Tipping Bucket Rain Gauge for Measuring Leaching Fraction in Container Nurseries
Task 7: Final Report

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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 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 container) 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 Task 1

An Arduino or data acquisition/communication device connected to a small tipping gauge will use Bluetooth communication to transfer tip counts to an application on a mobile device.

Methods set forth in Task 1 are to acquire hardware components and assemble prototype. A list of components is given below followed by photographs in Figs. 1-4.

A. Misol rain gauge sensor or "tipper" ($9.35) http://www.misolie.net/misol-spare-part-for-weather-station-to-measure-the-rain-volume-_for-rain-meter-for-rain-gauge-p-513.html?zenid=13q6jq1v93ptcjnf4tcijrodp7

B. Arduino microprocessor ($22.50) Bluno https://www.dfrobot.com/product-1044.html

C. Data-logging shield ($13.95) Arduino Installing the Headers | Adafruit Data Logger Shield | Adafruit Learning System 3V battery (CR1220; $1)) and memory card (8G SCHC; $10)

D. Battery ($22.99) 12V ML9-12 https://www.amazon.com/Mighty-Max-Battery-ML9-12-Rechargeable/dp/B00K8V2Y8W/ref=sr_1_5?crid=2VRHP7DVUQA08&keywords=ml9-12%2Bmighty%2Bmax%2Bbattery&qid=1641735840&sprefix=ML9-12%2Caps%2C93&sr=8-5&th=1

Description of hardware

The rain gauge sensor or "tipper" has a tipping bucket mechanism whereby each bucket tip of 1.6 mL of water activates a reed switch. For our application, the Arduino microprocessor not only houses a software platform for programing the acquisition of data but also provides a dedicated low voltage circuit for counting tips from the tipper. A data-logging shield is a specialized accessory that attaches to the Arduino. It provides a real-time clock by virtue of a 3V battery as well as a SD memory card for storing tipping count data. The shield stacking headers provide a means for attaching the data-logging shield onto the Arduino.

Results Task 1

Component parts for prototype leachate measuring device have been received and components assembled. An open-source IDE software package for the Arduino Uno unit has been loaded and programming by Craig Warner has successfully counted tips for four connected tippers. The number of tips for each tipper has been programmed to record onto the memory card at the end of the day after which the counter is reset to zero. Bluetooth connection to a smartphone has been successfully programmed to acquire data from the Arduino. The next step is to build the application to provide functions specific for this project, weatherproof components, and do initial testing of app for collecting leachate tip data from plants. App for mobile phone will be used to monitor tips and provide leaching fraction amount for the operator along with irrigation operation time adjustments.

Summary Task 1

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. The components of the system have been acquired and assembled for monitoring leaching fraction automatically in the production environment.

Methods Task 2

An Arduino or data acquisition/communication device connected to a small tipping gauge will use Bluetooth communication to transfer tip counts to an application on a mobile device (Fig. 5). A schematic of how the mobile application functions is given in Fig. 6. Methods set forth in Task 2 are to develop the application that will communicate via Bluetooth with the Arduino.

Results Task 2

The user connects via Bluetooth to the Arduino(s), scans the Arduinos and downloads tip counts (Fig. 7). Depending on whether the zone was previously entered, the user inputs irrigation or unit type (micro or sprinkler), application rate (gal/hr or inch/hr), target or desired LF (%), irrigation run time (min), and container diameter (inch), (Fig. 8) for the plants where the Arduino is used to adjust irrigation duration. The LF History is updated, and a new irrigation operation time (RTT) is outputted (Fig. 9). The operator or user changes the new duration or irrigation run time (min) at the time clock to achieve the desired leaching fraction (LFT). The Unit Calculations page can be used to edit inputs and delete Arduinos (Fig. 10). The next step is to do initial field testing of the application at University of Florida.

Summary Task 2

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. The components of the system have been acquired and assembled for monitoring leaching fraction automatically in the production environment. Additionally, a mobile application called WaterTips has been developed that receives via Bluetooth the tip counts recorded by an Arduino, or data acquisition device connected to tipping gauge. The mobile application uses the counts and inputs provided by the operator to calculate the desired irrigation operation time for achieving the desired leaching fraction.

Methods Task 3

An Arduino or data acquisition/communication device connected to a small tipping gauge will use Bluetooth communication to transfer tip counts to an application on a mobile device. Methods set forth in Task 3 are to test the application at University of Florida, IFAS in Gainesville.

Results Task 3

The Arduino and tipping gauge system were established at UF/IFAS using plants that received micro-irrigation (Fig. 11). For 3 – 4 weeks, tip counts for four gauges were downloaded approximately weekly from the Arduino to the mobile application on a Moto G-power phone with Android version 11. Tip information and calculations that resulted were reviewed and most of the changes or improvements in the application were completed to enhance functionality. For example, the names of Arduino units can now be sorted. Also, an option was added to the Unit Calculations page for selecting a RTT other than the most recent. In addition, the ability to delete Arduino units was repaired and options to manually exclude or change tipper counts were added. Updated screenshots from the application are given in Figs. 12-15. The next step is to test the application at commercial operations.

Summary Task 3

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. The components of the system have been acquired and assembled for monitoring leaching fraction automatically in the production environment. Additionally, a mobile application called WaterTips was developed and tested at UF/IFAS. Testing revealed several minor changes for the mobile application that uses the counts and inputs provided by the operator to calculate the desired irrigation run time for achieving the desired leaching fraction. A drop-down menu was added to the Unit Calculations page so the operator can select the origin of the value or change the value that populates the current run time used when calculating a new or desired irrigation run time. Also, the ability to sort a list of Arduinos was added. Further suggestions regarding modifications of the application will be obtained in the next step of the evaluation conducted by commercial operators.

Methods Task 4

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.

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. 16-17 and additional details of the setup are given in Figs. 18-20.

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. 21.

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.

Results Task 4

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. 22). 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. 23 and Fig. 24.

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.

Future Considerations for the Application Task 4

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 Task 4

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.

Methods Task 5

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. For this fifth task, we describe the interaction with two nurseries in which the tipping gauges were placed in production areas and monitored with WaterTips. BigTrees Plantation and Sunshine State Nursery were the participants.

For BigTrees Plantation located near Newberry in Alachua County Florida, one Arduino was used to monitor leachate from four trade #15-gallon containers of Nellie R. Stevens holly (*Ilex* x 'Nellie R. Stevens') in a spray-stake irrigated irrigation zone. Irrigation delivery was approximately 6 gal per hour. Photo of the zone at BigTrees Plantation is given in Fig. 25.

The other nursery engaged was Sunshine State, located near Palm City in Martin County Florida. Unlike BigTrees Plantation, there was limited micro-irrigated plant production, so an Arduino was set up in an overhead sprinkler irrigated zone. Irrigation delivery was approximately 0.5 inch per hour. One Arduino was set up to monitor leachate from four trade #3-gallon containers (9.1-inch diameter) of *Podocarpus macrophyllus* 'Pringles.' Photo of the zone at Sunshine State is given in Fig. 26.

Tipper systems or gauges and Arduinos were initially set up in February 2022 at BigTrees Plantation and April 2022 at Sunshine State. 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 operate the WaterTips' application. Follow-up trips by UF personnel were made to get feedback on using WaterTips. The systems were removed from both nurseries in October 2022. A summary of our experiences with each nursery is given in the results section along with information about educational events that were conducted.

Results Task 5

Users found the application easy to understand and comprehend the use of LF for guiding irrigation. Both nurseries engaged the application to monitor the appropriateness of their previously selected irrigation amounts or amount currently used. While this is an effective way to use the application, another possibility would have been to use the application to directly determine the need or amount of irrigation to apply, rather than as a verification for what they had chosen to apply. However, irrigation at each business is often managed differently and the participants engaged the application in the best way for their business.

At BigTrees Plantation, the irrigation was initially operating for 15 minutes once per day based on previous experience. However, during a site visit the manager was encouraged to use at 7-minute duration as LFs were high as noted using WaterTips (March 2 – April 20, Fig. 27). On May 16, a 7-minute run time (RT) was selected and resulted in LF of 26% on May 22, close to the target of 25%. Subsequently, the manager used a 7-minute run time once per day to achieve a water savings of approximately of 50%. The high LF of 41% on Oct. 6 was likely due to rain because the run time was 6.8 minutes.

At Sunshine State, the management was irrigating for approximately 20 minutes based on experience. When using WaterTips, the run time was verified (RTT) indicating the irrigation cycle duration (Fig. 28) was appropriate to achieve approximately a 15% leaching fraction (LF). The management found the verification helpful as weather conditions varied.

Educational Events Task 5

Use of the application by producers or nursery personnel can be an important step for others implementing the technology. Thus, an educational event was conducted at BigTrees Plantation and at an alternative location close to Sunshine State Nursery. The alternative location was selected due to the desires of Sunshine State management. However, that was a great decision because on the date selected for the event, electrical service was not available at the nursery.

An event was conducted subsequently to meeting of the Board of Directors of the Frontrunner's Chapter of FNGLA at BigTrees Plantation in Newberry on September 8. Twelve people participated in the event focused on the technology demonstration. Participants learned about leaching fraction for guiding irrigation, development of the Arduino technology for monitoring leaching fraction, and the benefits of using the technology.

The second educational event was conducted in Palm City during the Treasure Coast Chapter of FNGLA meeting at Alpha Zeta Landscape's service facility on September 22. Thirty-nine people participated in the event. A power point presentation was used to convey information regarding the use of application at Sunshine State Nursery. Participants learned about leaching fraction for guiding irrigation, development of the Arduino technology for monitoring leaching fraction, and the benefits of using the technology.

