GROWING KNOWLEDGE

Series content is coordinated by Dr. Jay Pscheidt, professor of botany and plant pathology at Oregon State University in Corvallis, Oregon.

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Figure C. Soil moisture sensors and solar-powered data logger installed in the field of young maple trees. Cabling and installation has to be situated out of the harms way of tractors and other field equipment. PHOTO COURTESY OF OREGON STATE UNIVERSITY

Sense and sensor ability

NWREC's Irrigation Classroom evaluates how to best use soil moisture sensors to improve water use efficiency

BY LLOYD NACKLEY

PERHAPS IT GOES WITHOUT saying, but the millions of trees, vines and shrubs — growing on thousands of acres — require large amounts of water and fertilizer.

As a large consumer of water, agriculture has been vilified for assumed water-intensive products. Increasing human population and extreme weather are further exacerbating competition for limited water supplies.

These natural and political constraints on water resources drive growers to be ever more efficient with the water that is applied to crops. However, perennial crops are fundamentally different from field or row crops, and therefore require different irrigation management plans. Trees, shrubs, and perennial vines have longer lifespans, greater rooting depths, and may have substantial variations in water-use between cultivars.

Despite the biological complexity of nursery production systems, many growers choose to use broad coverage overhead irrigation systems, and change valves on clocked, calendared, or "at-need" schedules.

Incorporating technology is often promoted as a solution to improve crop water-use efficiency, which is defined as a unit of water (e.g., gallon) applied per unit yield (e.g., plants). It has been widely demonstrated that incorporating soil-moisture sensors (SMS) can be an effective way to improve and increase efficiency. These sensors can continuously provide precise information, reflecting soil moisture status before and after irrigating.

Research with sensor-based technologies has shown irrigation efficiency » increases from 30–80% from the adoption of the sensor and modeled based programs. Estimating that fertilizers and water are 20% of an operating budget, even a low-end (30%) improved efficiency would result in annual savings of millions of dollars statewide.

Furthermore, sensor-based irrigation management directly addresses labor shortages by providing labor-saving technologies. Switching valves, checking lines or emitters, and moving pipes are time-consuming tasks, especially on large acreages. Having automated controls, or alert systems, can reduce the need for manual irrigation managers and allow growers to refocus labor on other tasks.

Factors pushing for greater adoption

At this point, SMS-based irrigation control has not been widely adopted by Oregon nurseries. Cited reasons for lack of adoption include high costs and technical barriers like computer programing required to integrate control and poor user-interfaces to access and analyze data.

However, continuous advances in distributed wireless networks, the internet of things, “smart” devices, and low-cost sensors are now making the option of using SMS-controlled irrigation more feasible than many growers may realize.

There are more options than ever, with new agriculture technology companies, or new sensors from established agriculture companies, offered every year. This surplus of services can be a barrier too. Too many choices make the right choice all the more difficult (Figure A, next page). We recognize this difficulty, as well as the opportunity, and are working with OAN members to provide information about robust, precise, and affordable SMS for nursery production.

This article will outline the basic principles of SMS for nursery systems and share a few of the on-going research and Extension projects currently being conducted by researchers at Oregon State University.

Soil moisture sensors basics

There are two main types of soil moisture sensors: 1) sensors that measure the volume of water held in the soil and 2) sensors that measure the tension (force) that the water is held in the soil. A chart called “a soil moisture release curve” can be used to correlate these two measurements, volume, and tension, for any given soil-type or substrate blend (Figure B).

For people, volumetric moisture sensors provide more intuitive information, akin to a rain gauge or other volumetric measurements. Volumetric moisture sensors commonly report the volume of water as a percentage, and sometimes in a decimal form of a volume ratio (e.g., $cm^3\ cm^{-3}$).

