2014
Annual Report

for

Multistate Research Project NC−1186

Water Management and Quality for Ornamental Crop Production and Health

Submitted on behalf of

Amy Fulcher, University of Tennessee – Chair
Genhua Niu, Texas A&M University – Vice-Chair
John Majsztrik, University of Maryland – Secretary
Sarah White, Clemson University – past Chair

to

Douglas Buhler (MICL), CSREES Advisor
Thomas A. Bewick, USDA-NIFA Representative

on

September 18, 2014

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Summary

Sixteen attendees from nine institutions (Appendix I) met for the 2014 NC−1186 multistate research project annual meeting (Appendix II) at the Ballston Room in the VPI Arlington, VA facility and tour (Appendix III). Attendees were comprised of USDA staff, university faculty, students, and staff from eight academic institutions that represented five national regions including the pacific-west, mid-west, mid-atlantic, southeastern and southern United States.

The meeting began with the formal annual meeting (Appendix IV).

Brief Summary of Minutes of Annual Meeting

Dr. Amy Fulcher (chair) welcomed everyone and presided over the meeting. The meeting was opened with presentations by the four invited speakers.

Invited Speakers

Dr. James Dobrowolski, USDA National Program Leader in Rangeland and Grassland Ecosystems, overviewed the drought status in the USA and water challenges in agriculture, introduced the water related research programs such as Water for agriculture challenge CAPS and National integrated water quality programs.

Dr. Tom Bewick, USDA-NIFA Advisor for NC1186 and National Program Leaders of Specialty Crop Research Initiative (SCRI), gave a brief introduction of the SCRI competitive program and the review of the proposals received this year. From 2014, SCRI has two review processes, the 6-page “Stakeholder Relevance Statement” (SRS) as the “Industry Relevance Review”, and the scientific merit review (full proposal review). Applicants will be invited to write a full proposal if their SRS passed the industry relevance review. He also mentioned that SCRI has removed the

requirement for matching for land grants, minority/Spanish serving institutions starting September 1, 2014.

Dr. Joe Albano, Research Program Director for Horticultural Research Institute, The research affiliate of AmericanHort, gave a brief background on HRI, its mission, and the history of HRI funding, statistical data of HRI proposals received by regions, funding breakdown by geographical region and research area. He introduced the timeline for future HRI research proposal RFP and proposal submission, proposal review and ranking.

Dr. Richard Olsen, Research Geneticist, USDA National Arboretum, briefly introduced the background of National Arboretum and the recent movement on strategic planning. The strategic plan has resulted in increases in ornamental research, public private partnerships and strong connection with American nursery industry to better tackle the nursery industry challenges on critical issues. Future research will look to increase in urban environment and economic and ecosystem services of plants.

Right after the invited presentation, station reports by members were followed, including activities in the past year and future plans (see attachment for detail).

Administrative Briefing – Dr. Doug Buhler

After the station report, the NC1186 group administrator advisor Dr. Doug Buhler, Michigan State University, gave a briefing on administrative review and project renewal schedule. Here are the deadlines:

- September 15, submit a request to write a proposal (Dr. Buhler recommended that we request the same number, NC 1186)
- October 15, upload the objectives section to NIMSS
- November 15, all participants need to submit the Appendix E form
- December 1, complete proposal is due in NIMSS
- December 15, AA review forms due in NIMSS

Website for renewal info: http://ncra.info/MSR_ApprovalProcess.php
Linda Haubert or Chris at MSU can assist us when we need help.

Business meeting
(renewal proposal, possible location for next meeting, and election of a secretary)

Renewal proposal – Genhua Niu will provide overall coordination for the renewal
The following are the original areas of investigation:

1) Source water management and quality
2) Irrigation management
3) Runoff water management and quality
4) Substrate and nutrition management
5) Pathogens and crop health management

Discussion of how to move forward:
- Focus on the achievements of the group over the past 5 years and how we, as a group, plan to move forward into the future.

Future objectives:
Instead of having the 5 objectives above, those categories will be reorganized into three areas (Economics will be included in all three objectives)

1) Water quality (includes pathogens) (leads: Sarah White, Tom Fernandez, Paul Fisher (?), Chuan Hong (?))
2) Water quantity (leads: John Lea-Cox, Marc van Iersel, Amy Fulcher, Tom Fernandez)
3) Substrate and nutrient management (Leads: James Altland, Jim Owen and Hye-ji Kim)

A more integrated approach: Connecting all is Water (quality, quantity)
1) Abiotic and biotic stress (pathogens, salinity) (lead: Chuan Hong)
2) Agrichemicals (source remediation) (leads: Jim Owen, Sarah White)
3) Substrates (physical and chemical properties, and source) (lead: James Altland)

Overarching objectives:
Economic, climate change, environmental, and societal benefits
Economics information (quantifying benefits) should be integrated into all aspects of renewal application

All those who are part of the group and have outcomes for a particular section should get it to the leads. Amy Fulcher, Tom Fernandez, John Lea-Cox have been working on this area and have outcomes for this section

Possible location for 2015 meeting
The following locations were discussed but final decision is not made yet. Genhua will send out to the group for vote in the near future.

- Ohio (Columbus or Wooster), NCERA-101, "Controlled Environment Technology and Use and Cultivate 2015 will be held in Ohio in middle July
- Hawaii
- US Virgin Islands
- Grand Rapids, Michigan June 15-30
- Combined meeting with economics group

Elections of Secretary
James Altland nominated and elected unanimously for secretary for 2014-2015.
Hye-Ji Kim volunteered for secretary for 2015-2016 term.
The meeting ended with a briefing for the following day's tour by Dr. John Lea-Cox.