The management of Sunshine State Nursery was not present during the meeting at Alpha Zeta due to the repair being performed to electrical service at the nursery. However, information from the management was conveyed to Yvette Goodiel, Martin County Extension Horticulturist. Yvette provided the information, regarding use of technology in the nursery and greenhouse industry, to the participants. That information is summarized in Table 3.

Summary Task 5

The WaterTips' application was used by two production nurseries and educational events were conducted. Users found the application easy to understand and comprehend the use of LF for guiding irrigation. Both nurseries used the application to verify the appropriateness of their previously selected irrigation amounts rather than relying on the WaterTips' application to provide the irrigation operation duration. However, irrigation at each business is often managed differently and the participants engaged the application in the best way for their business or the way they felt comfortable. Event participants were intrigued by the possibility of using wireless technology to monitor plant water need.

The investigators are grateful for the opportunity provided by National Horticulture Foundation to share with the industry a new technological application for a microprocessor. A future advancement might include modularization of the system's components.

User Guide Task 6: User Guide is separate file to facilitate use without report information.

Trade names, products, and companies are mentioned for informational purposes only and do not constitute an endorsement. This report has not been peer reviewed and is not a recommendation of UF/IFAS.

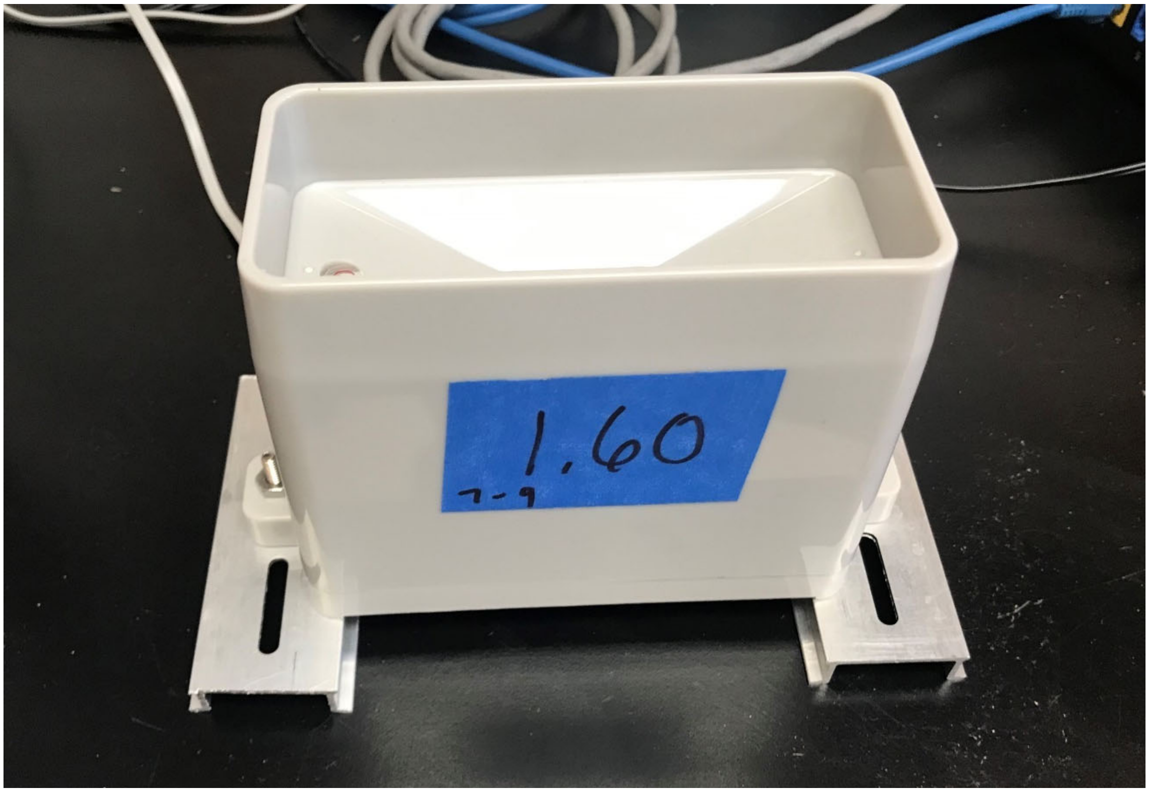


Fig. 1. Tipping gauge used for measuring container drainage is approximately 4.5L x 2.0W x 3.5H inches.

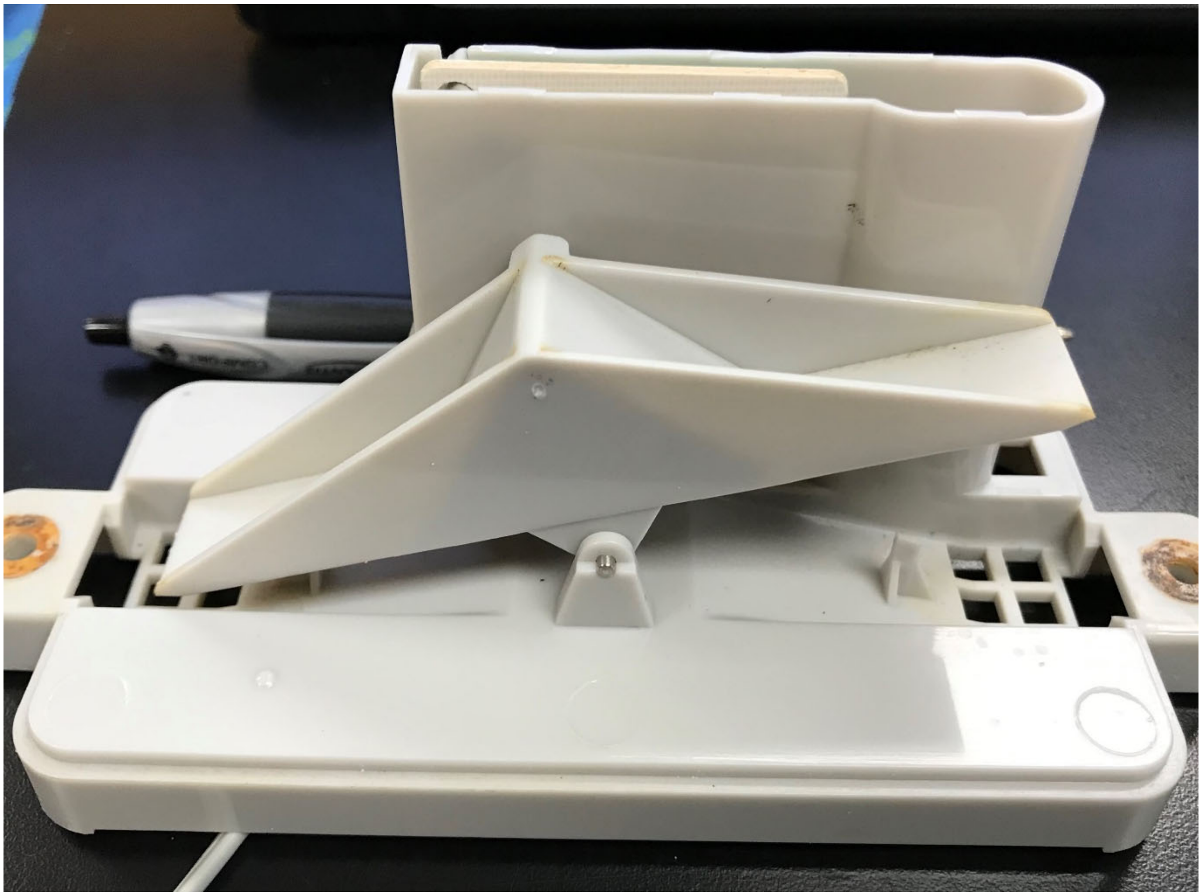


Fig. 2. The tipping bucket mechanism in the tipper (mini rain gauge) activates a reed switch at every tip (1.6 ml of water). The wire from the tipper will be attached to the Arduino so that tips can be counted, and leachate volume monitored.

