The Pioneer Grant Program

The 2016 Pioneer Grant Program aims to reduce nutrient and/or sediment contaminant loads to the Maryland portion of the Chesapeake Bay and Maryland Coastal Bays from any nonpoint source: agriculture, urban or suburban stormwater, air, and septic by seeking proposals that focus on new techniques, information, or programs that increase the rate at which load reductions can occur.

University of Maryland Cooperative Extension Service

Irrigation Sensor Technology to Reduce Nutrient Runoff from Intensive Agricultural Operations

2006-2009

Project Track: New technology

Research Question: Does sensor technology allow for better control of irrigation, hence being more efficient with nutrient distribution?

Research Results: Despite network connectivity issues during the second year, the sensor system functioned better than traditional cyclic irrigation systems. Research will continue to see exactly how much more efficient this technology as the technology itself improves.

Notable Information: In the nursery industry, irrigation management is the key cultural practice that determines the extent of nutrient runoff into receiving waters of the Chesapeake Bay. Presently, most irrigation systems are on a timer system, which does not account for actual plant water needs. The benefits of this monitoring and control system will be realized y significantly reducing irrigation volumes and nitrogen/phosphorus runoff into the Bay watershed.

PROJECT PARTNERS

UNIVERSITY OF MARYLAND EXTENSION
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Carnegie Mellon
THE ROBOTICS INSTITUTE

Flowers by Bauers

University of Maryland Cooperative Extension Service

Irrigation Sensor Technology to Reduce Nutrient Runoff from Intensive Agricultural Operations

2006-2009

Summary of Project

Calibration of Moisture Probes

EcH2O capacitance sensors (Decagon Devices, Pullman, WA) were calibrated to a range of soilless substrates (potting soil) with differing physical properties. This calibration procedure determined two important objectives 1) testing the probes' ability to accurately monitor water content and 2) to determine water content set points in these substrates. The calibration procedure involved the use of ac custom-built desorption table. The tables allows us to simultaneously desorb (remove) water from substrates incrementally by applying pressure into the columns, thus mimicking what plant roots do when they pull water from soil. The methodology for the calibration can be found in Arguedas et al. (2007), but briefly, substrate is packed in columns and probes are secured in a lid on the top of the column. Columns are filled with water and allowed to drain to "container capacity" similar to a nursery container after irrigation. As pressure is applied to the desorption tables, water expressed out the bottom of the column is collected and measured at every pressure increment. Simultaneously, probe data is taken which corresponds to the water content in the substrate.

A simple explanation as to the purpose of calibration is as follows. After irrigation, the moisture in the container is at "container capacity". At this point, plant roots do not have to work very hard getting water and this water is considered "readily available water" (RAW). Plant roots apply suction to extract that water. Suction is generated by cell growth and evapotranspiration (the movement of water through the leaves to the atmosphere). As water is "sucked" out of the substrate, it becomes more difficult to extract and less available. The readily available water is the easiest to extract but there is a point at which plants can no longer pull water out of a soil, a term called "unavailable water". At that point, you lose growth. In organic substrates that point occurs sooner than in mineral soils. In fact, over 60% of water in many organic substrates can be unavailable. It may be moist to the touch, but that moisture may not be available to plants. In determining set points by calibrating these probes, we identify the point at which water becomes unavailable through the use of a water release curve, generated by the desorption table. At that point, irrigation can be turned on before all available water is "sucked" out by the roots. We can also use the point of container capacity to determine when to turn the water off, as to not over apply and minimize nutrient loss from leaching. To sum up the last paragraph, there are two points we are looking for; a point to turn irrigation on before substrate water becomes unavailable to the plant, and a time to turn irrigation off-at container capacity.

These experimental runs were repeated 3 times for each substrate for a total of 30 individual data points. After the experimental run, water release curves were generated for each substrate, in similar size columns. Both 5-cm and 20-cm probes were calibrated in this way. The area between 1 and 10 kPa is the critical set point area or the area between readily available water and unavailable water. T

The precision of these sensors was confirmed with all soilless substrates tested, although the results revealed that a surprising amount of the total water in these substrates was beyond the commonly accepted range of readily-available water for plants. We are now confident that we can use these sensors, to more precisely schedule irrigation water applications, using the calibration curves from the data we derived in these studies.