Complete minutes are available in Appendix III.

The second day of the meeting was used for a tour led by Dr. John Lea-Cox (Appendix IV). Tour stops included a progressive cut flower grower (Flowers by Bauers), Raemelton Farm, Waverly Nursery in Maryland, and a green roof at Potomac Plaza, Washington, DC, all using irrigation from the MINDS project.

Accomplishments:

Water resource and management survey of ornamental plant producers was initiated in 2011. In 2012 the survey was disseminated nationwide. Analysis of data from the survey and round-table discussions conducted to define stakeholder needs were completed, and findings were presented on a poster at the 2013 American Society for Horticultural Science meeting in Palm Desert. The results from the survey are be utilized by the NC1186 research project as a baseline defining trends in industry behavior and cultural practices. Furthermore, results of the survey and round-table discussions were used to guide extension priorities and program development, as well as coordination of a 2014 SCRI-CAP grant proposal, in which the majority of collaborators are members of NC1186.

Participants in the NC1186 research group have undertaken the task of updating the seminal paper "Strategic vision of container nursery irrigation in the next ten years" by Dr. Richard Beeson and others. This article was originally published in the Horticultural Research Institutes' Journal of Environmental Horticulture in 2004. Members polled stakeholders and attended relevant information gathering sessions, such as the Seeley Summit. The article will serve to educate specialty crop producers about current water issues, risks due to changing regulations and practices including adoption of technology to more efficiently manage water.

At the 2013 American Society for Horticultural Science meeting in Palm Desert, CA, plans for renewal were initiated. More detailed planning and preparations took place prior to, during, and following the 2014 meeting in Arlington, VA.

Member Impact Statements:

NC-1186 Outcomes/Impacts: Auburn University found that mitigate nutrient runoff into the environment and better utilize limited water resources through increased use of secondary water sources instead of primary potable water sources. *Portulaca oleracea, Muhlenbergia capillaris, Illicium parviflorum,* and *Begonia semperflorens-cultorum* were tolerant of daily saline irrigation up to at least 6000 ppm NaCl, suggesting tolerance of particularly high saline environments or saline recycled irrigation water. *Andropogon ternarius, Coreopsis verticillata,* and *Ilex vomitoria* provided particularly effective phosphorus removal from bioretention areas when used in combination (polyculture) rather than alone (monoculture). Using a combination of growth habits provided more consistent year-round phosphorus removal.

Irrigation water conservation is important for nurseries because of restrictions on allocations, competition for water resources, and the impact nutrient-laden runoff water has on the environment. An ET based irrigation control system has been developed by University of Florida. Implementation of this system on a production area at a nursery in Florida resulted in a 20% reduction in overhead sprinkler water applied daily from March – July 2014. The amount of water applied to the ET based irrigated area was compared to an adjacent area of similar size with the same plants. The adjacent area was irrigated based on the Nursery Manager's decision regarding the amount of water to apply daily using a manual time setting. Plant growth was similar in both areas. Use of ET based irrigation is a BMP that not only provides a guide for irrigation management but results in a concomitant reduction of nutrients in runoff. At a nursery in Virginia, the owner indicated that nutritional amounts could be reduced 20% on some crops with implementation of the ET based irrigation BMP.

University of Georgia found that wireless sensor networks can effectively control irrigation in commercial nurseries and greenhouses, based on soil moisture sensor readings. Growers have seen shorter production cycles, less disease, and better quality, along with large water savings. Implementation of this technology in greenhouses and nurseries will benefit both growers and society. Societal benefits include reduced water use and a decrease in agrochemical runoff.

In order to determine water requirements of tropical ornamental plants, a sensor based irrigation system was used at University of Hawaii. Results indicate that substrate is the most important factor that affects irrigation frequency and volume and plant quality of *Leucospermum*. When grown with highly porous substrate, plants performed better. Although higher irrigation frequency and volume increased shoot growth of *Leucospermum* by 40%, it reduced root growth by 20%, resulting in the reduction of root-to-shoot ratio by 50%. This information can be critical to optimize plant production systems.

The methodology developed at Purdue will allow researchers to better quantify N losses from container plants. This technique can now be used to conduct experiments on how environmental and management strategies affect the fate of N in container systems.

At the University of Kentucky, the small UKREC Rain Gardens used to mitigate the run-off from gravel container research beds are the size that could be used by small local container production/retail nurseries that sell directly to the public. The Rain Garden/run-off control demonstrations are shared with the public via a June Open House.

Research and extension efforts are continuously being pursued at LSU AgCenter addressing irrigation management and water quality issues our industry is facing. Research on container substrate amendments and irrigation control with low leaching fractions are promising for further investigation.

Plastic containers are produced using petroleum with a high carbon cost and are typically not recycled since they are contaminated with dirt and possibly pests after initial use. The goal of this project was to evaluate the ability of alternative to plastic containers in producing ornamental plants of the same size and quality. Field trials were conducted over the past 3 years to evaluate plant growth, quality and water use in several alternative containers. Containers were

made of wood pulp, recycled and woven plastic, and keratin from chicken feathers. Plant growth and quality was unaffected providing irrigation was applied to replace the amount of water used but a higher number of some plants died overwinter due to water loss through porous sides of wood pulp and woven containers. The tradeoff between lower carbon inputs and higher water inputs is being evaluated.

Mississippi State University found that the supply of pine bark as a component of nursery and greenhouse growing media has become more limited in the Southeastern U.S. due to reduced forestry production and increased use of bark as a fuel source. Although previous studies has shown that growing media containing processed whole pine trees are a viable substitute for pine bark, this renewable material had not previously been tested for use in cutting propagation. Graduate student Anthony Witcher determined that processed whole pine trees can be used successfully for rooting cuttings of horticultural crops and is best used blended with peat moss. Results of this study will provide additional, sustainable substrate options for commercial nursery producers.