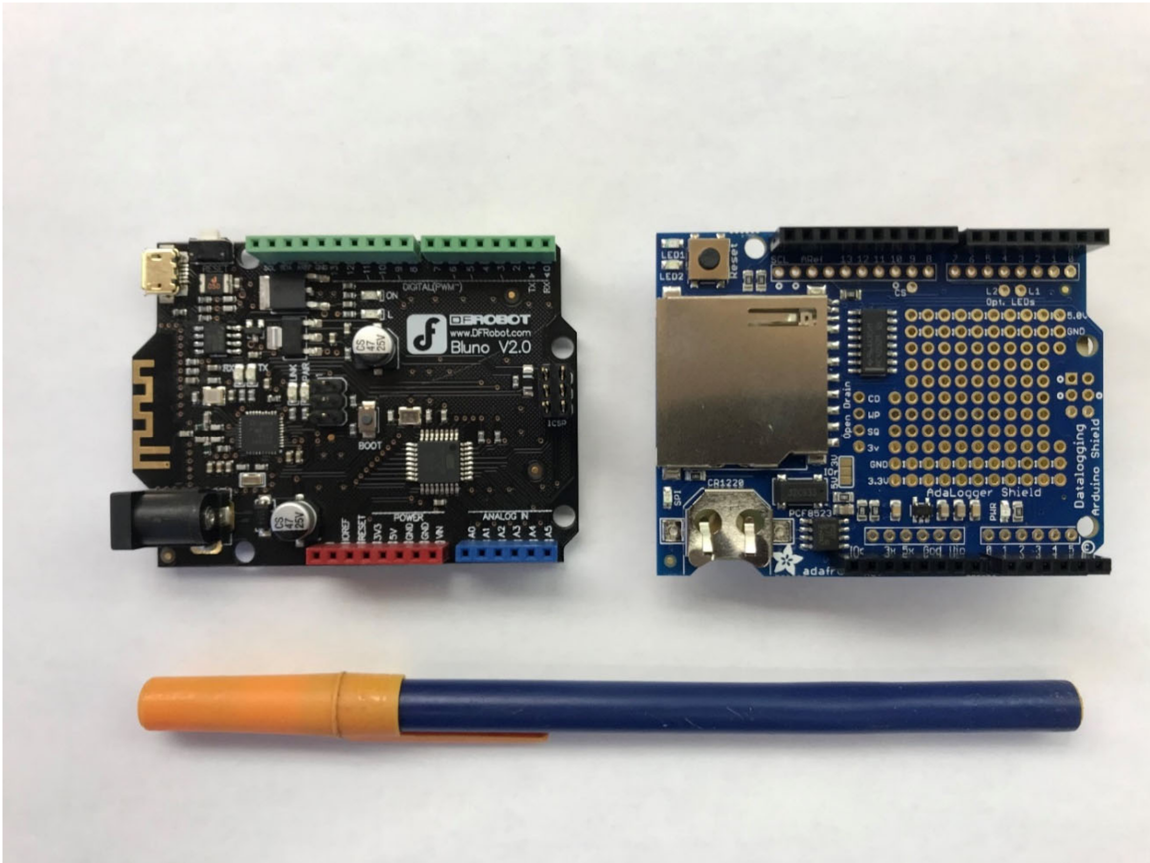


Fig. 3. The Arduino (left) consists of a microprocessor for programming, specialized 5VDC circuits for counting tips, and Bluetooth capability. The data-logging attachment or shield (right) allows data to be stored on a memory card and provides a real-time clock powered by a 3V battery.

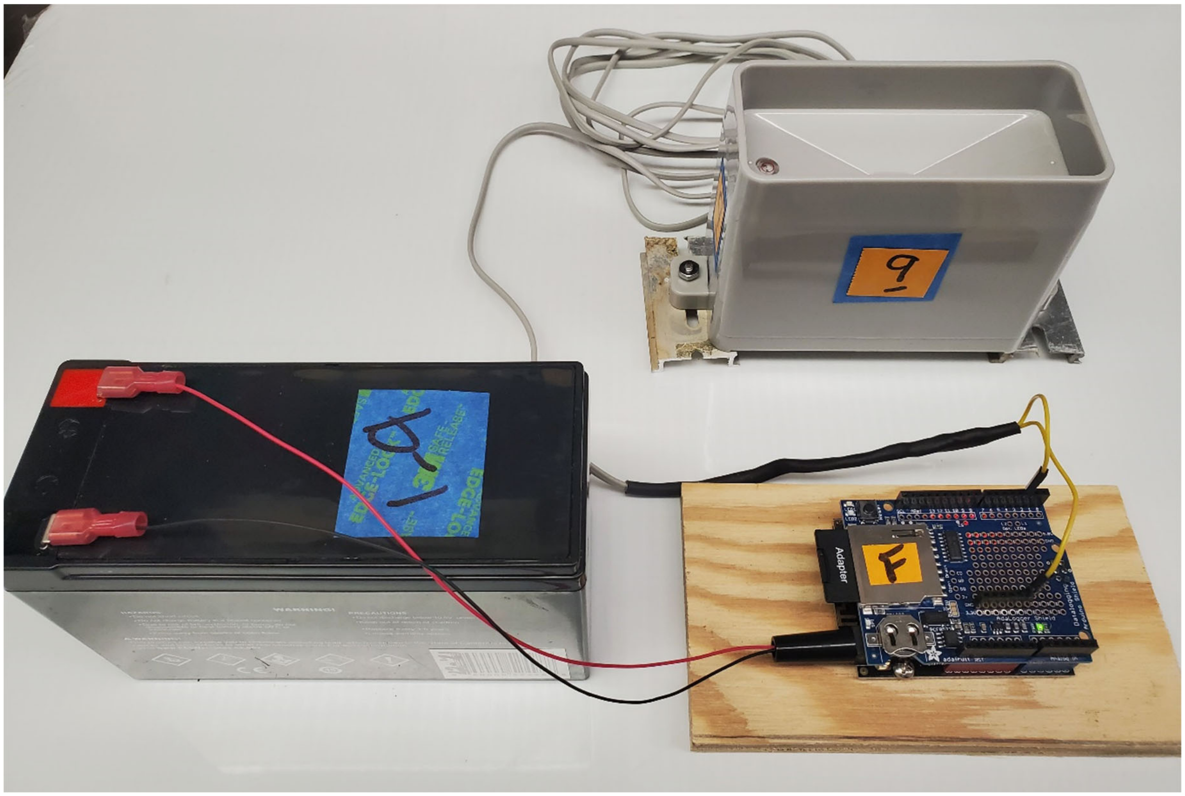


Fig. 4. Components of the system used to monitor drainage or leachate from the container. Power source or battery (12V), tipping gauge, and Arduino with shield are seen clockwise in the photo.

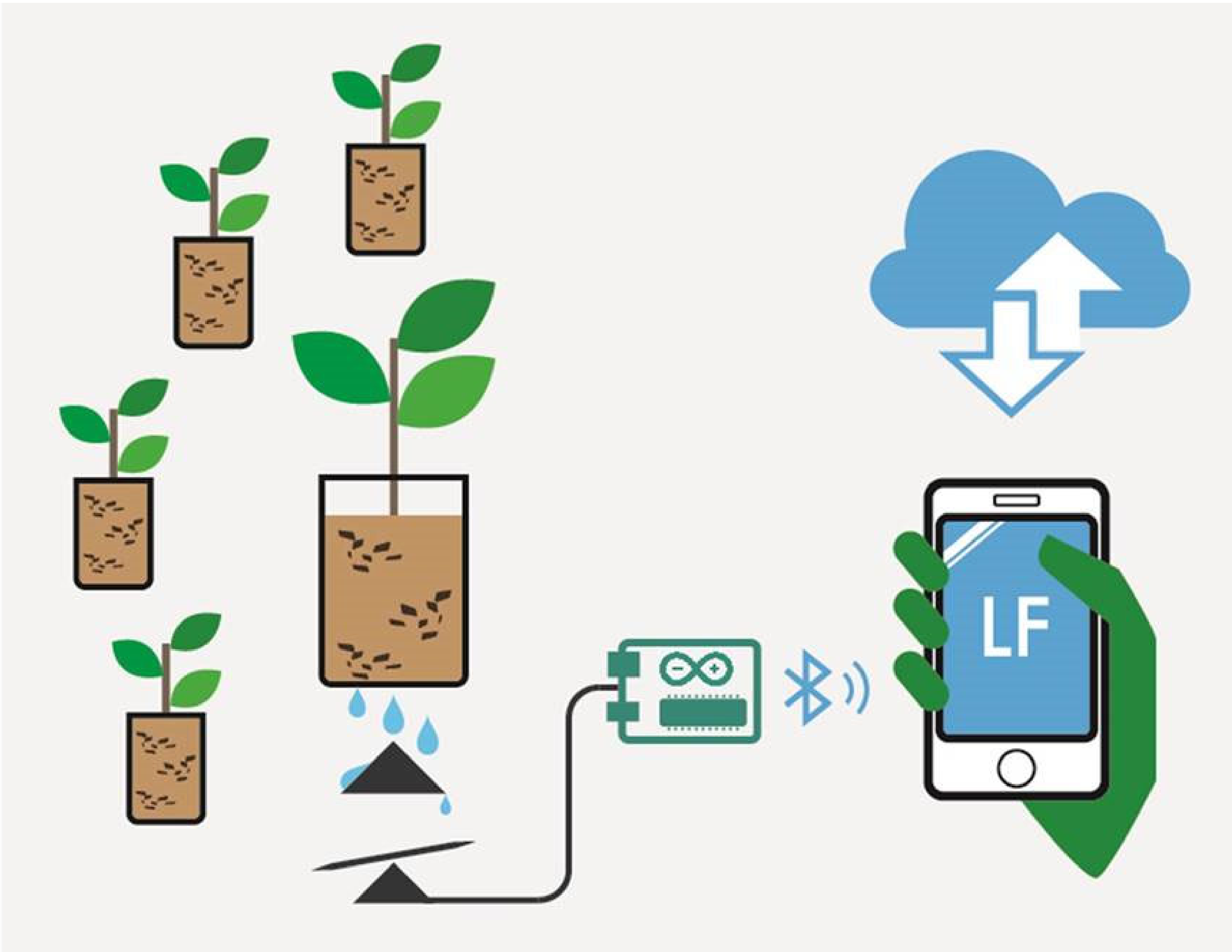


Fig. 5. Diagram represents the concept of monitoring container plant leaching and determining the leaching fraction using a mobile application. Leaching Fraction (LF) = leachate or drainage ÷ irrigation applied.