Interestingly, new information about sensor interactions with fertilizer salts (electrical conductivity) has recently surfaced in consultations with the manufacturer, Decagon Devices and we want to investigate this issue further, since tis sense will be exceptionally important for nutrient management as a tool for the nursery and greenhouse industry. There is no reason to believe that the present calibration data has been confounded because the calibration runs utilized municipal water with very low electrical conductivity values.

Calibration and Verification of Moisture/Electrical Conductivity Probes
The real-time measurement of electrical conductivity (EC) allows a nursery manager to monito the availability of nutrients in the root zone of plants. The precision of EC sensors required for accurate monitoring of salt concentrations in soilless substrates, up until now was questionable. The sensors that we have been testing have this capability and will have profound consequences on precision nutrient management from nursery crop production as they provide growers with an indication of when fertilizer salts are either unavailable (too few nutrients) or to avoid the unintended buildup of salinity in the root zone, compromising plant growth. In all, this will provide nurseries with the tools to more efficiently apply irrigation.

Past studies have shown that the direct measurement of EC in soils may not be what the plant root is experiencing, due to the effect of both the salts in aqueous solution and electrical charge of the soil or substrate solids. The researched performed this past year (2008) allows us to more accurately determine EC around the plant root zone in real-time. This is a unique and novel tool for the irrigation manager to make responsive decisions about irrigation application. Further research looking a greater number of different substrates will verify our present assumptions.

Confirmation of Calibration Points (2007)
A wireless sensor network has been integrated into an alternative crop/sustainability project funded by AgroEcology Inc at Wye Research and Education Center in the fall of 2007. The plants in this project are being grown in 2 gallon containers filled with one of the calibrated substrates consisting of pine bark and peat. Using the calibration set-points for this substrate, wireless nodes and sensors were randomly placed in 12 to 24 plots each plot having 25 plants. In this experiment, the best management practice of cyclic irrigation where plants are irrigated more frequently at shorter intervals, is challenged by the wireless sensor network as ;a more efficient method of scheduling irrigation.

The wireless network computer or node created by Carnegie Mellon Robotics Institute. Consider this node as computer that stores and relays new information. These little nodes are about the size of a brick and they can be placed anywhere in the nursery. The nodes can “talk” to each other as long as one is within “line of sight” (they can see each other) of any other. The nodes send information to your computer, wherever that may be. Together with the moisture probes connected to the node, a grower can receive information about substrate water content in real-time. Additionally, the nodes use the probe data and calibration settings to determine when to irrigate by directly controlling the water valve.

In the 4 weeks of operation from late September into October, the system performed adequately, irrigating when the “on” set-point was reached and turning off irrigation before containers were up to water holding capacity. Cyclically timed irrigation was set for three times a day, delivering an average of 1 liter of water per plant per day for an average of about 30 liters per plant during the month with about 15% leaching from the pots. By comparison the wireless network controlled irrigation averaged less than one liter per plant throughout the month without leaching. These preliminary results suggest that this wireless sensor system can control irrigation, and minimize leaching better than a recommended BMP, however, we need a full growing season to determine the relative water-saving effectiveness of this network system.

Confirmation of Calibration Points (2008)
In the second season, starting in June of 2008, the wireless node system was activated and controlled irrigation for the summer and fall of 2008. The system again was compared to a time clock-scheduled irrigation management program. Due to complication with the wireless connectivity of the research site, node communication was limited. Set-point adjustments were not able to be made as frequently as needed, and the system under-irrigated the first part of the season and over-irrigated the second part of the season. However, despite the connectivity complications, the system did automatically irrigate according to the set-points provided, there was no question as to the ability of the system to control irrigation, regardless of the communication problems. Since that time Carnegie Mellon Robotics Institute is producing the next generation of nodes that will circumvent the wireless connectivity problems at the research nursery. Trials with this new system are planned for the summer of 2009.