For plants, however, tension moisture sensors, often called tensiometers, are more relevant because the information provided (in units of pressure) equates to how much energy the plant must exert to extract water from the soil. Common units of pressure used to describe soil moisture tension include kiloPascals (kPa), bar, and pounds per

Soil moisture sensor overview

- Sensors are placed at predetermined depths based upon manufacturer guidelines and crop requirements.
- Data is recorded and stored on-site; or is transmitted wirelessly via modem, radio, or Wi-Fi directly to a computer or cloud-based data storage.
- The raw data can be exported for processing in spreadsheets, databases, and statistical programs; or further processed by software provided by the manufacturer or an aftermarket supplier.
- Software generally consists of a graphical user interface providing for easier interpretation by the user.
- The available software allows the grower to set low soil moisture thresholds to indicate when to irrigate
- SMS-controlled irrigation applies optimum water volume to replace soil-water depletion, thereby improving plant health and WUE
- SMS is an effective irrigation management tool for most agronomic crops.
- SMS=controlled irrigation benefits extend to energy efficiency as less electricity is expended to run pumping equipment

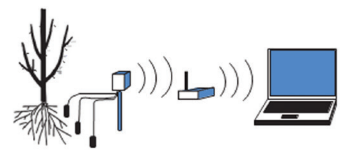

Figure 1. Sensors in the field feed data to a data logger which can wirelessly transmit the information to a computer

Figure A. There are so many options on the soil moisture sensor marketplace that it can be difficult for someone new to this area to decide which sensing system would work best for their operation.

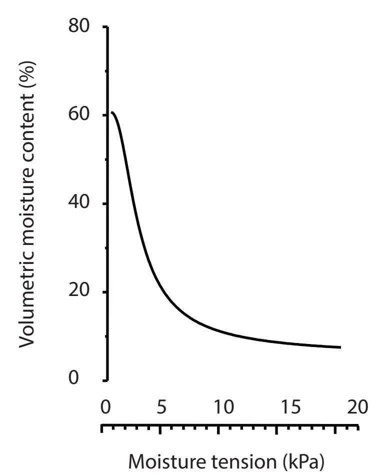

Figure B. Generalized soil moisture release curve relating soil moisture tension in kiloPascals to volumetric moisture content.