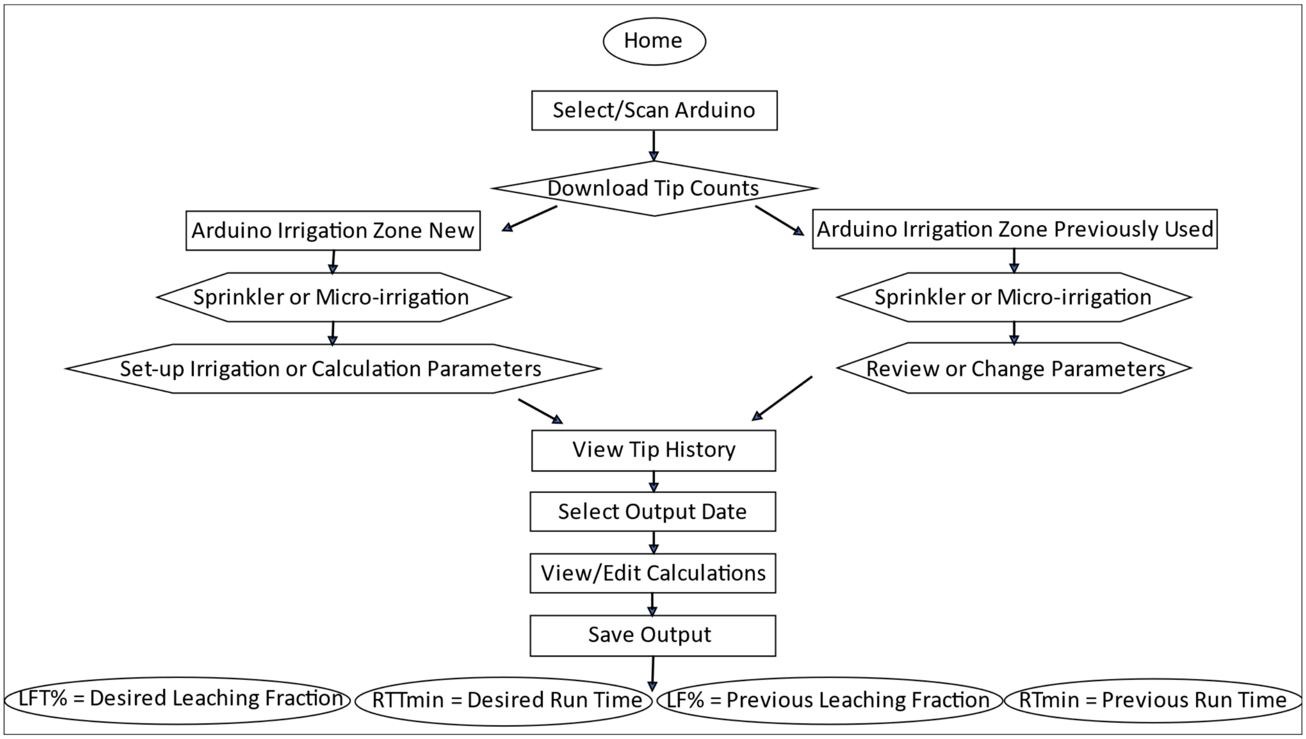


Fig. 6. Schematic represents the functional flow of informational inputs and outputs for WaterTips mobile application.

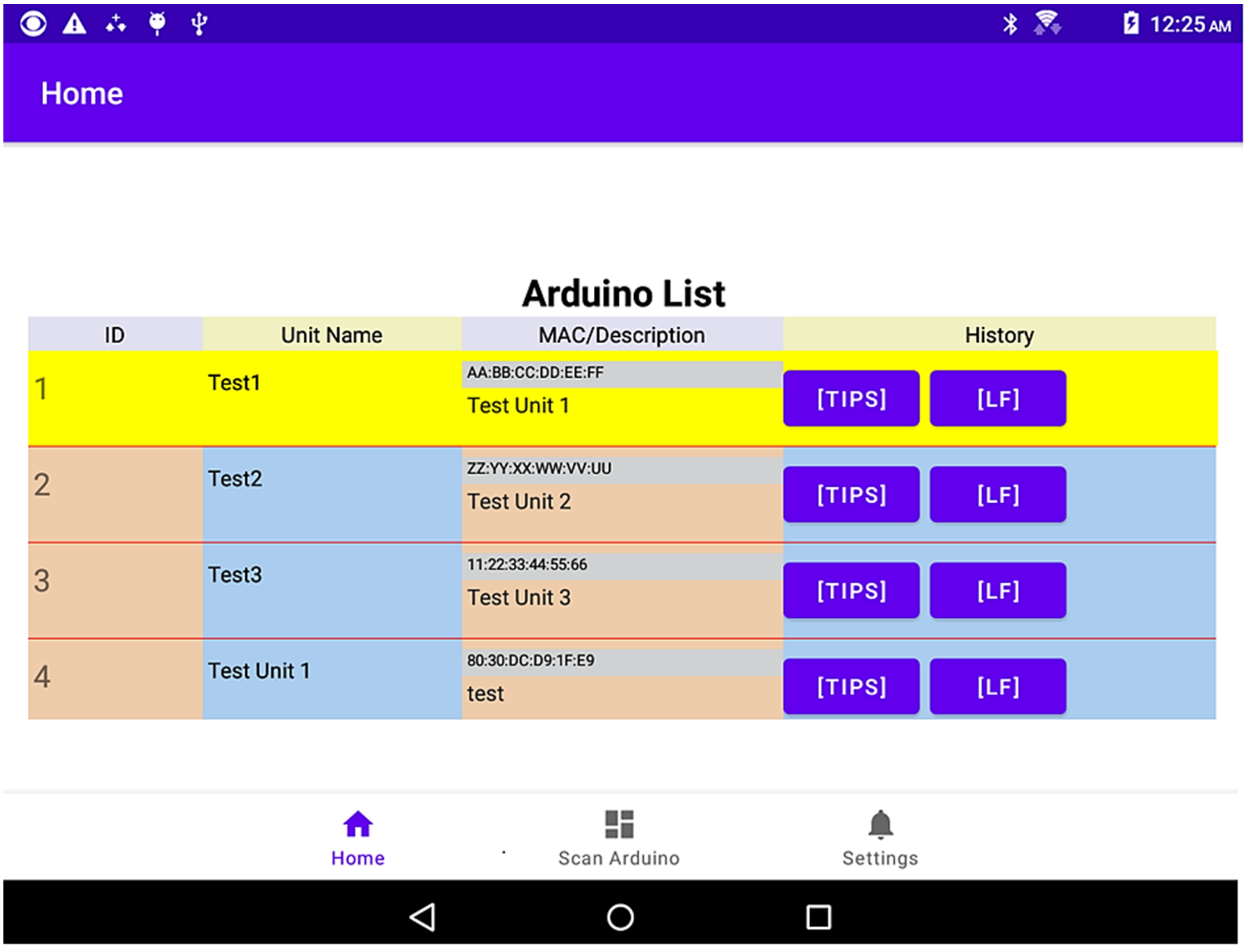


Fig. 7. Operator or user scans Arduinos and application provides list of units or Arduinos available. Names of units are assigned by the operator to designate irrigation zones or areas of consideration.

Fig. 8. The operator or user provides inputs for each unit or irrigation zone of consideration. Inputs can be modified from the Unit Calculations page seen later.

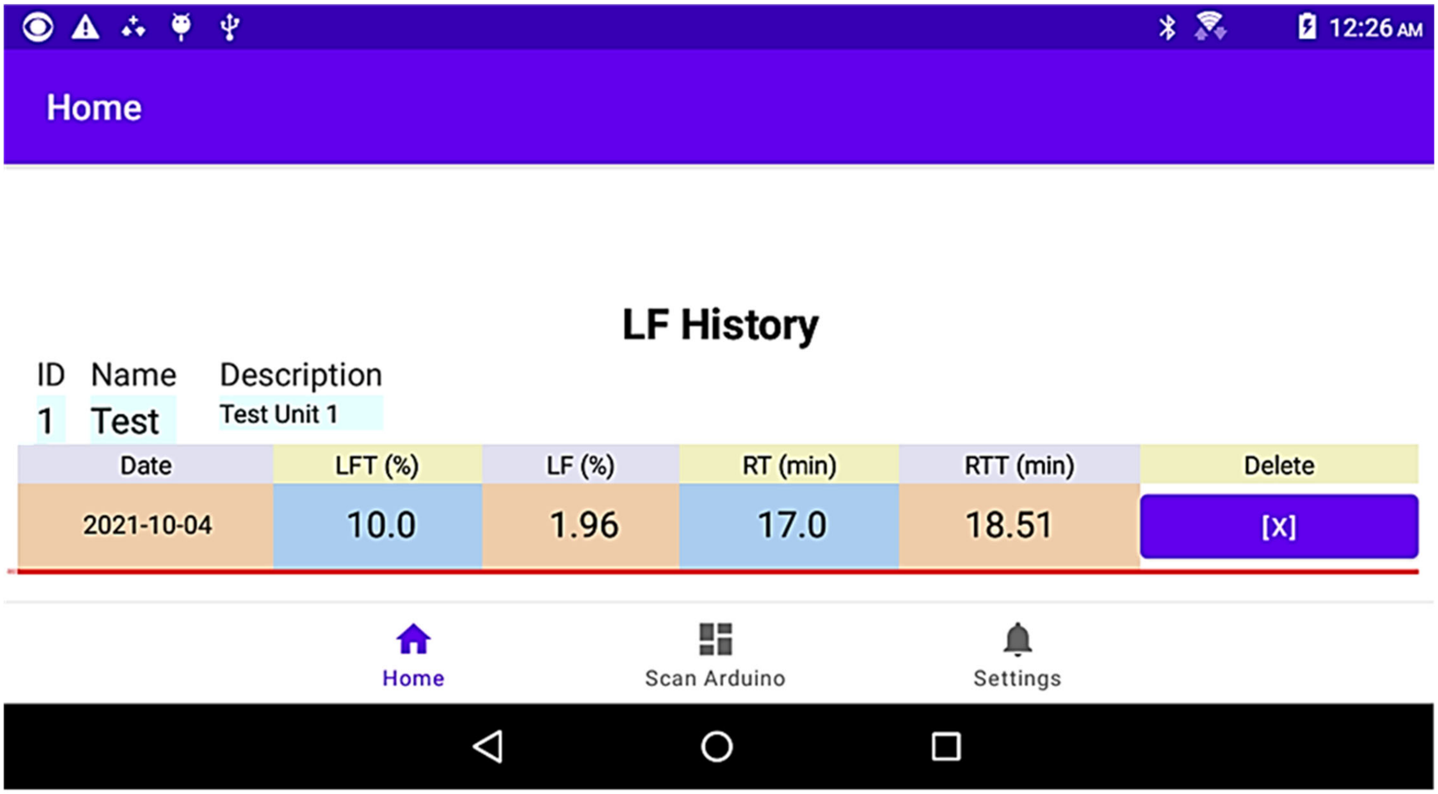


Fig. 9. The desired irrigation operation duration (RTT) is provided in the LF History.

