Sensor Network Deployment and Implementation in Commercial Nurseries and Greenhouses

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Abstract

Since testing of wireless sensor networks (WSNs) began in 2009, WSNs have been deployed in a variety of commercial horticulture operations. In deploying these WSNs, a variety challenges and successes have been observed. Overcoming specific challenges has fostered improved software and hardware development as well as improved grower confidence in WSNs. Additionally, members of this collaborative research project have observed growers utilizing WSNs in a variety of ways to fit specific needs; resulting in a variety of commercial applications. Some growers utilize WSNs as fully functional irrigation controllers. Other growers are utilizing components of WSNs to verify grower-controlled irrigation schedules. For example, early adoption of WSNs often begins with implementation of WSNs as irrigation monitoring via WSN software, without utilizing control capabilities. Only after grower(s) become comfortable with software and trusting of the WSN probe's ability to monitor correctly the water content of soilless substrate is WSN control capability instituted.

Introduction

The greatest challenge for many producers, with any technological advance, is the ease with which that technology can be effectively implemented and used. For this reason, our commercial horticulture partners in Georgia (McCorkle Nurseries, Inc. and Evergreen Nursery, Inc.) were selected based on their propensity to be early adopters of technology and their willingness to implement prototype systems within commercial production environments. McCorkle Nurseries is a large, shrub and tree grower, focusing on container sizes between 1 and 25-gallons that are overhead (impact rotors) irrigated. Evergreen Nursery is a mid-sized, groundcover and perennial grower, focusing on container sizes of 1-gallon or smaller that are overhead (impact sprinkler) irrigated.

Design, setup and installation of wireless sensor networks (WSNs) is covered by other 2012 IA proceedings articles and hence will not be discussed here (Lea-Cox and Belyaneh, 2012). However, deployment and implementation of WSNs, with a focus on grower adoption and confidence in WSNs, will be the focus of this article. Deployment and implementation of WSNs at both of the cooperating growers included two phases. In phase 1, initiated in 2009-10, systems were installed at both operations that *only* monitored soil moisture. During this phase, growers had the opportunity to view soil moisture and other environmental conditions (e.g. temperature, relative humidity, vapor pressure deficit) (van Iersel, 2012) graphically via a web-based interface called SensorWeb, developed by Carnage-Melon as part of this project (Kantor and Kohanbash, 2012). SensorWeb, as a monitoring tool, was a valuable resource for growers to determine if too much or too little irrigation was being applied and if irrigation scheduling should be altered to include or exclude cyclic irrigation, scheduled cycle skips to allow for dry down, syringing cycles to cool foliage, etc. During phase 1 of this project, growers and researchers constantly provided feedback on hardware (Kantor 2012), and more importantly software (Kantor and Kohanbash, 2012) bugs and successes, in order to create a graphical user interface (GUI) that best served the grower and allowed for customization based on grower needs. Overall, both grower cooperators were extremely pleased with the monitoring ability of the WSNs. More importantly, utilization of WSNs to monitor soil moisture levels caused substantial and nursery-wide changes in irrigation behavior that improved plant health without negatively affecting profitability (due to increased production costs) or production cycles (by lengthening cycles) (Majsztrik et al., 2012).

Phase 2, initiated in 2011-12, maintained the same software and hardware from phase 1 (with only slight upgrades) while incorporating the ability of the WSNs to monitor and *control* irrigation (Lea-Cox and Belyaneh, 2012). Irrigation control is achieved by setting a minimum soil moisture level in the software/GUI. When soil moisture drops below the set point, the software will initiate a predetermined irrigation cycle, defined by the grower in the software GUI (Kantor and Kohanbash, 2012). Irrigation control, unlike monitoring, has required retrofitting of existing irrigation systems to ensure solenoid control is linked to WSNs and not standard timers. In doing so, several hardware issues have been identified and remedied, particularly residual voltage that can cause solenoid malfunctions. Despite these challenges, as in phase 1 of this project, utilization of WSNs to monitor soil moisture levels has caused substantial and nursery-wide changes in irrigation behavior that has improved plant health without negatively affecting profitability (due to increased production costs) or production cycles (by lengthening cycles). In fact, cropping cycles have been reduced, disease incidence and severity have been reduced, fertilizer use has been reduced and plant growth regulator use has been reduced as a result of monitoring *and* controlling irrigation by using WSNs (Majsztrik et al., 2012).