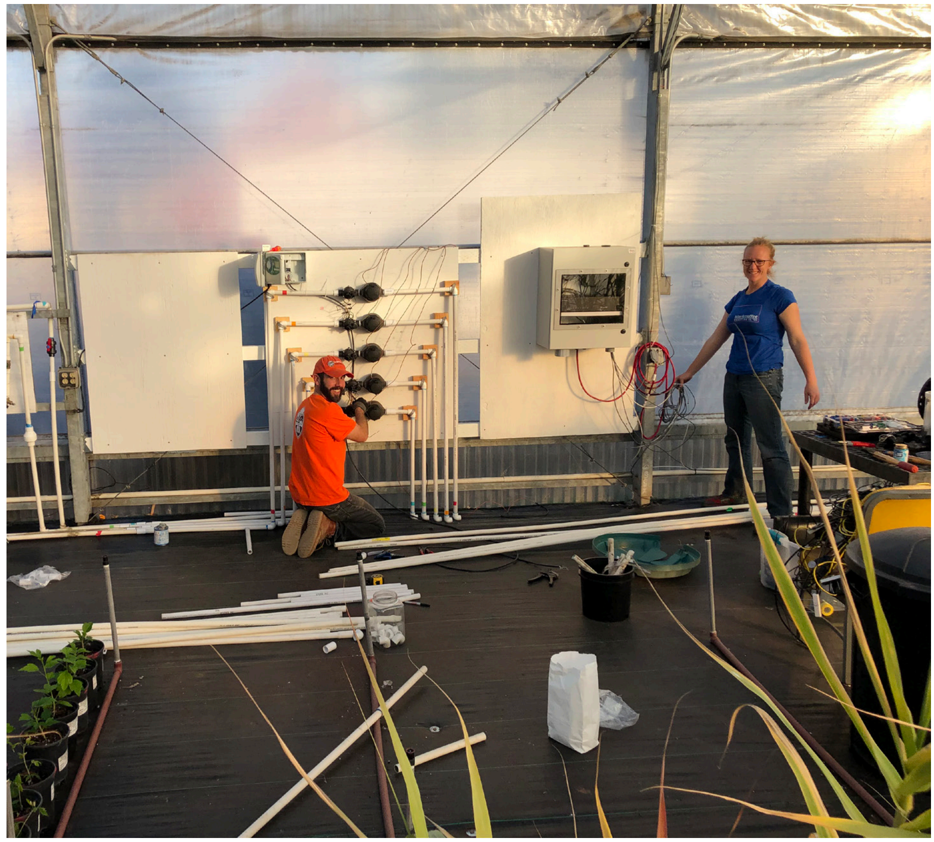

Figure D. Irrigation classroom being built at NWREC. The laborer is connecting flow meters to valves which can all be controlled by the data-logger large box on the wall, which is connected to sensors. PHOTO COURTESY OF OREGON STATE UNIVERSITY

square inch (psi). There are excellent examples of brands and technologies from both sensor types. Typically the choice of sensor boils down to grower preference.

When evaluating the utility of an SMS, it is important to consider the volume of soil measured, which is sometimes called the area of influence. This is the area in the soil or substrate that the sensor is measuring. For some sensors, this area of influence can be very close to the sensor — a 3 cm^3 volume of soil. For others, the strength of the signal can be as great as 10 cm^3. Even if the sensor could accurately detect moisture in 1000 cm^3 volume of soil, this volume is exceedingly small in the context of a field full of thousands of deeply rooted perennial plants.

Therefore, we recommend installing multiple sensors at multiple depths to capture the "dry-down" profile. Newer sensor models incorporate this design feature and offer multiple sensing depths within one probe that can be inserted into the soil.

Another very important aspect to consider is how the sensors will be used by the farm crew. It is not effective to purchase thousands of dollars of sensors and assume that irrigation will now be automated. Sensors require human intervention for installation, and maintenance, management.

Installation is very important because the sensors need to have adequate contact with the surrounding soil. Air pockets will lead to inaccurate measurements. For this reason, care must be taken especially in soils that have high shrink-swell, like many of the clay soils we can find in the Willamette valley.

Additionally, many of the sensors are cabled and must be able to fit within a row or planting system and not interfere with cultivators, sprayers and other equipment that can damage and destroy the sensor and logger (Figure C). It is not a "set it and forget it" situation with SMS, as some sensors need to be checked for accuracy on a weekly or bi-weekly basis. More accurately, it is a "use it or lose it" situation with SMS.

To generate a return on investment the data generated by sensors must impact irrigation decisions. It is possible to connect SMS to an irrigation controller that can open and close valves automatically. Other options include SMS transmitting data to computer, tablets, or smartphones, to inform irrigation managers of the soil moisture condition to know when to open and close irrigation valves.

Making sense of the sensing market

The Nackley Lab has established an Irrigation Classroom at the Oregon State University North Willamette Research and Extension Center (NWREC) in Aurora, Oregon. The purpose is to demonstrate sensor-based irrigation manager practices that can help growers become more familiar with the different sensing options and how the sensors may be incorporated into container and field-based operations (Figure D).

The field segment of the Irrigation Classroom is a demonstration and evaluation of the performance, consistency, accuracy and affordability of six commercially available soil moisture sensors: three volumetric sensors, and three tensiometers. The first year of the evaluation produced results that suggest highly variability within and between types. This type of variability suggests the need for multiple sensors within a field to generate reliable averages.

Since each sensor currently costs a couple of hundred dollars, at scale a grower would be looking at $10,000 investment. This type of financial commitment can be easily returned within a year or a few years if the data is reliable and actionable. That is why our research is so critical.

The container segment of the Irrigation Classroom also investigates sensor performance, consistency, accuracy of volume and the efficacy of tension-based sensors. Thanks to support by the Oregon Association of Nurseries, in 2020 we will also be evaluating weight-based sensing, which is known as lysimetry.

For containers, we also investigate how sensors can be used to compare the water holding capacity of different substrate blends and the interaction of substrates with different container types. Nursery production systems are so unique in the plants, pots, and substrates used. The possible number of combinations is great. It is our goal to produce actionable, generalizable information that can be translated to a majority of growers.

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