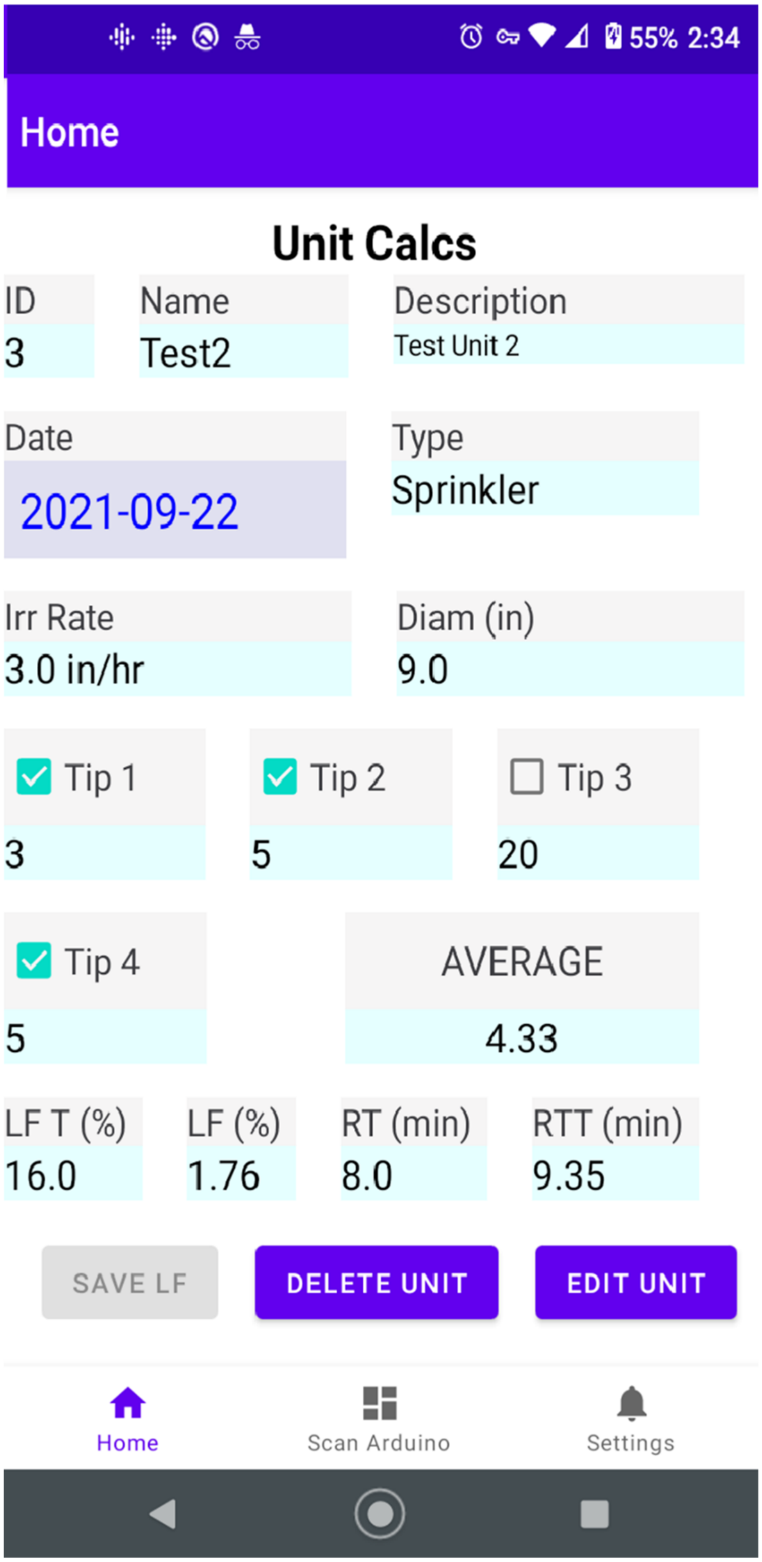


Fig. 10. The Unit Calculations page provides information for each unit.

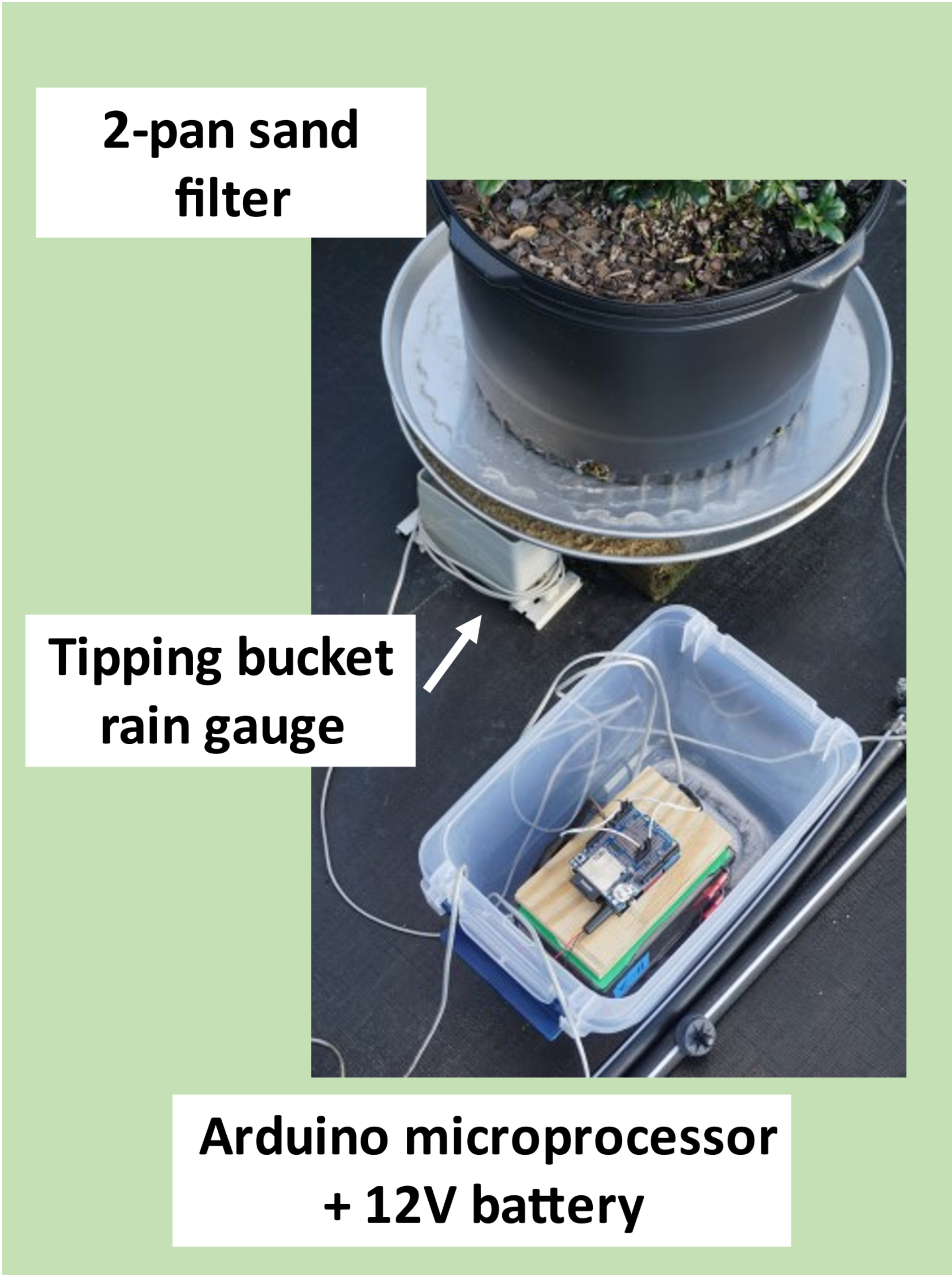
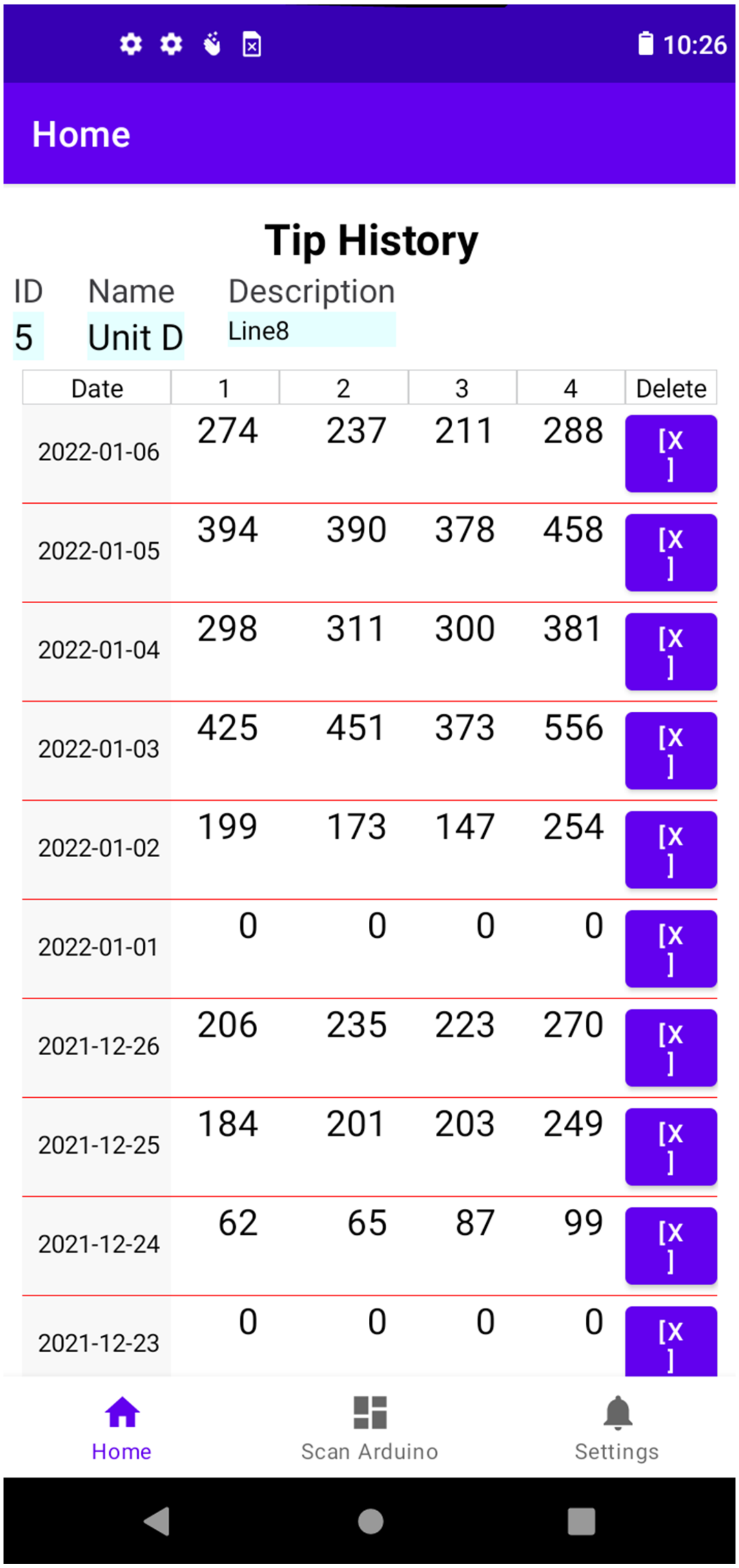


