Tipping Bucket Rain Gauge for Measuring Leaching Fraction in Container Nurseries

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Abstract

Leaching fraction is the amount of container drainage divided by the amount of water applied to the container expressed as a percentage. Leaching fraction measurements are conducted manually and have been used in container plant production to manage irrigation application amounts. However, due to the current shortage of personnel it is difficult to accomplish the task. Thus, the objective of the proposed work was to develop a technology-based system for automatically conducting leaching fractions.

An Arduino with Bluetooth capability was wired to small tipping rain gauge. The gauge was placed under an elevated container that rests on pizza pan with hole to direct container drainage into the tipping gauge. Each tip was counted by the Arduino. A mobile application was developed that received the tip data from the Arduino via Bluetooth connection. The application calculated the leaching fraction and desired irrigation operation or run time based on user inputs and tip data from the Arduino. Evaluations are currently underway at the University of Florida, IFAS to enhance the functionality of the mobile application and Arduino-based leaching fraction system for determining container plant irrigation needs. Subsequently, evaluations will be conducted in production nurseries.

Introduction

Monitoring the drainage or leachate from a container can be used to determine the amount of irrigation to apply. One method currently used to monitor drainage is conducted in the greenhouse or the field with a few materials such as pizza pan resting on wood supports as seen in Fig. 1

The container drainage after irrigation is collected and the volume or weight determined. The amount of drainage is usually expressed as a percentage of the irrigation applied to the container. This relationship of irrigation applied, and drainage is called the Leaching Fraction (LF) calculated with the following formula: LF = drainage or leachate from container ÷ irrigation applied to container. The intent is to collect as small amount of drainage as possible; however, our research has revealed that a LF of approximately 15% for trade 3-gallon containers and 20-25% for larger containers, such as trade 5 to 15-gallons are good targets.

Even though LF is a simple method for guiding irrigation application amounts, there has been some reluctancy for producers to use LF tests. That reluctancy is primarily due to the set up or preparation time needed for each test. Setup involves placing a reservoir or pan that collects drainage under hole in the pizza pan. During irrigation, drainage flows from the substrate onto the pizza pan and through the hole. Pizza pans are used for large or small containers to direct leachate or drainage as seen in Fig 1. Personnel return to the field after irrigation and physically measure the drainage as a weight or volume, record the value, and calculate the LF. Additionally, rain that occurs after setting up the LF assembly negates the effort as the LF test must be repeated. Thus, the purpose of the proposed research was to overcome the time constraints that result from these difficulties by automating the process for determining the LF.

Fig. 1. Leachate or container drainage moves through a hole in round pizza pan for collection in reservoir below.

Objective: Develop and evaluate a tipping gauge leachate-measuring system for container plants.

The Process or Methods

Tipping bucket gauges are used for measuring rain amounts and offer the ability to accurately measure small volumes of water. So, we purchased tipping gauges like that seen in Fig. 2.

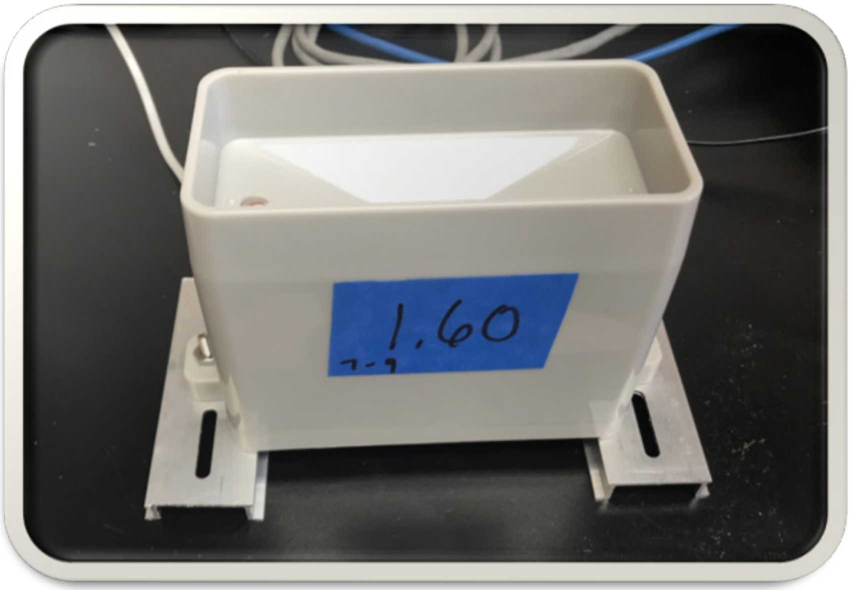

Fig. 2. Tipping gauge used for measuring container drainage is approximately 4.5L x 2.0W x 3.5H inches.