The implementation of conservation practices will prevent water pollution or improve water quality in streams and lakes in the targeted watershed in New Jersey. Benefits include the reduction of sediment and phosphorus to the Cohansey River, water conservation in areas of stressed aquifers, reduction of soils erosion, and the improvement of sustainability of New Jersey's plant nurseries and agricultural operations.

Educational activities, which focus on water concerns of the plant nursery and greenhouse industries reduce soil erosion, prevent water pollution in New Jersey's waterways, conserve water, and further the sustainability of the industries.

North Carolina State University found that the application of irrigation to nursery crops affects growth, health, and the amount of nutrients available to plants, as well as the nutrients lost in production runoff water. Because water, nutrients, and plant health are limited resources that affect environmental health, it is imperative that they are used judiciously. The Southern Nursery IPM (SNIPM) Working Group with funding from the Southern IPM Center provided training for growers on measuring irrigation efficiency. Approximately 75 growers in three different areas of the southeast U.S. learned how to measure irrigation application rate and its uniformity. By adopting these techniques that reduce water use, growers could reduce production costs while maintaining plant quality.

USDA-ARS in Wooster, OH developed BMP guidelines for substrate amendment with steel slag as an alternative to dolomitic lime. Substrate pH response curves were generated for greenhouse and nursery substrates, as a function of steel slag rate. Growers can use this information to determine the specific rate needed for their substrates and crops.

USDA-ARS in Wooster, OH gathered information on what has been published on cation exchange capacity for pine bark substrates used in the northern U.S. There was virtually no science based information on this topic, yet substrate management decisions are being made based on assumptions of how pine bark CEC affects plant nutrition. USDA-ARS's research

showed that particle size of the pine bark does influence CEC, but pH and peatmoss amendment have little impact.

USDA-ARS in Wooster, OH assessed physical and chemical properties of greenhouse and nursery substrates amended with gasified rice hull biochar (GRHB) and its impact on plant health and nutrient levels in leachates. GRHB affected nitrate release by temporarily absorbing nitrate and releasing it slowly. This could result in less drastic and fewer spikes between high and low nitrate availability in the soil solution. The GRHB was a net source of phosphates and potassium and, when incorporated into a greenhouse substrate at 10% by volume, provides enough of these two nutrients without the need to provide additional phosphorus or potassium fertilizers. Growers can reduce fertilizer costs by 33% using GRHB instead of traditional fertilizers.

USDA-ARS in Wooster, OH developed new best management practices for weed management that improves crop health and reduces the amount of pesticides returning to runoff irrigation reservoirs. By using rice hulls as an alternative to chemical herbicides for weed control, fewer herbicides are needed to produce healthy crops. This best management practice is especially relevant in enclosed production spaces such as greenhouses and hoophouses where use of chemical herbicides is limited by label restrictions. Nursery growers can reduce weed control costs by as much as 75% with the use of rice hulls.

During the past five years, researchers at Clemson University have monitored the efficacy of two constructed wetlands to facilitate removal of nutrient and pathogen contaminants from runoff. The wetlands reduced export of total nitrogen by 69%, phosphorus by 39%, and *Phytophthora* spp. (a pathogen) by 80%. Over 630,000 gallons of water flow through these wetlands each day, and an average of 143 lbs. of nitrogen and 0.12 lbs. of phosphorus are removed from runoff on a daily basis. Given that it takes only 0.02 ppm phosphorus to contribute to nutrient enrichment and potential impairment of surface waters[2], optimizing best management practices to reduce nutrient export into surface waters is critical. This technology to filter contaminants from runoff not only helps to protect our surface waters but can also be applied to increase re-use of irrigation runoff to save potable water sources for other uses.

Increasing regulation, public interest in sustainable practices, and droughts have increased nursery producer awareness of the need to more conservatively use natural resources such as water during agricultural production. The University of Tennessee has shown that substrate moisture probe placement does not matter for scheduling irrigation, for 11.4 L container filled with 75% pine bark and 25% peat moss. A severe drying event, 11% VWC reduces sensor accuracy due to the substrate holding less water. The University of Tennessee also showed that in Southern locations scheduling irrigation based on an on demand (OD) or daily water use (DWU) regime reduced water use. OD generally used less water than DWU and had either no or a positive impact on biomass in all but one trial.

Root rot pathogens lead to economic costs due to loss of crop and use of expensive fungicides. The University of Tennessee developed a system to apply irrigation water with a range of dissolved oxygen levels from approximately 5.0 $mg \cdot L^{-1}$, 7.0 $mg \cdot L^{-1}$, 11.0 $mg \cdot L^{-1}$, and 13.0 $mg \cdot L^{-1}$, approximately double the ambient concentration. This system will allow UT to test if

elevating oxygen levels will reduce pathogenicity of root rot pathogens and/or bolster plant health allowing plants to resist infection.

Severe drought and stiff competition for high-quality water supplies are forcing the green industry, particularly those located in urban areas, to consider the use of alternative irrigation sources like reclaimed, stormwater and graywater. An effective use of these sources could reduce municipal potable water dependence in urban areas. Research at Texas A&M AgriLife-Uvalde indicates that laundry-derived graywater, without bleach residues, can be used to satisfactorily grow annual and herbaceous perennials plants used for urban landscaping applications.

Salt tolerance of garden roses, including 18 Earth-Kind® roses and 15 Texas Superstar® landscape plants were evaluated in several greenhouse studies. The results of salt tolerance of these landscape plants will help nursery and landscape professionals and home owners to choose appropriate plants for landscapes where low quality water may be used.

