Nursery Production Technologies for Enhancing Water Quality Protection and Water Conservation

Principal Investigators:
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Project Objectives:
The broad objectives of the project are to develop economically feasible production systems and management practices that promote water conservation and protect water quality while sustaining or improving crop quality, production and profitability. Specific objectives include: improving water and nutrient use efficiency, capturing and recycling runoff, and remediating runoff containing excess nutrients and residual pesticides prior to offsite discharge. To achieve these objectives, the research team has engaged in research that addresses problems associated with (1) production inputs (i.e. predictive models), (2) production systems (i.e. irrigation control and substrate composition), and (3) production outputs (i.e. remediation of runoff). Together, the project takes a whole-systems approach to environmental resource management as the “dots” are connected from the fertilizer that leaves the “grower’s hand” to runoff that leaves the nursery.

Accomplishments:
1. Decision Support Tools for Preventing Water Quality Degradation and Waste. Progress and accomplishments have been made towards developing decision support tools that can be used by growers to assist in crop scheduling, in the efficient use of nutrients and water, and for estimating runoff quantity and quality. Two projects in the team have focused their efforts on developing decision support tools: Dr. Tom Yeager, University of Florida, and Dr. William Bauerle, Colorado State University. Dr. Yeager’s project “Development of a Web-based Simulation Tool for Managing Resources in the Container Nursery” is a plant production simulation model that does not require an extensive network of sensors, which are often cost prohibitive and can require maintenance and calibration for optimum functionality. Dr. Bauerle’s project “Measurement and Modeling Plant Water Use to Quantify Nursery Water Requirements” is a decision support tool that relies on both deployed sensors and remote sensing technologies. Dr. Yeager’s and Dr. Bauerle’s projects are relevant to container and field nursery production, respectively, and both are “real-time” tools that provide information to the grower based on current environmental and production data. Research into developing decision support tool models are completely new endeavors for the team since 2006.
Specific accomplishments for Dr. Yeager’s project include conducting the research and the development of mathematical descriptions for simulating growth and water and nutrient processes during container plant production. The resultant plant growth simulation model (CCROP, Container Crop Resource Optimization Program) uses weather data downloaded from the automated weather stations and critical management inputs to predict plant growth and water and nutrient requirements. A Web-based interface has been developed to provide a user-friendly means for selecting management inputs, running CCROP, and viewing outputs. Example uses of CCROP include 1) comparing the amounts of irrigation water applied and runoff generated using ET-based or fixed application irrigation scheduling, 2) comparing runoff nutrient losses as affected by irrigation and fertilizer application rates, and 3) comparing time to finish a crop as affected by geographical location and resource inputs. A real-time tool was also developed which can be used for daily ET-based irrigation scheduling.

Specific accomplishments for Dr. Bauerle’s project include the development and validation of a process-based approach to predict genotype-specific transpiration of deciduous field-nursery trees. More importantly, Dr. Bauerle has successfully quantified phenotypic traits (e.g., biomass accumulation and transpiration rate) in woody perennial trees via readily applicable genotype-specific parameter sets. The development of this process-based approach has allowed for the prediction of nursery water needs on a species and/or genotype specific basis. Moreover, the process-based approach has allowed them to decipher some physiological responses that can be generalized among deciduous tree species and across the growing season. In particular, they have developed general models that extrapolate the response to substrate moisture and seasonal biochemical changes. At the same time, the research approach has allowed them to pinpoint parameters that require species- and/or genotype-specific values (e.g., minimum stomatal conductance). Collectively, the parameter arrays permit Dr. Bauerle to accurately predict plant water use among species/genotypes and across the entire growing season. Progress also includes collaboration with other researchers to couple the models with user friendly interfaces.

2. **Controlling Runoff Volume and Quality at the Container-Level.** Progress and accomplishments have been made towards developing and optimizing production systems to improve water and nutrient use efficiency of container plants for the purpose of reducing runoff, irrigation, and fertilizer inputs. Three projects in the team have engaged in research to conserve water and protect water quality at the “container” level of production: Dr. Tom Yeager, University of Florida; Dr. Jim Owen, Oregon State University; and Dr. Ted Bilderback, North Carolina State University. Dr. Yeager’s project focused on understanding container spacing and canopy interactions on runoff volume and quality, and plant growth. Dr. Yeager quantified [plant] intercepted and un-intercepted irrigation and light, and container substrate temperature under various container spacing treatments during the production cycle of sweet viburnum, an ornamental shrub with relatively high water and fertilizer requirements. Dr. Yeager’s findings had direct application for nursery growers in demonstrating the importance of crop spacing during a production cycle on reducing environmental impacts of production and for the efficient use of production inputs (i.e. water
and nutrients). This data was also used by Dr. Yeager in developing CCROP described previously. Container substrate temperature has a major influence on nutrient release from controlled-release fertilizers (CRF), and the nutrient release characteristics of various CRFs was studied by Dr. Albano. Drs. Owen and Bilderback, worked cooperatively on improved container substrate for reducing runoff volume and quality in the team project “Irrigation Method and Substrate Composition for Nutrient and Water Use Efficiency for Containerized Nursery Crops”. Their research focused on the use of clay products, specifically, calcined clays. Their research showed that clay amendments significantly reduce water application (90,000 gal water /acre) and leachate volume (40,000 gal/acre) including a 50 percent reduction in ammonium and phosphate loss in effluent. In addition, clay has been shown to be able to adequately contribute the needed phosphorus to maximize crop growth making it a value added substrate component. Thus, clay (calcined) can reduce environmental impacts associated with production by reducing runoff volume and nutrient contamination while improving crop quality and profitability by “delivering” sufficient water and nutrients. More recently, they have initiated research on using a gravimetric approach for controlling irrigation which has been successful at further reducing container leachate by 8 percent while providing water based on real-time crop water status. Two wireless-gravimetric systems are currently undergoing field testing in North Carolina and Oregon in hopes to soon be commercialized. This new device could allow growers to monitor or control irrigation in container nurseries. Concurrently, research is investigating the ability to reduce fertilizer use in combination with no leaching in an effort to maximize crop nutrient use efficiency. In addition, Drs. Bilderback and Owen continue to look at substrates and possible additives to increase nutrient and water use efficiency.