The story of system deployment and implementation at these two nurseries will be presented as a case study broken into phase 1 and phase 2 of deployment and implementation.

McCorkle Nurseries

Four WSNs were installed in a 1-acre production area to monitor substrate water content in various gardenia crops in 2010. However, due to our desire to study comparative water use between a monitored system and a monitored and controlled system, control capability was quickly initiated. To control irrigation we used MoistureClick irrigation controllers (Dynamax, Houston, TX) (Fig. 1).

Figure 1. A MoistureClick irrigation controller with soil moisture sensor.

We compared water use of plants irrigated with these controllers to water use in plots irrigated by McCorkle's irrigation manager. Most of the crops were inside a large greenhouse (Fig. 2), with one crop grown outdoors on a gravel pad.

Figure 2. An overview of the study with gardenia 'Heaven Scent' at McCorkle Nursery.

The most interesting results from our work at McCorkle Nurseries, Inc. in 2010-11 came from a study with gardenia ‘Heaven Scent’, a problem crop for this and many other nurseries. This cultivar is very susceptible to a variety of pathogens and growers typically lose about 30% of the crop to water molds (root pathogens). By monitoring and controlling irrigation using soil moisture sensors, we hoped to minimize overwatering and reduce disease. Surprisingly, we found that water use was similar. Unbeknown to us, McCorkle’s adjusted the irrigation in their plots to match the volume of water that was applied in plots controlled by MoistureClick controllers, as determined by flow meters that tracked irrigation volumes of the two treatments.

Although this study appeared to be a total loss from a comparison perspective, we noticed that disease was not a problem in this crop. Additionally, plants grew much faster than normal and the production time was decreased dramatically (6-9 months) (Fig. 3). By reducing diseases and shortening the production cycle, there was an economic benefit of roughly $1/ft2. This does not take into account the reduced need for fungicide applications or the opportunity cost related to the ability to start growing another crop in this same space (this was greenhouse space, which is highly valued). Clearly, the payback time for wireless networks is very short if such financial returns can be obtained!

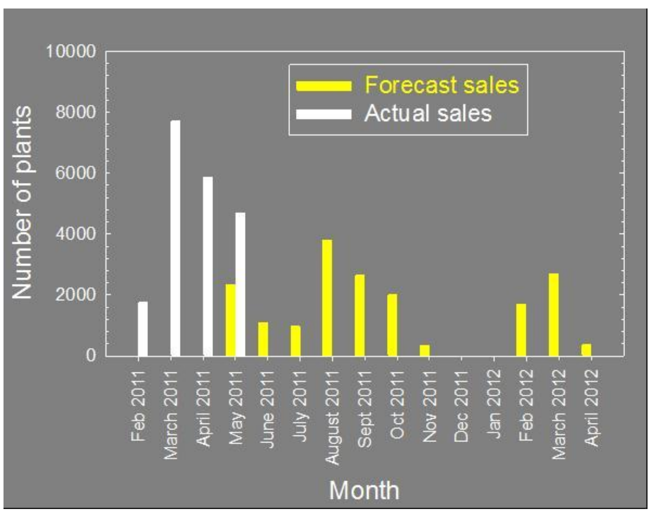

Figure 3. Forecast and projected sales of gardenia 'Heaven Scent'. Note that better control of irrigation resulted in much improved growth and quicker sales. The sorter production cycle reduced production costs.