Virginia developed and launched a monthly webinar series: Irrigation Pathogens and Water Quality on October 8, 2013 . This series is a key component of our SCRI project educational program and has attracted national and international audience. Also, a workshop on Water Management for Ornamental Crops was held in Virginia Beach, Virginia in October 2013 with participants from green industry and water treatment companies from several states.

Publications:

Book Chapters Collaborative among NC1186 Members:

Chappell, M.R., J.S. Owen, S.A., White and J. Lea-cox. Irrigation management practices. In: T. Yeager, T. Bilderback, D. Fare, C. Gilliam, J. Lea-Cox, A. Niemiera, J. Ruter, K. Tilt, S. Warren, T. Whitwell and R. Wright (eds.) Best management practices: Guide for producing nursery crops. 3rd edition. Southern Nursery Association, Atlanta, GA. In press in English and Spanish.

Ivors, K. L. and G. W. Moorman. 2014. Oomycete Plant Pathogens in Irrigation Water. Pages 57-64 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

Nambuthiri, S., A. Fulcher, and R. Geneve. 2014. pp. 295-309. Chapter 21. Micro-irrigation Systems for Pot-in-Pot Ornamental Nursery Production: Concepts and a Case Study. In: Goyal, M. (Ed.), Research advances in sustainable micro irrigation: Management, performance, and applications of micro irrigation systems, vol 4. Apple Academic and CRC Press. Waretown, NJ.

Ristvey, A. G. and G. W. Moorman. 2014. An Integrated Approach to Minimizing Plant Pathogens in Runoff Water from Containerized Production Systems. Pages 365-375 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

Conference Papers Collaborative among NC1186 Members:

Hong, C. X., P.A. Richardson, P. Kong, and G. Cafa. Tracking water quality dynamics in a multi-basin agricultural water recycling system, 2013 AWRA Spring Specialty Conference on Agricultural Hydrology and Water Quality II, St. Louis, MO, March 25-27, 2013

Hong, C. X., P.A. Richardson, P. Kong, G. Cafa, J.D. Lea-Cox, B.E. Belayneh, and A. G. Ristvey. Dramatic fluctuations of water quality in agricultural runoff containment basins. 2013 AWRA Spring Specialty Conference on Agricultural Hydrology and Water Quality II, St. Louis, MO, March 25-27, 2013

Hong, C. X., and G. W. Moorman. Diversity and significance of plant pathogens as agricultural water contaminants. 2013 AWRA Spring Specialty Conference on Agricultural Hydrology and Water Quality II, St. Louis, MO, March 25-27, 2013

Refereed Journal Articles Collaborative Among NC1186 Members

Lea-Cox, J.D., W.L. Bauerle, M.W. van Iersel, G.F. Kantor, T.L. Bauerle, E. Lichtenberg, D.M. King, and L. Crawford. 2013. Advancing wireless sensor networks for irrigation management of ornamental crops: an overview. HortTechnology 23:717-724.

Merhaut, D.J., E.K. Blythe, J.P. Albano, and J.P. Newman. 2013. Nutrient release from controlled-release fertilizers in nursery production systems. UNCFA News: Vol. 17, No. 3, Fall 2013. University of California, Agriculture and Natural Resources, Nursery and Floriculture Alliance. (Posted at: http://ucanr.edu/sites/UCNFAnews/Feature_Stories/Nutrient_Release_from_Controlled-Release_Fertilizers_in_Nursery_Production_Systems/).

Nambuthiri, S., A. Fulcher, A. Koeser, R. Geneve, G. Niu. Moving towards sustainability with alternative containers for greenhouse and nursery crop production: A review and research update. Accepted HortTechnology.

Nambuthiri, S., R.L. Geneve, R.T. Fernandez, G. Bi, G. Niu, and X. Wang. Substrate temperature in black plastic, wood pulp, keratin, and fabric root pouch nursery containers. HortTechnology, submitted.

Starry, O., J.D. Lea-Cox, J. Kim, and M.W. van Iersel. 2014. Photosynthesis and water use by two *Sedum* species in green roof substrate. Environmental and Experimental Botany 107:105-112. DOI: 10.1016/j.envexpbot.2014.05.014.

Taylor, A.J., R.T. Fernandez, P. Nzokou, and B.M. Cregg. 2013. Carbon isotope discrimination, gas exchange, and growth of container-grown conifers under cyclic irrigation. HortScience 48:848-854.

Van Iersel, M.W., M.R. Chappell, and J. Lea-Cox. 2013. Sensors for improved efficiency of irrigation in greenhouse and nursery production. HortTechnology 23:735-746.

Wang, X., R.T. Fernandez, B.M. Cregg, R. Auras, A. Fulcher, D. Cochran, G. Niu, Y. Sun, G. Bi, S. Nambuthiri and R.L. Geneve. 2014. Multi-state evaluation of plant growth and water use in plastic containers and alternative nursery containers. HortTechnology, submitted.

Conference Proceedings Collaborative among NC1186 Members:

White, S.A., J.S. Owen, J.C. Majsztrik, R.T. Fernandez, P. Fisher, C.R. Hall, T. Irani, J.D. Lea-Cox, J.P. Newman, and L.R. Oki. 2013. Grower identified priorities for water research in ornamental crops. SNA Research Conference Proceedings, 58, 299-301.