Fig. 11. The mobile application and four tipping gauges connected to an Arduino were used to monitor the leaching for Dwarf Burford holly grown in trade 7-gallon containers. Average Leaching Fraction, (LF) = leachate or drainage ÷ irrigation applied, was determined with the mobile application that received tip counts from the Arduino via Bluetooth.

Fig. 12. Operator scans Arduinos and application provides list of units available. Names of units are assigned by the operator to designate irrigation zones or areas of consideration. Note there is History for Tips and LF.


10:26
Home
Tip History
ID
5
Name
Unit D
Description
Line8

Date	1	2	3	4	Delete
2022-01-06	274	237	211	288	[X]
2022-01-05	394	390	378	458	[X]
2022-01-04	298	311	300	381	[X]
2022-01-03	425	451	373	556	[X]
2022-01-02	199	173	147	254	[X]
2022-01-01	0	0	0	0	[X]
2021-12-26	206	235	223	270	[X]
2021-12-25	184	201	203	249	[X]
2021-12-24	62	65	87	99	[X]
2021-12-23	0	0	0	0	[X]

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Fig. 13. Tip History provides a record of the tips recorded each day for each gauge.

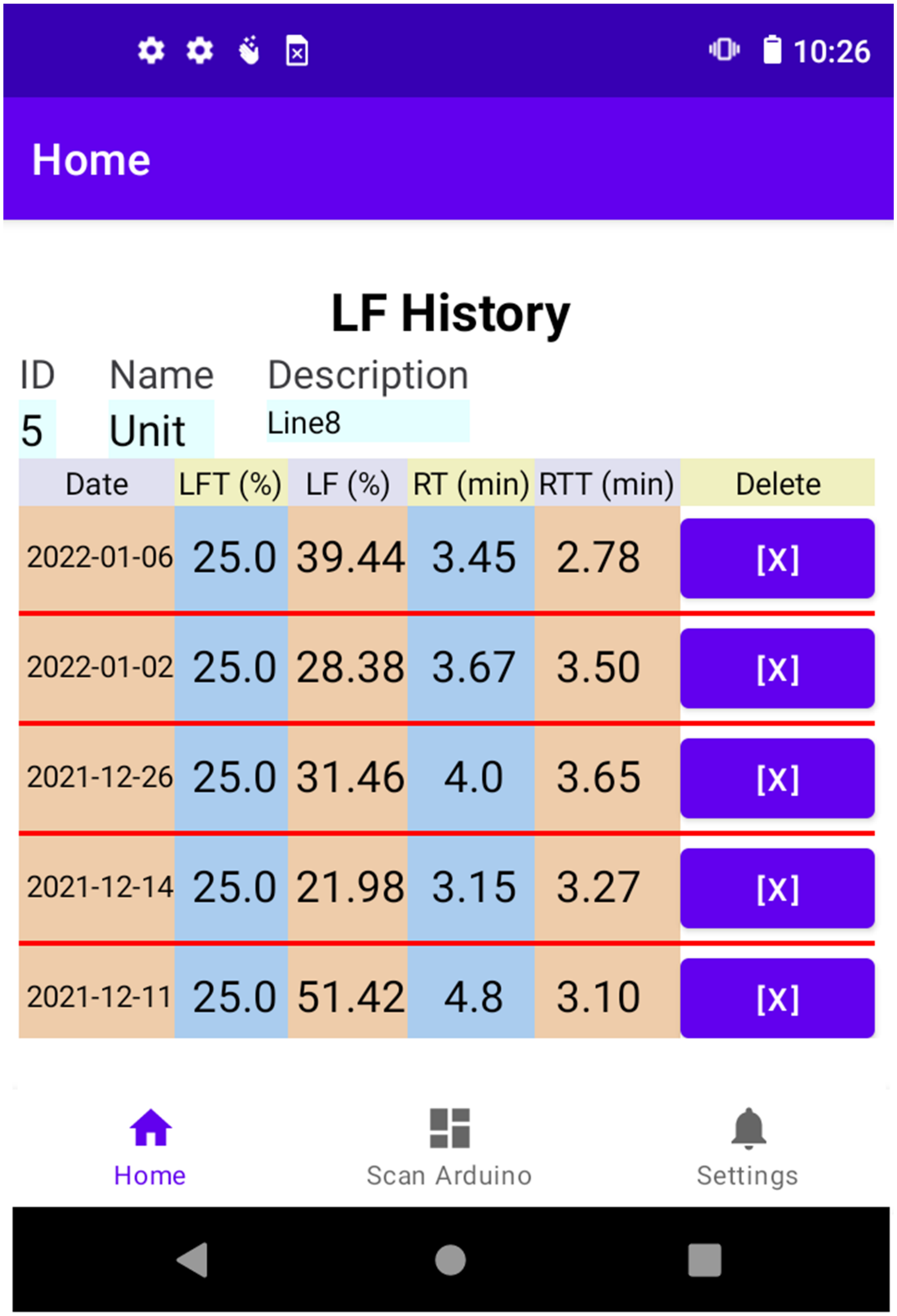

Fig. 14. LF History provides a record of the measured Leaching Fraction (LF), the target or desired LF (LFT), the irrigation run time (RT), and the new or desired run time (RTT) to achieve LFT.

