# A National Perspective on Irrigation Trends and Sensor Network adoption in Ornamental Nursery and Greenhouse Operations

John Majsztrik[*1], Erik Lichtenberg[2], and John Lea-Cox[1]

[1] University of Maryland Department of  Plant Science and Landscape Architecture 2102 Plant Science Building, College Park, MD 20742

[2] University of Maryland Department of Agricultural and Resource Economics, 2200 Symons Hall, College Park, MD 20742

* Corresponding author: jcmajsz@umd.edu

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**Abstract**

The way that irrigation water is applied within ornamental operations is dependent on a number of factors including the type of operation, the amount and quality of water available, and the irrigation infrastructure present within each operation.  Wireless sensor networks can provide additional information which growers can use to monitor soil moisture and the microclimate in an operation, to determine how to irrigate more efficiently.  The results presented here are a part of a larger project aimed at developing the hardware and software required to implement irrigation monitoring and control networks in intensive horticultural operations.  As part of this project, we have developed and implemented an extensive survey, to understand current national perceptions, trends and practices for irrigation and water management in ornamental operations.  Surveys were distributed through regional and national grower organizations and state ornamental extension agents, as well as through trade shows.  The general perception of using sensor networks was found to be positive, with many respondents indicating that they thought these systems would benefit them at their operation.  In regards to irrigation practices, growers were found to rely heavily on qualitative methods, such as visual appearance, crop development, or time-based scheduling, compared with quantitative assessment methods, such as leaching fraction.  An integration of environmental conditions and plant response was often used for adjusting irrigation schedules in greenhouse and container operations.

## Introduction

How irrigation water is applied and how irrigation scheduling decisions are made have major impacts on plant growth, yield and quality. In ornamental operations, supplemental irrigation is typically required for greenhouse and container operations. Irrigation is often applied in field operations for establishing transplants and maintaining adequate soil moisture during drought. Irrigation managers base their irrigation decisions on a number of factors including crop type and maturity, container size, previous and future weather conditions, and type of irrigation system used (Majsztrik et al., 2011). The goal of an irrigation event is usually to provide the plant with enough water to replace the amount loss due to evapotranspiration, while avoiding nutrient leaching losses due to over irrigation. Current irrigation application is often applied in excess of plant water requirements to ensure adequate soil moisture (Lea-Cox, 2012). Applying irrigation more efficiently has the potential to reduce labor and water pumping costs, maintenance costs for equipment, reduce disease pressure and subsequent agrochemical application costs, and reduce crop production time. Until recently, it has been difficult to obtain real-time, accurate soil/substrate moisture levels. A national specialty crops research project is currently underway to correlate the impact of a better understanding of soil moisture and irrigation decisions on ornamental plant production using wireless sensor networks (Lea-Cox et al., 2010). For more information about this project, and our results to date, see additional articles by contributing authors in these proceedings (Chappell and van Iersel, 2012; Kantor et al., 2012; Kim, 2012; Kohanbash and Kantor, 2012; Lea-Cox and Belayneh, 2012; van Iersel, 2012), or visit the project website at www.smart-farms.net.

## Materials and Methods

An extensive survey was developed and targeted at greenhouse, container and field operations growing ornamental plants for wholesale or retail sale in the United States. Growers were contacted in two main ways, through emails and by direct contact at trade shows. For email contacts, ornamental nursery and greenhouse extension specialists were contacted in each state. The extension specialists were asked if they would be willing to help distribute emails through their listservs, and asked to contact state nursery and landscape and greenhouse organizations to help facilitate survey dispersal via their listserves. A state-level approach was used for several reasons. These listservs were likely to be the most comprehensive and up-to-date contact lists, and growers were thought to be more receptive to a survey being distributed through their state contacts. Also, there would be no breach of confidentiality, since we did not have direct access to email addresses. All extension specialists and grower organizations that were willing to participate were compiled into a database. Emails were sent to state contacts, who then forwarded the information on to their listserves. Survey responses are still being collected through the end of 2012, but preliminary results based on collected responses are presented here.