Poster Presentations Collaborative among NC1186 Members:

White, S., J.S. Owen, J. Majsztrik, R. Fernandez, P. Fisher, C. Hall, T. Irani, J. Lea-Cox, J. Newman, and L. Oki. Grower identified priorities for water research in ornamental crops. 2013. Proc. Southern Nursery Assoc. Res. Conf. 58:299-301. (poster presentation)

Popular Articles Collaborative among NC1186 Members:

Majsztrik, J., J.S. Owen, S.A. White, and J. Lea-Cox. 2013. Efficient irrigation: The state of water II. Greenhouse Management. September. 33(9): 22-25. http://www.greenhousemag.com/gm0913-water-efficiency-irrigation.aspx

Majsztrik, J., S.A. White, J.S. Owen, and J. Lea-Cox. 2013. “Water Smarts: The State of Water I.” Greenhouse Management. August. 33(8): 24-26. http://www.greenhousemag.com/gm0813-water-smarts.aspx

Majsztrik J., J. Owen, S. White, and J. Lea-Cox. 2013. The state of water in the green industry II: Water use efficiency. Nursery Management. July. 29(7):24, 26, 28.

Majsztrik J., S. White, J. Owen, and J. Lea-Cox. 2013. The state of water in the green industry I: Water resource availability. Nursery Management. June. 29(6):28, 30-32.

Majsztrik J., S. White, J. Owen, and J. Lea-Cox. 2013. The state of water in the green industry III: Water quality. Nursery Management. August. 29(8):20-21, 23-25.

White, S.A., J.S. Owen, J. Majsztrik, and J. Lea-Cox. 2013. Water Quality: Salts, Pests, and Pesticides - The State of Water Part III. Greenhouse Management. October. 33(10): 40, 42-46. http://www.greenhousemag.com/gm1013-water-quality-monitor.aspx

Professional/Outreach Publications Collaborative among NC1186 Members:

Fulcher, A. and R.T. Fernandez. 2013. Sustainable nursery irrigation management: Part 1. Water use in nursery production. Univ. TN CES W278, https://utextension.tennessee.edu/publications/Documents/W278.pdf

Fulcher, A. and R.T. Fernandez. 2013. Sustainable nursery irrigation management: Part 2. Strategies to increase efficiency. Univ. TN CES W 279, https://utextension.tennessee.edu/publications/Documents/W279.pdf

Fulcher, A. and R.T. Fernandez. 2013. Sustainable nursery irrigation management: Part 3. Strategies to manage nursery runoff. Univ. TN CES W280, https://utextension.tennessee.edu/publications/Documents/W280.pdf

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Brumfield, R.G., G. Bi, D. Cochran, R.T. Fernandez, A.F. Fulcher, R.L. Geneve, A. Koeser, G. Niu, J.R. Stewart, and X. Wang. 2014. Economics of utilizing biodegradable containers in ornamental crop production systems. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press (abstract).

Crawford, L., J.D. Lea-Cox, J. Majsztrik, W. Bauerle, M. van Iersel, T. Martin, and D. Kohanbash. 2013. Behind the curtain: The support component of wireless soil moisture networks. HortScience 48:S181-182 (abstract).

Li, T., G. Bi, G. Niu, S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, A. Fulcher, Y. Sun. 2013. Use of biocontainers in pot-in-pot nursery production system. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S48 (abstract.)

Nambuthiri, S., R.L. Geneve, Y. Sun, X. Wang, G. Bi, R.T. Fernandez, and G. Niu. 2014. Impact of alternative materials on container physical properties and substrate temperature. 2014

American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. (abstract).

Nambuthiri, S., R.L. Geneve, G. Niu, Y. Sun, G. Bi, R.T. Fernandez, and X. Wang. 2013. Impact of container material on substrate heat buildup in an outdoor nursery. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S45 (abstract).

Thomas, P.T., M. Chappell, J.M. Ruter, E. Lichtenberg, and M.W. van Iersel. 2013. Wireless sensor networks for automated irrigation control in container nurseries: implementation and economic impact. HortScience 48:S179 (abstract).

Wang, X., R.T. Fernandez, G. Bi, A. Fulcher, R.L. Geneve, G. Niu, S. Verlinden, B.M. Cregg, M. Ngouajio. 2013. Plant growth and water use in plastic, fiber, keratin, and Root Pouch containers. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S108 (abstract).

White, S.A., J.S. Owen, Jr., J. Majsztrick, R.T. Fernandez, P.R. Fisher, C.R. Hall, T.A. Irani, J.D. Lea-Cox, J. Newman, and L.R. Oki. 2013. Containment, remediation, and recycling of irrigation water for sustainable ornamental crop production: Results of a SCRI Planning Grant. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S264 (abstract).

Individual Papers supporting NC1186 Objectives:

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Altland, J.E. and C. Krause. 2014. Parboiled rice hull mulch in containers reduces liverwort and bittercress growth. J. Environ. Hort. (in press).

Altland, J.E., J.C. Locke, and C. Krause. 2014. Influence of pine bark particle size and pH on cation exchange capacity. HortTechnology (in press).

Bailey D., J.S. Owen, J. Selker, and J. Wagner. 2013. In-situ performance and usability of a distributed, wireless sensor network via mesh connectivity at a production container nursery. Applied Engineering in Agriculture 29:779-782. (DOI: 10.13031/aea.29.10006).

Bayer, A., I. Mahbub, M. Chappell, J. Ruter, and M.W. van Iersel. 2013. Water use and growth of *Hibiscus acetosella* 'Panama Red' grown with a soil moisture sensor controlled irrigation system. HortScience 48:980-987.

Behe, B.K., R.T. Fernandez, P.T. Huddleston, S. Minahan, K.L. Getter, L. Sage and A.M. Jones. 2013. Practical field use of eye-tracking devices for consumer research in the retail environment. HortTechnology 23:517-524.

Cabrera, R.I., K.L. Wagner and B. Wherley. 2013. An evaluation of urban landscape water use in Texas. Texas Water Journal 4(2):14–27.