Inside the gauge cover is a rocker that tips once full of water. Each tip of the rocker (Fig. 3) completes the electrical circuit of an energized gauge.

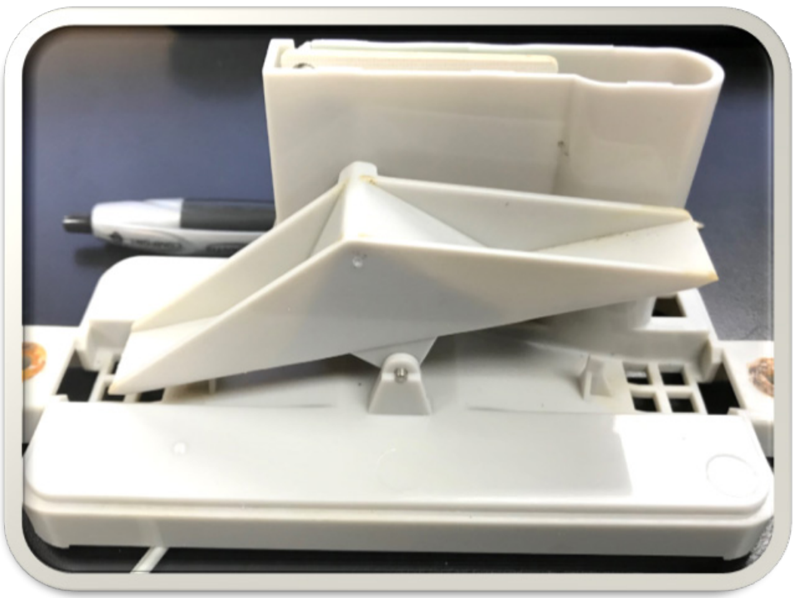

Fig. 3. Rocker tips after filling with drainage or leachate.

Our initial efforts to count the tips were facilitated by electronic digital counters. Counters were connected by wire to gauges, and both were energized with a 9-volt battery (Fig.4).

Fig. 4. Digital counters were connected to gauges, and both were energized with 9-volt battery.

A tipping gauge was placed beneath the 0.5-inch hole in pizza pan (Fig.5a). For sprinkler irrigation systems, irrigation water was shielded from entering the pizza pan by placing medical wrap (Fig. 5b) around the pizza pan lip and lower container sidewall.

Fig. 5a and 5b. Tipping gauge beneath container for micro-irrigation (left, 5a) and for sprinkler irrigation (right, 5b). Medical wrap was placed around pizza pan to inhibit sprinkler irrigation from entering pan.

Calibration tests were conducted, and it was determined that each tip of the gauge equated to 1.6 milliliters of drainage (Fig. 6). The digital counters functioned well; however, it required manually recording the count data for each tipping gauge used to calculate the LF.