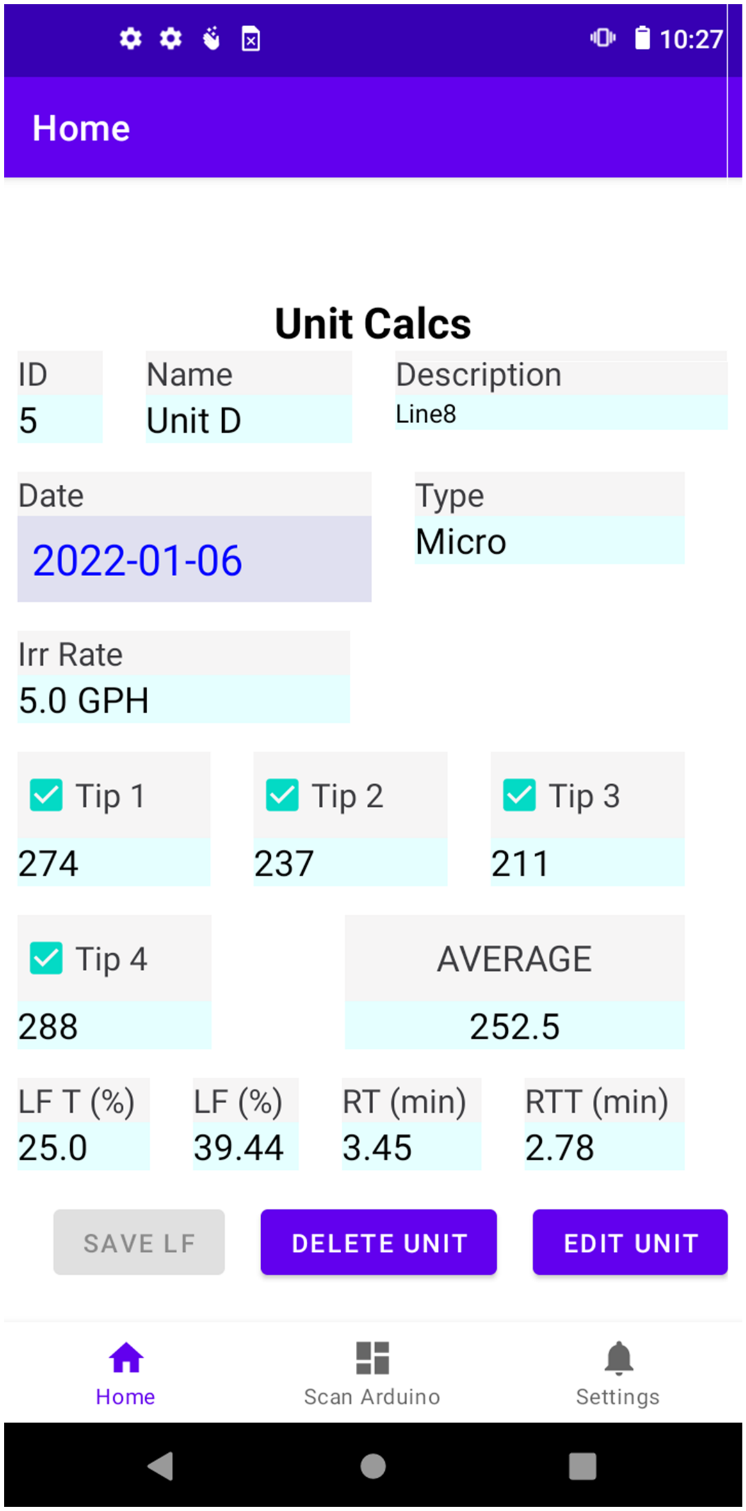

Fig. 15. The Unit Calculations page provides information for each unit or Arduino. The operator provides inputs for each unit or irrigation zone of consideration. Inputs can be modified from the Unit Calculations page.

Fig. 16. 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. 17. 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. 18. 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.

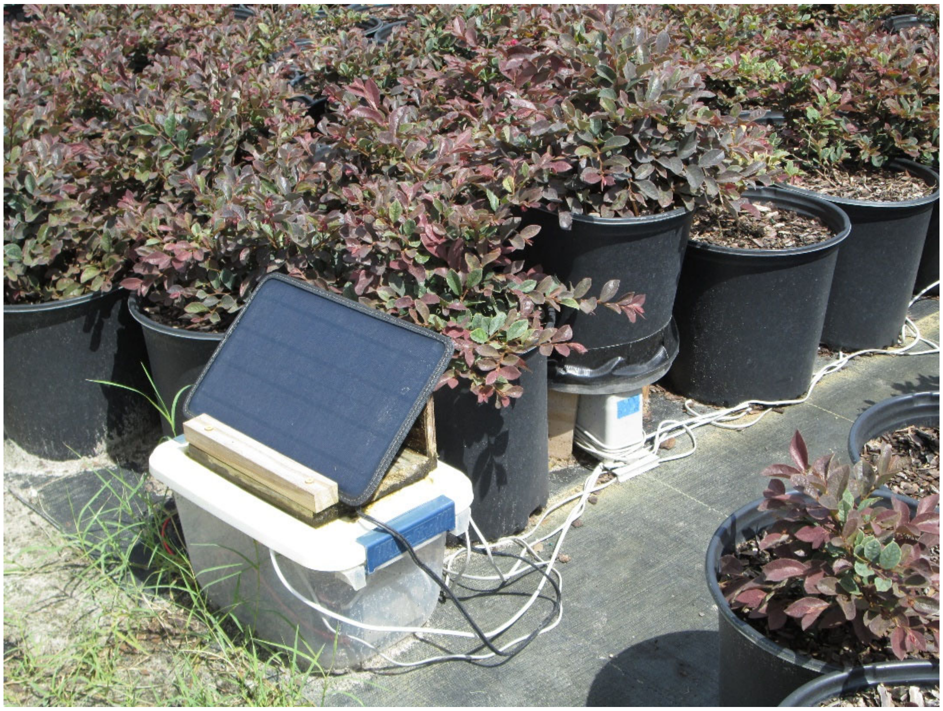

Fig. 19. Loropetalum in trade #3-gallon containers with sprinkler irrigation at Hibernia nursery during recording of WaterTips' data (June 2022).

Fig. 20. 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. 21. 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.

Fig. 22. Collector setups in Magnolia tree location at 1-D in June 2022 showing the lack of routine checking of the components.

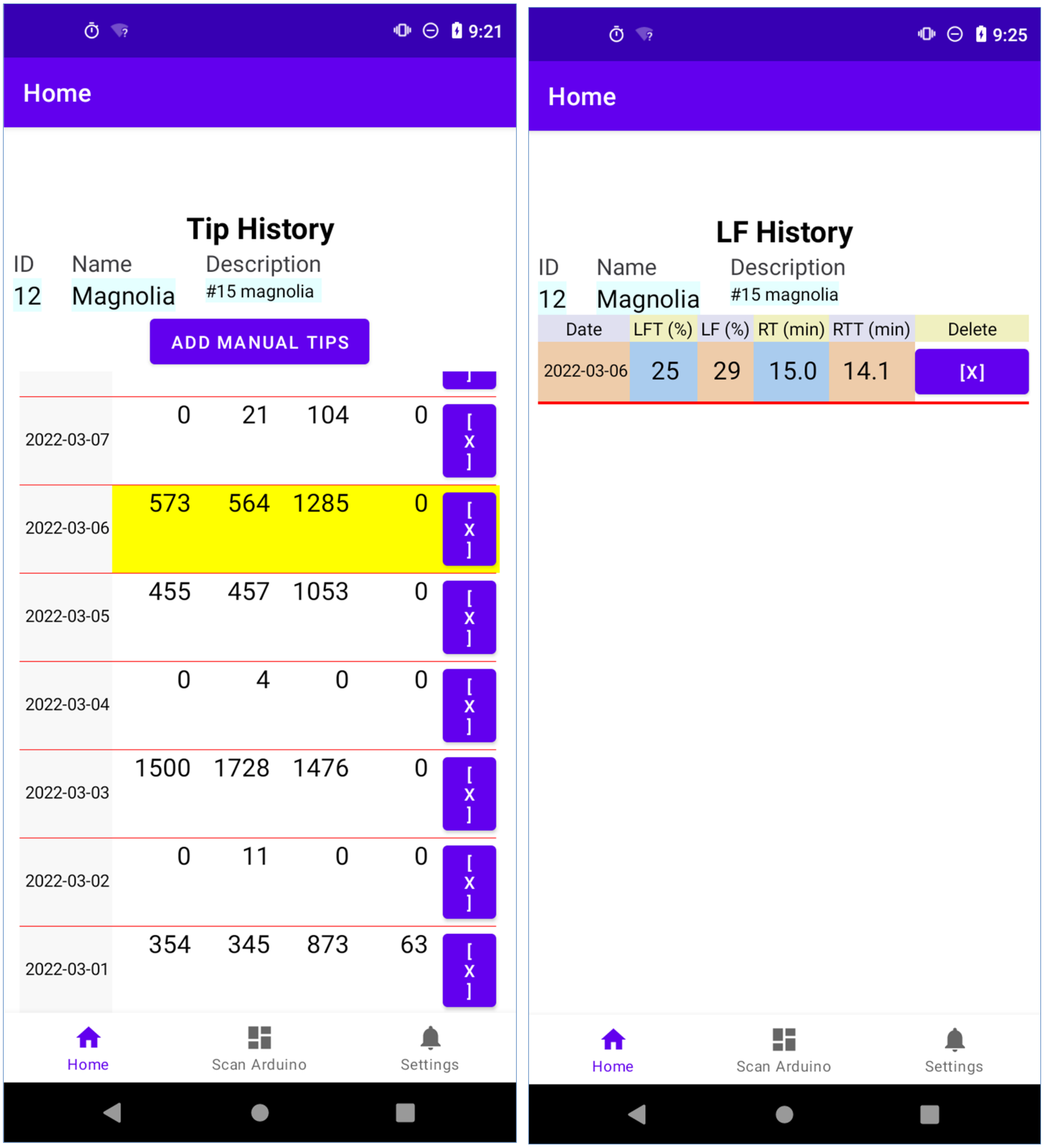

Fig. 23. Screenshot of WaterTips' app during early evaluation at 1-D nursery in Brandon, FL. Yellow (left) highlights a saved LF test that was saved into WaterTips' LF History (right). The desired run time (RTT) for this day should be used as the irrigation run time going forward until another desired run time is selected.