Cai, X., Y. Sun, T. Starman, C. Hall, and G. Niu. 2014. Response of 18 Earth-Kind® Rose Cultivars to Salt Stress. HortScience 49(5):544–549.Cai, X., T. Starman, G. Niu, and C. Hall. 2014. The effect of substrate moisture content on growth and physiological responses of two landscape roses (*Rosa x hybrid* L.). HortScience 49(6):741–745.

Cai, X., G. Niu, T. Starman, and C. Hall. 2014. Response of six garden roses (*Rosa x hybrid* L.) to salt stress. Scientia Horticulturae 168:27-32.

Campbell, B., B.K. Behe, H. Khachatryan, C. Hall, J. Dennis, P. Huddleston, and R.T. Fernandez. Incorporating eye tracking technology and conjoint analysis to better understand the green industry consumer. HortScience in press.

Chappell, M., S.K. Dove, M.W. van Iersel, P.A. Thomas and J. Ruter. 2013. Implementation of wireless sensor networks for irrigation control in three container nurseries. HortTechnology 23:747-753.

Contreras, R.C., J.S. Owen, W. Hanna, B. Schwartz. 2013. Evaluation of seven complex Pennisetum hybrids for container and landscape performance in the Pacific Northwestern United State States. HortTechnology 23:525-528.

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Appendices

Appendix I - NC1186 2014 Meeting Attendees

Amy Fulcher, University of Tennessee (Chair)
Sarah White, Clemson University (Past Chair)
Genhua Niu, Texas A&M University (Chair-elect)
John Majsztrik, University of Maryland (Secretary)
James Altland, USDA-ARS
Hye-Ji Kim, University of Hawaii
Jim Owen, Virginia Tech
Julie Brindley, Virginia Tech
Jeb Fields, Virginia Tech
Rachel Mack, Virginia Tech
Gene Blythe, Mississippi State University
Tom Fernandez, Michigan State University
Doug Buhler Michigan State University
John Lea-Cox, University of Maryland
Bruk Belayneh, University of Maryland
James Zazanis, University of Maryland

Appendix II - NC1186 2014 Meeting Schedule

July 15, 2014

8:00 - 8:05 Welcome and call to order - Amy

8:05 - 8:35 Dan Schmoldt and Tom Bewick, National Program Leaders, USDA NIFA – 30 minutes

8:35 - 9:05 James P. Dobrowolski, USDA, National Program
Grassland Ecosystems, Agriculture Water Security – 30 minutes

9:05 - 9:15 Break

9:15 - 9:45 Richard Olsen, Research Geneticist, USDA National Arboretum – 30 minutes

9:45 - 12:00 Station Reports: Reports from each member in attendance on current status of their research and extension efforts related to this working group (5-10 minutes per person, oral, no powerpoint) – 2 hours 15 minutes

12:00 - 1:15 Lunch

1:30 - 2:00 Joe Albano, Research Programs Director, HRI

2:00 - 2:15 Admin Briefing - Doug Buhler, MSU – 15 minutes

2:15 - 2:25 Break

2:25 - 3:45 Renewal - Genhua Niu, Incoming Chair – 1 hour 20 minutes (confirm the writing committee at the meeting and set up deadlines.)

3:45 - 4:45 Other Business
- Determine date and location of next mtg – Genhua
- Elections – elect secretary - Amy
- Summary of survey or focus groups results – Sarah
- Report from Seeley Conference
- Open discussion, sharing new ideas, other
- Briefing for the following day's tour – John Lea-Cox – 10 minutes

Must vacate room by 5:00

Notes on renewal from 2013 meetings minutes:
- Genhua will provide overall coordination as chair the year of renewal.
- John Lea-Cox will help Genhua with the submission.
- Marc van Iersel– is excellent editor. Could be the executive editor of our document.
- John Lea-Cox will be the water quantity team leader.
- Sarah White will be the water quality team leader.
- Jim Altland will be the substrates team leader, but may delegate
- Doug Buhler has person in his office and also Chris at director's office can help. Send Doug the documents in word and his office will actually submit them.
- Ronda Koski, Colorado State University, new member, volunteered to proofread the proposal.

John Lea-Cox – Suggests internal deadline 2 months in advance of real deadline.

Appendix III - NC1186 2014 Tour Schedule

NC 1186 Working Group
Wednesday, July 16, 2014
Tour Details

Tours leave at 8am on Wednesday from Arlington, VA.
Exact departure location to be announced.

8:30 am: Green roof at Potomac Plaza in Washington, DC (30 minutes)
9:00 am: Drive to Frederick, MD
10:00 am to 12 noon: Raemelton Farm & Waverley Nursery (Frederick, MD)
12 noon: Drive to Bauers (Boxed lunch and drinks, on the way)
1:30 pm to 3 pm: Bauers Greenhouse (Jarrettsville, MD)
4 pm: Drop off at BWI Airport

5 pm: Drop off at National Airport

Please Note: Please make your own transportation arrangements to the hotel in Arlington as you arrive on Monday. There is no arranged transportation service.

More information on these locations:
Raemelton Farm, a field site for the wireless sensor work
http://www.raemelton.com, Waverley Farm
http://www.waverlyfarm.com/home-about.html,
Bauers Greenhouse cut-flower hydroponic operation
http://www.greenhousemanagementonline.com/Author.aspx?AuthorID=5567, also a MINDS research site, and Potomac Plaza, Washington, DC. http://potomacplaza.org/going-green/ where we will take in the apartments building's green roof and a great view of the Watergate Hotel.