In 2011-12, the wireless sensor network at McCorkle Nurseries has been upgraded to Decagon nR5 nodes with fully automated irrigation control in two nursery locations; one 2-acre covered house and another 4-acre production house. Also, unlike the previous system, the updated monitoring and control system was wired directly into the existing McCorkle’s control timer. During this process, some hardware issues in the Decagon nR5 nodes were identified. Examples include; the relay in nodes was not sized to facilitate control of more than 3-4 solenoid valves with a single node and there was an issue with AC current 'leakage' in the 24 VAC detection circuit. After many trials and errors, the system became fully functional in late April, and we have been controlling irrigation in a 2 acre greenhouse since then. We initially used 8 Decagon nR5 nodes to operate the 54 valves in the 2 acre greenhouse. Each valve controls water flow to multiple overhead, stationary sprinkler heads. We have since scaled this back to 7 Decagon nR5 nodes, based on the crops that are currently grown in this greenhouse. Having such a large number of valves in the greenhouse created significant challenges in setting up the network, but now that it is in place, also provides McCorkle Nurseries with much flexibility in how they can configure the system. They can easily change what valves are controlled by what node, and are thus able to reconfigure the irrigation setup based on their production needs.

Initial results of the irrigation control at this nursery have been stunning: the first crop that was grown completely using the sensor network was a gardenia 'Heaven Scent' crop that was placed in the greenhouse on June 18, 2012, with an anticipated finish data of July 2013 (Fig. 4). Growth rate of the plants was much faster than anticipated and some of the plants were ready for sale in September 2012, and all plants will be finished this fall. McCorkle Nurseries may not sell all plants this fall, but that is due to market limitations, and not the salability of plants themselves.

Figure 4: The first gardenia crop irrigated entirely using the wireless sensor network. Note that the anticipated finish date on the label on the right was May 2013. Plants were all ready for sale in fall 2012.

Following the very positive results seen in this 2-acre greenhouse, we have now installed Decagon nR5 nodes (with Decagon EC-5 sensors) in a 2nd, 4-acre greenhouse. The configuration of the irrigation system in very different from that in the greenhouse were we installed the first part of the network: the 2nd greenhouse has only two valves, each controlling approximately two acres of irrigation using overhead impact sprinklers. This greenhouse is currently used for hydrangea production.

Evergreen Nursery

Initial setup of the WSN at Evergreen nursery was initiated in 2010, with the goal of monitoring irrigation practices. The wireless sensor network at Evergreen consisted of four Decagon EM50R loggers that transmitted data to a Base Station at the nursery office. One of the Decagon EM50R loggers functioned as a weather station with a temperature and humidity sensor, light (PPF) sensor and rain gauge. The other three loggers were used to monitor substrate water content in several different crops (e.g. gaillardia, Heuchera, and ferns). Will Ross, the grower at Evergreen, monitored the system and utilized the information to help him make daily irrigation decisions. From looking at the data, Will noticed that some of his crops (e.g. gaillardia) were drying out faster than he realized. To reduce drought stress and improve plant growth, he changed irrigation practices for his gaillardia crop from once a day to twice a day; with smaller irrigation volumes at each irrigation event. This allowed him to better meet the water demands of the crop while minimizing leaching. The computer screenshot below (Fig. 5) shows that Will changed the manner that he irrigated this crop on October 14, 2010. The pink bars show irrigation events, and while he initially irrigated once a day, you can see that he switched to watering twice a day while reducing the amount of water applied at each irrigation event.