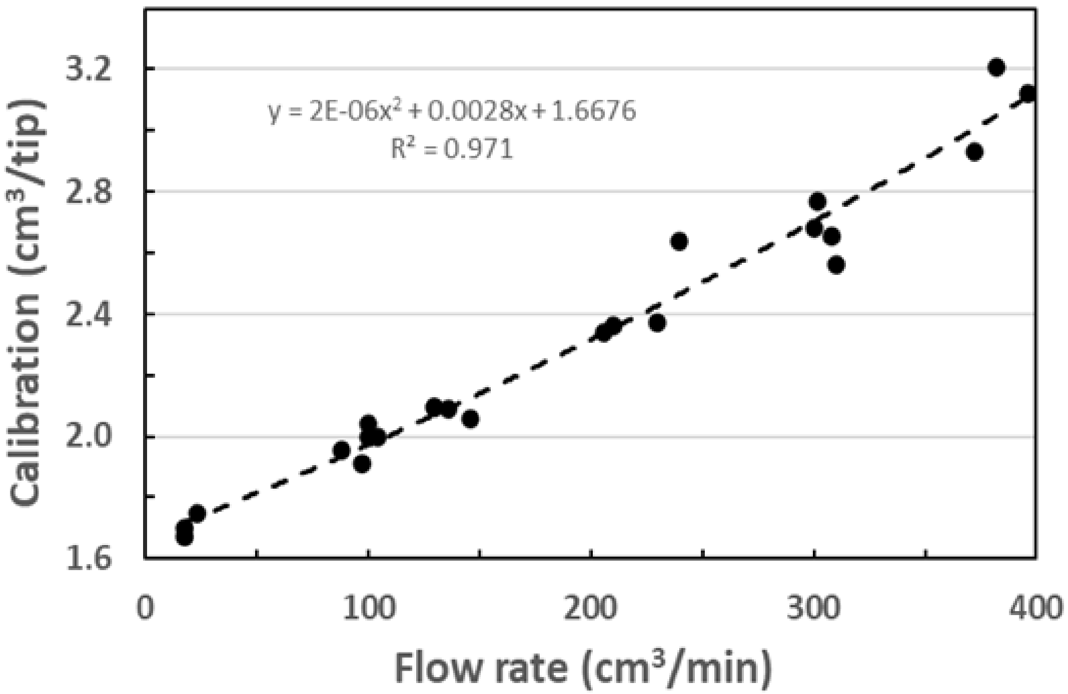

Fig. 6. Calibration tests revealed each tip was 1.6 milliliters (1.6 cm3) when flow was 30 milliliters per minute.

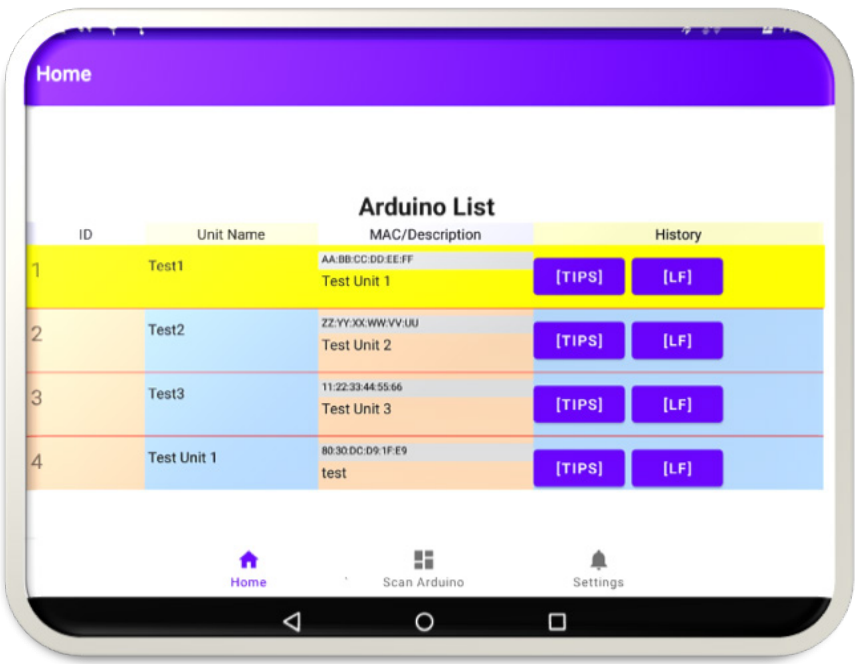

Fig. 7. Arduinos within Bluetooth range are listed on screen of the mobile application.

Results of the Process

To eliminate manually reading and recording tip counts, and further automate the LF procedure for guiding irrigation management, we proposed to use an Arduino microprocessor connected to the tipping gauge. The Arduino has Bluetooth capability and a data shield with memory card for backup data storage. The Bluetooth capability of the Arduino enables communication between an application on a mobile device and the Arduino. Thus, an application was developed to manage tip count data collected by the Arduino.

Users of the application provide inputs such as an Arduino unit name. The Arduino name entered by user will most likely refer to a designated irrigation area or irrigation zone. The screen shot in Fig. 7 represents a scan of the Arduinos within range of the mobile device. The Media Access Control (MAC) number is specific for each Arduino and is automatically assigned by the manufacturer. From the Arduino List screen of the application, the settings can be selected.