Appendix IV - NC1186 2014 Complete Minutes

8:00 - 8:05 Welcome and call to order - Amy

8:05 - 8:35 James P. Dobrowolski, USDA, National P
Grassland Ecosystems, Agriculture Water Security – 30 minutes

- The trend is moving from treated effluent water (purple water pipes) to wastewater treatment plants producing potable water (seen in California)
- Drought is becoming a bigger problem
- Water is at the nexus of many problems (food security, population growth)

Two new(er) areas for helping understand water and water relations
- Water for agriculture challenge CAPS
National integrated water quality programs

8:35 - 9:05 Dan Schmoldt and Tom Bewick, National Program Leaders, USDA NIFA – 30 minutes

Tom Bewick
- SCRI recently introduced an "Industry Relevance Review" as part of a new pre proposal before being asked to submit a full proposal. This review determines if the project is "industry relevant" before full proposals are submitted. If the project does not pass this review, you are not asked to submit a full proposal.

- For SCRI, the plan is for RFA to be put out mid-September to provide more lead time to researchers (starting 2015 or later).

- SCRI has 25 million for Citrus greening research. This money is not tied to a particular year so it can be spent at any time during the authorization period (also called "no year" money). The plan is to get the RFP out soon since this disease is so devastating. In future years, the RFP should be rolled in with the regular SCRI RFP.

- SCRI has removed the requirement for matching for land grants, minority/Spanish serving institutions starting September 1, 2014 (yeah!). There is still some question about how much work these types of institutions must do in the overall project in order for the whole project to be exempt from matching.

9:05 - 9:15 Break

9:15 - 9:45 Joe Albano, Research Programs Director, HRI

- In the History of HRI, they have distributed $6.9 million since 1954.

- Since combining ANLA with OFA to become American Hort, projects that will be funded will now include: Greenhouse, floriculture, garden center, Christmas trees, grape vines etc. Available funding is also expected to increase, although how much is yet to be seen.

- HRI has 4 regions. The percent of proposal received by region for the last 4 years was:
11% Northeast
58% Southeast
9% West
23% Midwest
This is not consistent with the breakdown of operations by region, which is much more uniform (about 25% per region).

- Funding breakdown (last 4 years):
24% crop production
20% pest management
18% water
13% resource management
10% marketing
3% Landscape
3% post production
9% other (mainly invasive plant and post production research)

- Review process:
- 2 initial review panels (grower and industry) review and assign points.
- High scoring proposals moved to high level donors for review and comments (no ranking is done by donors)
- Proposals are then moved to HRI executive committee for vote
-Highest ranking proposals are funded
- HRI tries to do its best to fund projects at the $ level requested

- HRI Proposal timeline will likely change starting next year to the following timeline:
RFP out April 1
RFP due June 15
Decision made November through January
Money sent out March through July (to coincide better with getting research going in spring where it can have the most impact for data collection).

9:45 – 10:25 Richard Olsen, Research Geneticist, USDA National Arboretum
National Arboretum recently went through an extensive strategic planning process to equip it to move forward.

Some results from the strategic plan:
- Increase ornamental research
- Arboretum seeks to increase their advocacy for industry (i.e. HRI)
- Increase public private partnerships

-Increase their mission/partnership/connection with the American nursery industry to better equip it to tackle medium and long term nursery industry challenges
- Revamp legacy programs (i.e. crape myrtles) to make sure they are focusing on the most important issues

Future arboretum research will look to increase research in:
- Urban environments
- Slow food movement/local
- Economic/ Ecosystem services of plants

10:30-12:00 Station Reports: Reports from each member in attendance on current status of their research and extension efforts related to this working group (5-10 minutes per person, oral, no powerpoint) – 2 hours 15 minutes

John Lea-Cox U of Maryland
NSSI (National Sustainable Strawberry Initiative)
- Project includes 2 growers and research at Wye research and education center to implement sensor networks to improve irrigation, economics, yield, disease pressure etc. in strawberry. An additional network will likely be installed in CA to work with growers there.
- Decagon will be coming out with a commercial wireless irrigation network in early fall 2014 that uses the hardware and software developed as part of the SCRI MINDS project.
- Cost effective scale up to a whole nursery scale (Hale and Hines Nursery, McMinnville, TN). Integration of irrigation controllers (i.e. Tucore) with sensorweb (sensor network software) to monitor and control irrigation only using sensors.
- Greenroof instrumentation (NASA Johnson Center) utilizing 3G networks to measure greenroof performance.
- 3G nodes were also installed in Ecuador looking to quantify ET to help growers gain back rights to their water.

Jim Owen and Schwan Hong Virginia Tech

- In regards to recycling water in ponds: path length from water entrance to being reused is one of the most important factors
- Pathogens are also effected by pH, temperature, EC etc.

Other projects being completed at Virginia Tech:
- Evaluating wetting fronts in container plants under different irrigation
- Understanding BMP's and policy impacts
- Increase water efficiency and availability in containers
- Evaluating compost filter socks to mitigate fertilizer, and potentially pesticides
- Phosphorus is being applied at 0.5ppm to woody temperate (ilex, azalea, hydrangea), and it seems to be sufficient for optimal plant growth. Research is also being done to determine the impact of lime and micronutrients to bind P.

Tom Fernandez Michigan State University

- Alternative containers- particularly water use
Porous pots have higher water needs/water transmissions than plastic.
RFID (radio frequency identification) tags to help with scale up of SCRI MINDS (species aware irrigation) and inventory control of ornamentals.