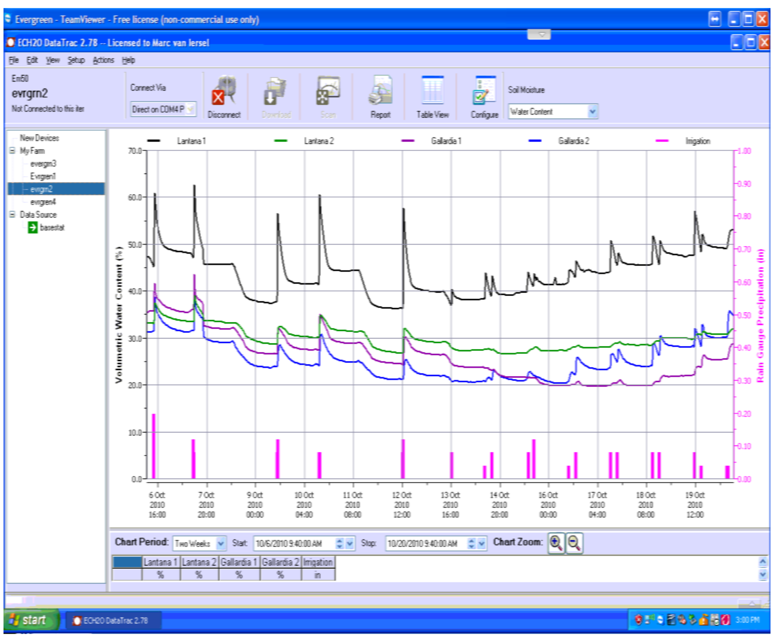

Figure 5. A screenshot for the computer at Evergreen displaying substrate water content measurements (lines) and irrigation (pink bars). Note the switch to irrigation twice daily during the latter part of this period.

Will Ross also focused on trying to reducing leaching. We have worked together on interpreting the data, and have looked specifically at the rate of decrease in substrate water content following irrigation. Since Evergreen uses small containers, we felt confident that a rapid decline in substrate water content following irrigation is indicative of leaching (rather than the water draining to part of the substrate below the sensor). We introduced Will Ross to the ‘Delta VWC’ tool that has been incorporated into SensorWeb at our request. Delta VWC shows the change in substrate water content since the previous measurement and is ideally suited for monitoring leaching. This is but one example of how grower input has resulted in improvements of software and/or hardware products being developed as part of this project.

In 2012, the WSN at Evergreen was upgraded, with the addition of several Decagon nR5 nodes over the summer of 2012. Will Ross, the grower at Evergreen (Fig. 6) had been using WSN data to help him make better irrigation decisions (including switching from once daily to twice daily cyclic irrigation to reduce leaching in 2011).

Figure 6. Will Ross, grower at Evergreen, in a cold frame at the nursery. Note the wireless node above his head, and the rain gauge among the plants used to monitor irrigation. Four pots have sensors to measure substrate water content.

The current network configuration consists of three Decagon EM50 and five Decagon nR5 nodes (Fig. 7). All nodes are using Decagon EC-5 sensors and the Decagon nR5 nodes have been configured for irrigation control. The nR5 nodes are controlling irrigation in five hoop houses and two small greenhouse sections (one of which currently is uncovered). Crops grown in these sections include heucheras, euphorbs, echinacea, lavender, and hellebores. The automated irrigation was started in early August and it is still too early to determine if it has any clear effects on crop health or production cycle speed. However, the system has worked well and all crops appear to be doing well.

Figure 7. An nR5 node used as part of our wireless sensor network. Up to five sensors can be plugged into the ports at the bottom. On the right side there is a relay that can be used to open and close irrigation valves (red and white wire). The nodes transmit all collected data to a base station and computer using a radio signal.

Conclusions

These two case studies exemplify the enormous strides that can be taken in product development, deployment and implementation when researchers work hand-in-hand with commercial growers. This research project has resulted in successful WSN implementation at two commercial nurseries in Georgia that now trust and rely on WSN data to mot only monitor substrate moisture but to also control substrate moisture via 100% automated irrigation control. Not mentioned in this article, but of vital importance, is that similar grower implementation of WSNs, related to this project, is occurring in Maryland, Colorado, Tennessee and other states. When asked if growers would invest in a commercial product, the response is a unanimous yes. When asked why, growers point to reductions cropping cycles, disease incidence and severity, fertilizer use and plant growth regulator use; all as a result of monitoring *and* controlling irrigation by using WSNs.

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