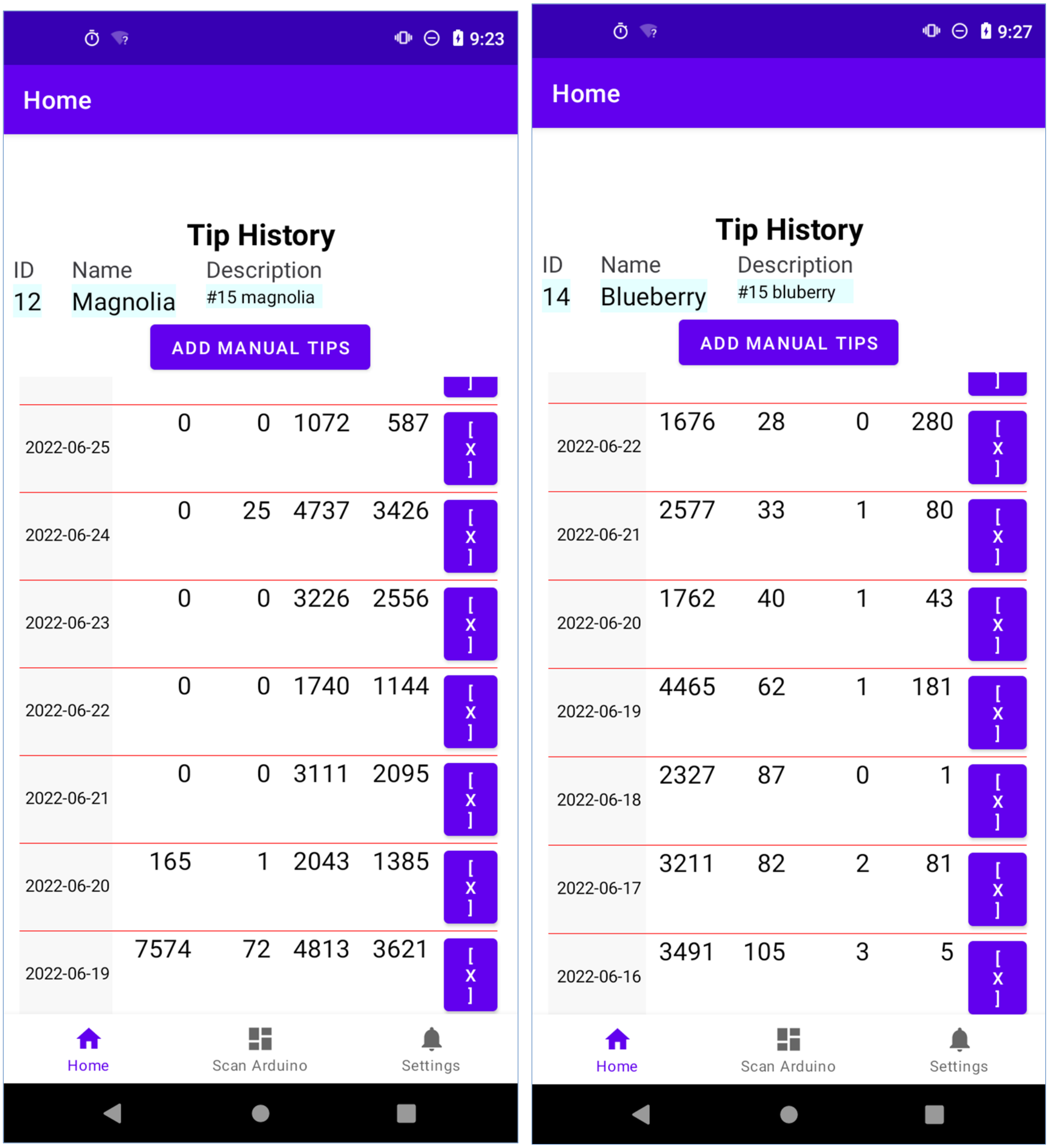

Fig. 24. WaterTips' screenshots during evaluation at 1-D nursery in Brandon, FL. At this point, tipper setups were not being maintained. The low tip values indicate the tippers or gauges that need maintenance.

Fig. 25. Leachate from Nellie R. Stevens holly grown in trade #15-gallon containers with spray-stake irrigation at BigTrees Plantation in central Florida. The Arduino, housed in the plastic tote with white lid and solar panel on top (left), was connected to four tipping gauges (one on right) to monitor container leachate using WaterTips' app. The site was initially set up in February 2022.

Fig. 26. *Podocarpus* grown in trade #3-gallon containers with sprinkler irrigation at Sunshine State Nursery in south Florida. The Arduino, housed in the plastic tote with solar panel (right), was connected to four tipping gauges (one on left) to monitor container leachate. The above photo was taken in April 2022 when tippers were initially set up.

1:52

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LF History

ID	Name	Description
3	Big Trees	15 gal

Date	LFT (%)	LF (%)	RT (min)	RTT (min)	Delete
2022-10-06	25	41	6.8	5.3	[X]
2022-05-22	25	26	7.0	6.8	[X]
2022-04-20	25	32	15.0	13.5	[X]
2022-03-05	25	54	15.0	9.1	[X]
2022-03-02	25	50	15.0	9.9	[X]
2022-03-01	25	10	2.0	2.3	[X]
2022-02-24	25	85	10.8	2.0	[X]
2022-02-23	25	45	15.0	10.8	[X]

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Fig. 27. Screenshot of WaterTips' app during use at BigTrees Plantation, Newberry, Florida. The run time (RT) was changed to 7 minutes on May 16.

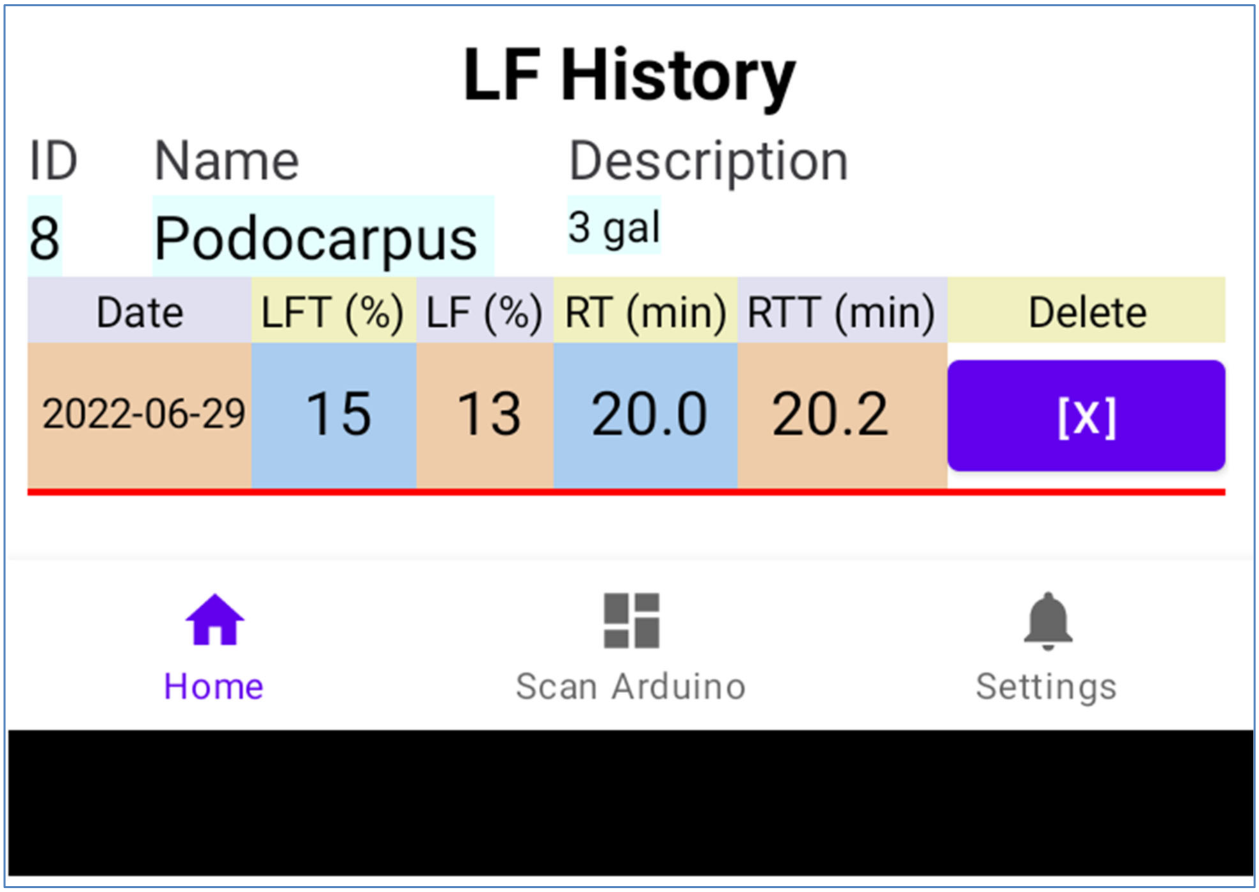

Fig. 28. Screenshot of WaterTips' app during use at Sunshine State Nursery in Palm City, Florida. The desired run time (RTT) for this day should be used as the irrigation run time going forward until another desired run time is selected.

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

Table 3. The following information regarding the use of WaterTips' application and Arduino system for monitoring container plant irrigation was provided by management of Sunshine State Nursery.

Reduce labor inputs because no need to feel substrate moisture.
Apply correct amount of water especially during dry times.
Prevent soil borne diseases because not over-watering.
Easy to use!