## 1. The 30,000' view.

Water quality and quantity are increasingly important concerns for agricultural producers and have been recognized by governmental and non-governmental agencies as focus areas for future regulatory efforts. In specialty crop systems, irrigation management is extremely challenging. This is primarily due to the limited volume of water available to container-grown crops after an irrigation event, varying cultivars within an irrigation block, and/or varying plant ages within an irrigation block. To prevent moisture stress, irrigation of specialty crops is often excessive, resulting in leaching and runoff of applied water and nutrients. For this reason, improving the application efficiency of irrigation is necessary and critical to the long-term sustainability of commercial specialty crop industries. The use of soil moisture sensing technology is one method of increasing irrigation efficiency, with on-farm studies described in many of the modules and impact statements located on this website. Since on-farm testing of these wireless sensor networks (WSNs) to monitor and control irrigation scheduling began in 2010, WSNs have been deployed in a diverse assortment of specialty crop operations. In deploying these WSNs, a variety of 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, growers are using WSNs in a variety of ways to fit specific needs, resulting in multiple commercial applications. Some growers use WSNs as fully functional irrigation controllers. Other growers utilize components of WSNs, specifically the web-based graphical user interface, to monitor grower-controlled irrigation schedules.

## 2. The specific challenge – freshwater is not infinitely available.

Managing the quality and quantity of global freshwater resources is one of the most imperative environmental challenges of the 21$^{st}$ century, with agriculture accounting for 70% of all global freshwater use. Population growth and increasing urbanization worldwide have elevated competition for freshwater resources among domestic, industrial and agricultural users, with agricultural water use deemed unsustainable in many parts of the world. As a dominant and growing segment of agriculture in the U.S., specialty crops are not immune to water quality and quantity issues. Several U.S. states have regulations in place and/or are under federal mandates related to watershed-based agricultural irrigation withdrawals, including specialty crop intensive areas such as the Chesapeake Bay watershed and Florida. Further restrictions are predicted by researchers and commercial nursery producers throughout the U.S. in the future. To meet the long-term freshwater needs of the world's population, it is critical to increase

the efficiency of agricultural water use. The use of moisture sensing technology is a promising avenue to address irrigation efficiency without compromising crop quality.

## 3. How can technology help?

The use of technology has historically been the cornerstone of improving irrigation efficiencies, first in arid lands and modernized nations and more recently in developing nations. Examples of irrigation system components used to increase irrigation uniformity in specialty crops include drip, micro-irrigation nozzles, and matched precipitation sprinkler nozzles. These technologies have been incorporated into best management practices for production of specialty crops, with the goal of reducing runoff of nutrient- and pesticide-laden water from production sites. However, good uniformity is only part of what is needed to achieve high efficiency, with the other component being application of the appropriate amount of water, based on crop water needs.

Recently released commercial irrigation controllers that have improved irrigation efficiency in specialty crops include evapotranspiration (ET) based controllers and ET plus daily light integral (DLI) based controllers. While appropriate for homeowner applications, these controllers have proven to lack the accuracy required for many commercial agriculture applications, as data is frequently gathered for calculation of ET from weather reporting stations distant from the production facility employing the controller technology. Additionally, if located on-site, instrumentation used to calculate ET and DLI can be inaccurate due to improper installation, calibration, and/or maintenance. For this reason, a simpler to operate and maintain irrigation control system, based on sensing of environmental conditions, is required for long-term adoption and use in commercial specialty cropping systems.

## 4. Why soil moisture sensing makes sense.

Jones (2007) concluded that monitoring of soil water content is the most valuable measure of plant or soil water status for the purpose of irrigation scheduling, as soil moisture monitoring consolidates all environmental conditions (e.g. temperature, light levels, humidity) into one measurement. For this reason, researchers over the last decade have initiated studies on the plausibility of utilizing soil-moisture based irrigation control to improve irrigation efficiency. Many studies have indicated that using on-site, real-time sensing technology to monitor and control irrigation events serves three

valuable purposes: 1) it reduces the number of environmental measures required to control irrigation to one, the volumetric water content of the soil or substrate; 2) it reduces the maintenance and calibration of sensors required to calculate an irrigation event to one, the capacitance-based soil moisture probe; 3) it utilizes on-farm data to determine soil moisture and therefore increases the precision and accuracy of environmental measurements compared to using measurements from off-site locations. Additionally, these data are easily integrated into existing, timer-based, irrigation systems and allows for easy automation. Despite a great deal of scientific work, no automated irrigation control system based on soil moisture has been widely adopted by specialty crop industries.

One reason for a lack of adoption of soil moisture-based sensor irrigation systems by commercial specialty crop industries has been a reluctance to implement any new irrigation technology without significant research, testing, and economic analysis; first in a controlled research setting and subsequently in on-farm settings. However, many soil moisture sensors have been developed in the last two decades that can be utilized in specialty crop agriculture systems. This includes the widely adopted Acclima TDT control system (Acclima Inc., Meridian, ID) developed for turfgrass applications. Yet, until recently, no soil moisture sensor-based control system (hardware) has been matched with a software package targeted to specialty crop producers. We have accomplished this goal, with the help of 2009 USDA-NIFA Specialty Crops Research Initiative funding and commercial partners Decagon Devices, Inc. and Mayim, LLC. The PlantPoint™ system, being released in 2015, should give growers a set of tools that affords them the ability to better monitor and manage not only irrigation; but also a host of other soil and environmental parameters.

*Jones, H.G. 2007. Monitoring plant and soil water status: Established and novel methods revisited and their relevance to studies of drought tolerance. J. Exp. Bot. 58:119-130.*