An example of the settings is given in **Fig. 8**. The user will enter the irrigation zone description, irrigation application rate and run time or duration, along with container diameter and the desired or target LF (%) for the area or zone under consideration. The application will calculate a new irrigation operation run time (minutes) based on these inputs and the current LF calculated from the previous tip counts. The Arduino records tips at the end of each day; however, the user may initiate a scan anytime to see current tip values.

The LF History screen (**Fig. 9**) reveals the current LF and run time RT, as well as the desired run time (RTT) to achieve the desired or target LF (LFT). The RTT value (minutes) was used to set the irrigation controller to achieve the LFT (%).

Evaluation of the mobile application and Arduino for determining the LF of container plants is currently underway at the University of Florida, IFAS, Gainesville, Florida. The Arduino and battery were placed in water-tight plastic tub and connected to tipping gauge with flexible insulated wire. A photo of an Arduino connected to tipping gauge is given in **Fig 10**. The LF assembly and Arduino remain in the field or irrigation zone, ready for the next irrigation. Hence, the user does not spend time getting ready for the next LF test.

Fig. 8. The user inputs information needed at the settings screen for the application.

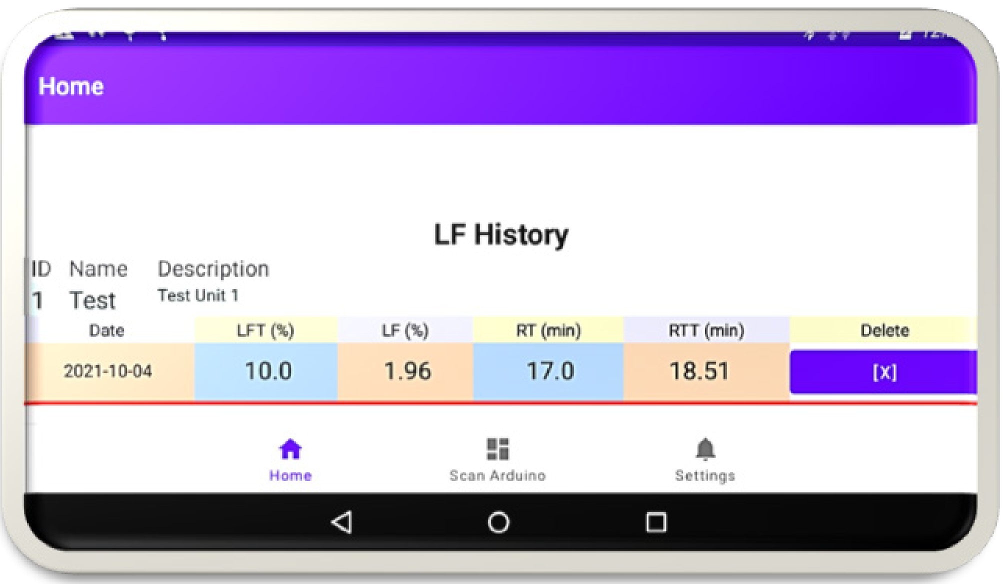

Fig. 9. The RTT value is used to set the irrigation operation time to achieve the desired leaching fraction (LFT) of 10 %.