Furthering System Deployment
As was originally planned in our initial proposal to deploy these networks in commercial operations, we were able to find other ways to achieve this goal. We utilized Raemelton Farm, a commercial in ground nursery in Adamstown, MD, owned by Steven Black, where we fitted a wireless sensor network (Decagon Devices) to monitor soil moisture content. At this nursery, we have been monitoring soil moisture for one growing season. Three sets of sensors were placed at 3 soil depths, of 6, 12 and 18 inches and soil moisture content is shown. While the Decagon System was easy to install and operate, it only had monitoring capabilities and lacks a control option for switching irrigation on or off.

Our partners (Carnegie Mellon) node system has been deployed at the greenhouse operation of Flowers by Bauers, a cut flower and floral arrangement business located in Jarrettsville, MD. This system has also been used for monitoring in a closed irrigation system (hydroponics) with perlite, an expanded glass substrate, being used as a rooting medium.

Project Evaluation

According to our extension programs, these goals were achieved within the first year of this project and further programming continuing into the second year (no-cost extension period), increased interest in this system.
Initial research phase: Calibration of sensor system
Outputs: Substrate calibration, research findings, educational programming to encourage adoption
Indicators: Irrigation set-points developed and tested
Baseline: Calibration Set points unknown
Project goal: Successful irrigation control achieved using set-points in different potting media. Successful extension education programming with at least 20 nursery and/or greenhouse businesses expressing interest in moisture sensing system

Transferability and Sustainability

As referenced in section *Summary of Results (2207-2008)*, the project research successfully calibrated proves so that they could be integrated with the Carnegie Mellon wireless node system in nursery operations using soilless potting media. The outcomes of the calibrations were measured through results with the Wye Research Wireless Network. At the very best, the system's efficiency in irrigation water use was better than the cyclic irrigation timing employed. When problems were encountered the second season with internet connectivity, making quick management decisions of the system difficult, the system performed adequately, and similarly to cyclic irrigation.

Monitoring and Maintenance

The systems, now deployed at both the Raemelton Farm in-ground field operation and Flowers by Bauers' greenhouse are presently being used as monitoring tools. Both have increased the awareness of soil/substrate water relations and plant water use. Irrigation decisions will be made at Raemelton Farm based on soil moisture data in the summer of 2009. The research at Wye Research and Education Center's experimental nursery will continue through the summer of 2009. With the wireless connectivity improved at the experimental nursery, the wireless system will again be challenged by the cyclic irrigation scheduling. We think that we will have similar results as in the fall of 2007 with greater irrigation efficiency than the cyclic irrigation scheduling.

Community Involvement and Outreach Activities

Extension Programming 2007
Since the inception of this grant we have offered extension talks concerning the application of this system. In 2007 these talks were included in local and regional programming and also national and international conferences including the Far West Show of the Oregon Nursery Association, the Southern Nursery Association Research Conference in Atlanta, International Plant Propagators Society Research Conference in Nashville, the GreenSys Research conference at the University of Naples, Italy, and the 4th Annual Conference of Irrigation Programming, Lleida Spain. Additionally, a Maryland Cooperative Extension Twilight Tour was offered at the end of October 2007 which exemplified the Wireless Network System in operation, utilizing the calibration data generated by this research.

Extension Programming 2008
In 2008, further outreach programming focusing on this research included the Sustainable Nursery Production Conference at Wye Research and Education Center, January 24th. In February our research team was invited to the 4th Annual Conference for Irrigation Programing in Lleida, Spain, where we were able to highlight out research to an international audience. WE highlighted our present research at the Maryland Nursery and Landscape Associations Annual (2008) summer field day, and also in September 2008 during a research field day hosted by Steve Black, owner of Raemelton Farm in Adamstown, MD. This field day event was sponsored by the Department of Agriculture and University of Maryland featured the first wireless network system placed in a commercial in-ground nursery operation. Over 70 guests attended, representing Maryland's nursery industry and state and federal government agencies.

Partnerships

University of Maryland, Carnegie Mellon Robotics Institute, Raemelton Farm (Adamstown, MD), and Flowers by Bauers (Jarretsville, MD).

Accounting of Expenditures

CBT Funds: $46,000
Total Funds: $46,000