Growers were also asked to participate in the survey at tradeshows. Tradeshows were used to contact growers that might not be on listserves, and allowed for interaction with individual growers. Five tradeshows were visited across the United States (Maryland, Alabama, Ohio, California, and Oregon). Growers were asked about their operation to determine if they produced ornamental plants for wholesale or retail markets. If so, they were asked to fill out this anonymous survey, and were given business cards with information about the survey, and the web site for survey completion. All growers were given the option to "opt-in" by providing contact information at the end of the survey, for follow up purposes, but this decision was entirely voluntary.

## Results and Discussion

We do not know the total number of potential respondents that were reached through email and tradeshows, but there are approximaltely 39,000 operations in the US (Alan Hodges, Extension Scientist, Univ. of Florida, Pers. Comm.). Surveying by email led to a relatively high response rate, since individuals who received the email, but did not click to start the survey were not counted. A total of 132 responses have been collected to date, with 104 (79%) respondents indicating that they were willing to participate and met the criteria for participation (they worked at an ornamental operation). A total of 52 respondents (39%) completed the survey. Results provided below are based on the number of responses for each question, with a varying number of responses throughout the survey. The number of respondents and completed surveys is lower than expected, and grower participation will continue to be requested in the upcoming months. A large grand prize incentive was recently added, and it is hoped that it will increase response rates.

In order to determine where revenue was received, growers were asked about the revenue contributed by each type of operation. Container operations were reported to contribute an average of 44% of total revenue, greenhouses contributed 31%, field operations accounted for 23% of income, and other farming operations accounted for an additional 2% of income.

### A. Sensor Networks

Part of this survey assessed how likely growers would be to use irrigation sensor networks to provide real-time information at their operations, and the perceived benefits and drawbacks of these networks by grower / managers. When asked whether they would use a sensor network at their operation, 46% said they would be likely to use one, while 54% were unlikely to use a sensor network at this time. Considering that there was limited information in the survey about what a sensor network was capable of, and the benefits that were seen across a variety of growing situations, this was considered a relatively high positive response response rate. It is not likely that 46% of growers would use sensor technology, since this is a hypothetical situation, but the growers seemed to understand the potential applications of these kinds of systems to their operation.

Growers were asked what way they thought sensor networks would benefit their operation. Respondents believed sensors would increase irrigation efficiency (87%), increase plant quality (82%), reduce product loss (71%), reduce disease occurrence (69%), help manage growth rates (67%), reduce management costs (60%), and reduce monitoring and time costs (49%). Survey respondents saw the potential for sensor networks to benefit their operations, and had high expectations that these networks would help to produce better plants. It was not clear why growers had such a positive view of this type of irrigation technology. Based on results collected to date, sensor networks have been implicated in providing some of these benefits under a variety of conditions and production environments. Those same growers were concerned that sensors would be too expensive (77%), not reliable (52%), would not control irrigation correctly (45%), and would have too many maintenance requirements (29%). The major respondent concerns centered around cost and proper functioning, which are not trivial.

It is clear that the growers in this project, growing in a variety of locations and a variety of species and types of operations, see the benefit of these networks, and place a high value on the information that they provide. Sensor networks have been shown to reduce irrigation requirements in ornamental plant production (van Iersel et al., 2009; Chappell et al., 2012). However, initial cost and maintenance considerations may still be important considerations, depending upon the net benefit (return on investement) that sensor networks can provide(van Iersel et al., 2009; Chappell et al., 2012).

Saving irrigation-related (resource-use) expenses through the use of sensor networks will likely add a modest increase to the net profitablity of ornamental operations. In small operations, irrigation-related expenses accounted for 6.4% of their overall costs, 10.0% for medium size operations and 2.3% for large operations (Table 1; sum of water treatment, pumping costs, water purchases, labor for irrigation system and cost of irrigation maintenance). The cost of buying, pumping, and treating water and maintaining the irrigation system turn out to be a relatively small portion of an operation's expenses, although the percentage of cost appears to be higher in mid-sized operations compared to larger operations.