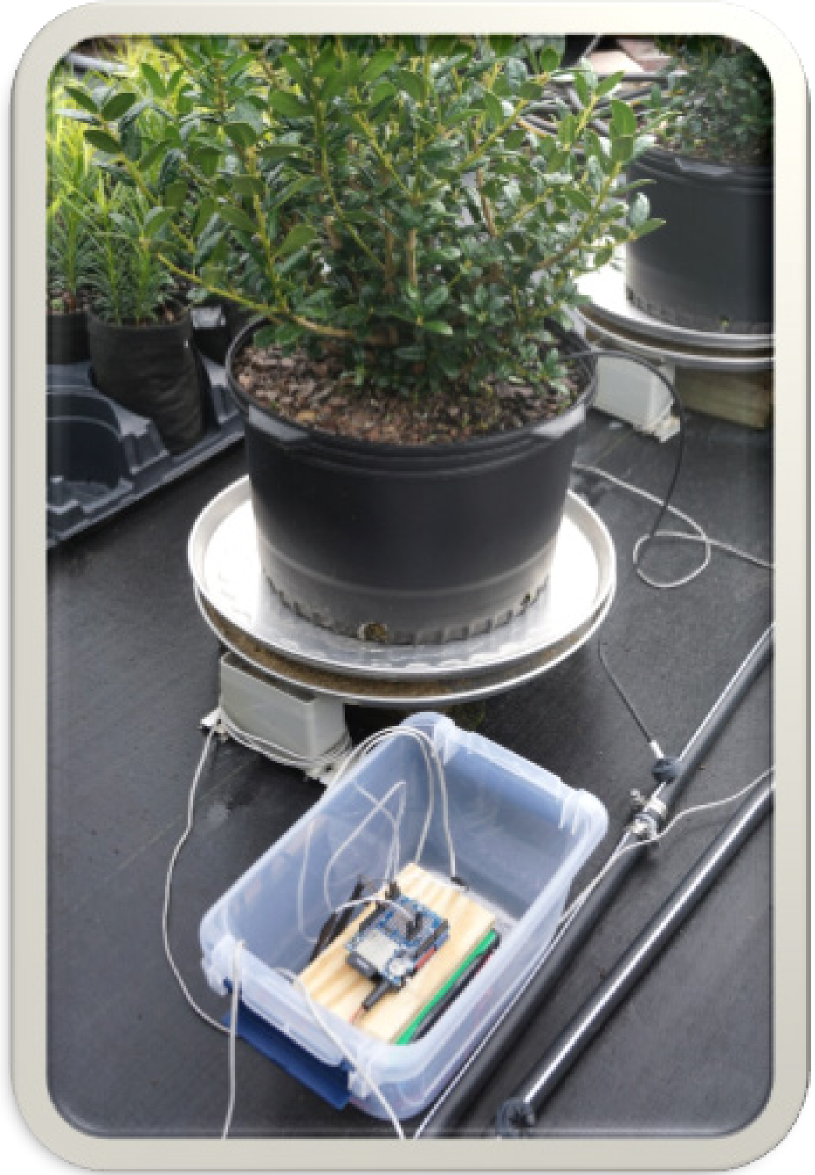

Fig. 10. Arduino in plastic tub is connected by wire to tipping gauge under hole in pizza pan.

Table 1. Preliminary data for average tip counts obtained via mobile application that was Bluetooth connected to Arduinos or electronic digital counters wired to tipping gauges.

Date	Irrigation Line	Arduino with Mobile Application	Electronic Digital Counting
	ID Number	Average Counts for Four Gauges	Average Counts for Four Gauges
Nov. 23, 2021	2	282	284
Nov. 23, 2021	7	307	334

Preliminary counts obtained with tipping gauges at University of Florida are given in Table 1. These limited data indicate a maximum variation of 27 tips that accumulated over two irrigation cycles. Additional data will be collected to help understand the variation in tip counts that might occur in the field.

The Future

Future evaluations in the nursery will provide insight regarding the number of LF assemblies and Arduinos needed for managing an irrigation zone for optimal crop production as well as tailoring the mobile application for efficient use. Producers may relocate LF assemblies and Arduinos as needed or make additional assemblies and purchase components rather than moving them. Currently, Arduino with the data shield that facilitates data storage when power is lost costs approximately fifty dollars and recyclable batteries are twenty-five dollars. Arduinos can be powered off to conserve energy; however, the longevity of battery power has not been determined. A tipping gauge is approximately twelve dollars, depending on quantity purchased. All components have been purchased at websites of vendors. Thus, monitoring LF for two containers requires approximately one-hundred dollars of electrical components compared with a single electronic substrate moisture sensor that exceeds one-hundred dollars. In addition, a moisture sensor should be calibrated and removed from the container before sale. Additionally, the moisture sensor will likely require a network or grid of electronics in the greenhouse or in the field where lightning is a detriment.

How will the producer determine the substrate moisture status or how much irrigation to apply in the future? Whether it is a future of LFs and Arduinos or sensor-based technology - time will tell. However, we can count on a future filled with electronic-based tools not only for managing irrigation, but for accomplishing most tasks in the environmental horticulture industry.

Tom Yeager spent his teenage years helping a neighbor with growing container plants. His inquisitive mind had many questions about why things were conducted a certain way and he often wondered if there was a better way to accomplish the task. After completing undergraduate studies, Tom was employed by a wholesale nursery. That was an opportunity to ground-truth some of his inquisitiveness that later culminated in a move to graduate school where the inquisitive hypotheses could be rigorously tested and new methods developed for growing plants. TOM IS NOW CELEBRATING 40 YEARS WITH IFAS.