3. Runoff Remediation of Excess Nutrients. Representing the greatest research efforts of the team project in terms of time has been research on developing systems and technologies for remediating nursery runoff of excess nutrients prior to offsite discharge or onsite containment for irrigation recycling. Two projects represent the major emphasis in this area of research: Dr. Sarah White, Clemson University, “Use of Wetland Systems to Treat Nursery Runoff”; and Chris Wilson, University of Florida, “Water Quality Protection Using Bioremediation and Decision Support Technologies”. Dr. White’s research team focused on developing and optimizing mixed constructed wetland systems that combine a deep, surface-flow cell with a shallow subsurface-flow cell, lined with coarsely ground clay (brick or calcined clay) substrate. They found this system to be very effective at reducing export of both nitrogen (surface-flow cell) and phosphorus (subsurface-flow cell). The impact of these discoveries is a better understanding of how to remediate nutrients from nursery effluent using plants and substrates in constructed wetland systems. Dr. Wilson’s research focused on the development of a bacterial-based bioreactor system for nitrate-nitrogen removal from runoff water. The system was adapted from aquaculture bioreactor systems. The difference is that in aquaculture operations the system maintains an aerobic environment for ammonium-nitrogen removal, and in horticulture operations the system needs to maintain an anaerobic environment for denitrifying bacteria colonization and nitrate-nitrogen removal. The system is currently composed of a series of tanks containing a media for the bacteria to grow on. The system requires carbon input with nutrients supplied in the runoff water. The bioreactor
systems have consistently removed 95 to 100 percent of the nitrate-nitrogen introduced into the system. The wetlands and bioreactor remediation systems have been developed to serve large nurseries without land constraints and smaller nurseries with limited land, respectively.

In 2009, new research was initiated on an algae-based remediation system. Drs. Joseph Albano and T.J. Evens, USDA-ARS, “Integrated Horticultural Production Systems for Water Quality Protection and Water Conservation” began to investigate the adaptability of algae turf scrubber systems for use in treating nursery runoff water. This new project is also associated with USDA-ARS bio-energy efforts as there is the potential to harvest the algae for biofuel production. In this endeavor, they have discovered that the composted algae biomass has many favorable physical and chemical traits that suggest that it might be suitable as a nursery substrate or amendment.

**TECHNOLOGY TRANSFER/IMPACT:**
The research team has transferred a series of related technologies that individually or in combination serve to significantly improve water quality and water conservation in the production of containerized nursery crops. Information has been transferred to other researchers and stakeholders through presentations at scientific and stakeholder meetings, peer-reviewed and trade papers, and public-access posting of documents on the Web. The number of technology transfer activities, including papers, presentations, and workshops during the reporting period exceed 100. Specific examples of these activities include:

“Production Practices for an Environmentally Friendly Nursery Industry”, J. Owen, Jr. and S. White (ed.), is a set of technology papers for each research project in the team. The papers summarize each project, identifying the technology, how it can be adopted, and the economic and environmental benefits of the technology. This publication can be freely accessed on a Web site hosted by Clemson University (http://tinyurl.com/sustainable-nursery) or one hosted by Horticulture Research Institute (http://tinyurl.com/ERMpdf).

**Selected Papers:**


Collaborators:
T.J. Evens, Stewart Reed, Cindy McKenzie, Scott Adkins, Erin Rosskopf, Nancy Burelle, and Kwesi Boateng, ARS-U.S. Horticultural Research Laboratory, Fort Pierce, Florida; Don Merhaut and Julie Newman, University of California, Riverside; Gene Blythe, Mississippi State University; Jeff LeBlond, Middle Tennessee State University; Jeff Million, Claudia Larsen, Joe Ritchie, and Craig Warner, University of Florida; Steve Klaine, Ted Whitwell, Bob Polomski, Y. Wang, and R.F. Reynolds, Clemson University; Milton Taylor, Insectigen Inc.; John Selker, Heather Stoven and Oregon State University; Helen Kraus, Brian Jackson, Mike Benson, and Kelly Ivors, North Carolina State University; Stuart Warren, Kansas State University; George Kantor, Carnegie Mellon University; James Altland, ARS Wooster, Ohio; Carolyn Seagal, ARS Corvallis, Oregon; Ross Dumdi, Bailey Nursery; Jim Zablocki, Ostara Nutrient Recovery Technologies, Inc.; S. Anantharamu, University of Arkansas; J.D. Bowden, Stephanie Kampf, and Michael Lefsky, Colorado State University; John Lea-Cox, University of Maryland; Marc van Iersel, University of Georgia; D.J. Timlin and Yakov Pachepsky, ARS Beltsville, Maryland; and Tom Demaline, Willoway Nurseries Inc.
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- USDA-ARS: $ 200,000  
- Oregon State University: $ 251,614  
- University of Florida: $ 122,375  
- North Carolina State University: $ 186,406  
- Colorado State University: $ 71,000  

Total Leveraged: $ 841,395