipper value (don't use)

Avg. Tips = average of all checked tippers

LF (%) = LF based on tipper

RT (min) = actual run time in minutes per day

RTT (min) = run time to achieve desired LF

Table 2. WaterTips' output data recorded by Hibernia personnel for sprinkler irrigated trade #3-gallon Loropetalum crop.

Description	3-gal loropetalum
Irr type	Sprinkler
Irr rate	0.45 inch/hr
Desired LF	15%

Irrig. date	Irrig. day	Tip_1		Tip_2		Tip_3		Tip_4		Avg. Tips	LF (%)	RT (min)	RTT (min)	Nursery comments	UF comments
		Tips	✓	Tips	✓	Tips	✓	Tips	✓						
17-May	Tue	0		0		1		0		0	0	45	53		Small plants so nursery wanted to not overwater
18-May	Wed	0		45		3		0		12	4	45	50		
19-May	Thu	12		85		11		7		28	11	45	47		
20-May	Fri	2087		2070		2000		1667		1956	765	45		rain	
21-May	Sat	470		477		405		350		425	124	60			rain likely - no weather data
24-May	Tue	69		132		90		61		88	25	60	52		
26-May	Thu	51		109		26		14		62	18	60	58		
27-May	Fri	165		251		175		114		173	51	60	35		afternoon irr?
28-May	Sat	66		103		64		43		69	20	60	56		
4-Jun	Sat	254		170		37		170		198	58	60	30		afternoon irr?
5-Jun	Sun	79		137		11	x	71		95	28	60	51		
6-Jun	Mon	49		50		14	x	47		40	11	60	62		
7-Jun	Tue	322		370		104		217		254	74	60	18		rain
8-Jun	Wed	498		377		276		413		391	114	60			rain
9-Jun	Thu	1		0		0		0		0	0	60	71		nursery likely turned irrig off
11-Jun	Sat	58		162		10		87		78	23	60	54		

✓=good tipper value; X = bad tipper value (don't use)

Avg. Tips = average of all checked tippers

LF (%) = LF based on tipper

RT (min) = actual run time in minutes per day

RTT (min) = run time to achieve desired LF

Future Considerations for the Application

Two considerations regarding the application surfaced during the evaluations. First, it became apparent that scrolling within a page of the application needs to be accomplished without lifting your finger off the screen. If you lift your finger off the screen while scrolling, you may move to another unit. If not aware of this, you can be editing and saving information for the wrong unit which can be frustrating. However, this issue was not reported by nursery personnel.

The second consideration involved the rounding up or down of irrigation run times. Currently, the user makes that decision or determination to round based on outputs in units reported to one-tenth of a minute. Until most time clocks used in nurseries have choices of seconds or fractions of minutes for establishing run times, the current resolution of 0.1 minute for the application is sufficient.

Summary

We proposed to develop and test a system with Bluetooth capability that will automatically measure leachate amounts with a small, tipping bucket rain gauge and a data acquisition/communication system that can be left in the field or greenhouse. Hence, the new technology will decrease labor inputs for conducting leaching fraction tests, a Best Management Practice. In addition, by adjusting irrigation to maintain low leaching fraction target values, economic plant production can be achieved that conserves water and justifies the irrigation amount.

In this report, we described the installation of the system at two cooperating nurseries in central Florida to get an initial evaluation of the technology. UF staff instructed nursery staff how to use WaterTips to download daily tip data and how to use the information to output daily LF values and adjusted run times. At one nursery, personnel were able to use WaterTips but did not devote time to maintain tipper setups and routinely monitor tip data. However, the observations from the gauges at that nursery emphasize the importance of maintaining the system. In a second nursery, WaterTips was found to be useful to the nursery when the WaterTips' output was recorded daily on a form that was accessible by nursery staff, including the water manager. It became clear to us from these initial evaluations in cooperating nurseries, that the user must be dedicated to using the app on a routine basis and communicate results directly with the water manager if output is to be useful for adjusting irrigation, its intended purpose.