The real benefits of these sensor networks are derived from a combination of reduced irrigation costs, which can be significant in some situations, coupled with additional saving that can be realized through better control of irrigation. For example, deployment of a sensor network in a Gardenia (*Gardenia augusta* 'Heaven Scent'™) crop cut both production time and disease losses roughly in half; combined with savings in expenditures on fertilizer and fungicide use, these improvements in productivity more than doubled annual profit (Chappell et al., 2012). These experimental results, combined with the survey data on the relative importance of cost items associated with sensor use, suggest that the greatest financial benefits from sensors are likely to come from improvements in disease management, fertility management, and accelerated growth rather than from savings in irrigation alone.

**Table 1.** Weighted average percent cost by operation size, from a national survey of ornamental growers. Note that data is not segemented by operation type (e.g. field, container-nursery or greenhouse operation).

| Gross annual income ($) | **0-200,000** | **200,000-1,000,000** | **1,000,000 +** |
|---|---|---|---|
| Fertilizer | 2.66% | 2.34% | 2.02% |
| Disease management | 0.98% | 0.86% | 2.60% |
| Water treatment | 0.00% | 0.24% | 0.10% |
| Pumping costs | 2.04% | 1.48% | 0.65% |
| Water Purchases | 0.66% | 0.45% | 0.43% |
| Labor for irrigation system | 1.52% | 5.42% | 0.81% |
| Cost of irrigation Maintenance | 2.22% | 2.38% | 0.30% |

### B. Irrigation applications

Respondents were asked whether they monitored irrigation water (quality and / or quantity) at their operation. In general, monitoring rates were highest in greenhouse operations, which is not surprising since irrigation water quality has a major impact on plants, especially young plants. Irrigation water coming out of nozzles was monitored by 48% of greenhouse, 42% of container, and 32% of field growers. Container and field growers were more likely to monitor containment ponds (29% and 27% respectively) compared to greenhouse growers (16%).

The type of irrigation system has direct impacts on distribution uniformity, labor, and the volume of water required to irrigate a crop. Greenhouse operations most often used hand irrigation (32%), overhead (31%), drip (18%), and boom sprinklers (9%). Container-nursery operations most often used overhead irrigation (49%), drip irrigation (33%), or hand irrigation (18%). Field operations reported mainly using drip irrigation (56%), while 19% used overhead, and 18% used traveling guns.

Determining evapotranspiration, and therefore when and how much irrigation to apply is a decision that incorporates a number of environmental (i.e. temperature, humidity, wind speed) and plant-based factors (i.e. growth phase, container size, substrate water holding capacity) (Bacci et al., 2008). Growers were asked about the qualitative methods that they use to help schedule irrigation. Greenhouse growers most often (95%) use visual observations (apprearance, weight etc.), crop development (80%), time-based delivery which may or may not be adjusted for season or plant species (55%), and much less often an indicator plant species (17%). Container operations reported using visual observations (100%), crop development (80%), time-based (64%), and indicator species (24%). Field operations typically use visual observation (88%), indicator species (81%), crop development (69%), and time-based methods (50%), to determine when to schedule irrigation events. Visual observation was most often cited as the qualitative criteria used to determine whether irrigation should be applied.

Growers were also asked about quantitative methods that were used at their operations. Environmental conditions were most often cited as used to help schedule irrigations (85% greenhouse; 80% container and 56% field). Soil moisture sensors were reported to be used for 17%, 8% and 6% for greenhouse, container and field operations respectively. Measuring leaching fraction was reported for 20% of container-nursery operations and 6% of greenhouse operations. It is not surprising that leaching fractions were measured infrequently, considering the labor costs involved; however, it is a relatively quick and efficient way to measure how much of applied irrigation is leaching through a container, allowing for adustment of irrigation durations.

## Conclusions

Although survey responses are still being collected, these preliminary data suggest that growers believe that sensor networks have the potential to increase the efficiency of their operation, although there are percieved operation and maintenance issues. Irrigation decisions require the integration of a number of variables to determine when and how much irrigation should be applied. It appears that growers most often use qualitative, and to a lesser degree quantitative information to make irrigation decisions, which speaks to the overall cost structure of most ornamental operations, as resource costs are relatively low compared to labor and other costs. Understanding the true cost of over-irrigation (in terms of crop health and other cost issues) is likely an under-recognized factor in irrigation scheduling among ornamental producers. Recognition of the cost of reduced productivity due to inefficient water management is likely to increase demand for sensors and other forms of information provision that allow growers to improve irrigation management.

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