Bert Cregg
- Carbon isotope discrimination in conifers
Urban tree selection for climate change

Bridget Behe
- Eye tracking in consumers for marketing in retail operations

Genhua Niu Texas A&M
- Feasibility of biocontainers for ornamental production: degradation of pots in the landscape
- Water quanitity: selecting plants for drought tolerance
- Water quality: low quality (high salt) water for landscape plants
- Greywater (laundry) use in container and greenhouse plants
- Salt tolerance of garden roses
- Controlled environment: hydroponic systems (5% of water compared with field) local ornamental/food production. Genhua is translating a book from Chinese about growing plants in high density controlled environments

Sarah White Clemson University
- Remediation of nutrients from ornamental operations using treatment wetlands
- Ecological treatment of pathogens (floating wetlands, veg buffers etc.)
- 2011 SCRI Planning grant about water quality led to SCRI CAP grant titled:
Clean WateR^3: Reduce Remediate and Recycle

James Altland USDA ARS Wooster Ohio

- Understanding levels of plant growth regulators (PGR) in ponds and the impact on greenhouse plants
- Biochar research (winding down). Biochar concentrates nutrients found in source material.
- Silicon research as a substrate amendment to increase pH
- Weed control strategies in nurseries and greenhouse (rice hulls) and analyzing how they filter water
- Rice hulls have high P and K levels, which as biochar allowed for no additional P and K application during a production season.

Hye-Ji Kim University of Hawaii
Major research objectives:
- Substrate comparison: volcanic cinder with peat vs conventional potting media.
- Water quality and quantity
- Developing a Protea lucosperma breeding program (enhanced heat tolerance for Hawaii)
- Phosphorus rate reduction: Reduced P loads to Lantana did not reduce vigor (10 ppm continuous fertigation vs 40 ppm)

Winn Dunwell U of Kentucky

- Developed PLC control systems for irrigation automation (similar to decagon system, only cheaper). Currently a small pilot project.
- Cyclic irrigation for container production
- Wayne Ingram is continuing to work on lifecycle assessment for Carbon and water footprint
- Work is being done on educating growers on BMPs for blueberries

Eugene Blythe Mississippi State University

- Fertilizer application rates for ornamentals
- Continuing propagation work
- Work analyzing essential oils

Amy Fulcher U of Tennessee

- Biocontainer project – Biocontainer group will present at length at ASHS
- There is a planned biocontainer "special issue" in HortScience in the near future
- Experimented with VWC (volumetric water content) sensor placement in containers. - Also withheld irrigation to determine how sensors responded to drying and rehydrated substrates (found substrate was difficult to rewet).
- Elevating dissolved oxygen for irrigation water

2:00 - 2:15 Admin Briefing - Doug Buhler, MSU – 15 minutes
Website for renewal info: Ncra.info
Direct link to renewal info: http://ncra.info/MSR_ApprovalProcess.php

Website has all the info that we should need for renewal
Please ask Linda Haubert or Chris for help as needed

Deadlines:
- Sept 15 submit request to write a proposal
Also recommended that we request the same number (NC 1186)
- October 15 upload objectives section to NIMSS
- November 15 All participants need to submit Appendix E form
- December 1 completed proposal must be submitted
- Reviewed by Dec 15

2:15 - 2:25 Break

2:25 - 3:45 Renewal - Genhua Niu, Incoming Chair – 1 hour 20 minutes (confirm the writing committee at the meeting and set up deadlines.)

Original areas of investigation (from founding document)
5 interrelated areas relevant to this project

6) Source water management and quality
7) Irrigation management
8) Runoff water management and quality
9) Substrate and nutrition management
10) Pathogens and crop health management

Discussion of how to move forward:
- Focus on the achievements of the group over the past 5 years and how we, as a group, plan to move forward into the future
Future objectives:
Instead of having the 5 objectives above, those categories will be reorganized

Initial discussion identified the following 3 areas:

4) Water quality (includes pathogens) (Sarah White lead with Genhua Niu, Tom Fernandez, Paul Fisher (?), Chuan Hong (?))
5) Water quantity (JLC lead with Marc van Iersel, Amy Fulcher and Tom Fernandez)
6) Substrate and nutrient management (James Altland with Jim Owen and Hye-ji Kim)

Economics will be included in all three objectives

A more integrated approach (pictures included at the end):

4) Abiotic and biotic stress (pathogens, salinity) (lead: Chuan Hong)
5) Agrichemicals (source remediation) (leads: Jim Owen, Sarah White)
6) Substrates (physical and chemical properties, and source) (lead: James Altland)

Connecting all three above is Water (quality, quantity)

Overarching objectives:
Economic, climate change, environmental, and societal benefits
Economics information (quantifying benefits) should be integrated into all aspects of renewal application

Potentially include Ecosystem services

Doug Buhler accepted nomination to remain as advisor to the group

Deadlines:
- Request to write a proposal: internal deadline 7/17/14
- Objectives (due 10/15/15). We will submit by 10/1/14
2 page limit with sub-objectives included
- All participants must submit Appendix E by 11/15/14. Internal deadline 11/1/14

- Completed proposal (Due date 12/1/14) Internal deadline 11/15/14

All those who are part of the group and have outcomes for a particular section should get it to the leads. Amy Fulcher, Tom Fernandez, John Lea-Cox have been working on this area and have outcomes for this section

3:45 - 4:45 Other Business
Determine date and location of next mtg – Genhua
Options
- Controlled environments conference Wooster Ohio
- Cultivate 2015 July 11-15
- Hawaii
- US Virgin Islands
- Grand rapids Michigan June 15-30
- Combined meeting with economics group

Possible locations to be sent out for vote by Genhua

Elections – elect secretary – Amy
James Altland nominated and elected unanimously for secretary for 2014-2015

Hye-Ji Kim volunteered for secretary for 2015-2016 term
The meeting ended with a briefing for the following day's tour – John Lea-Cox – 10 minutes

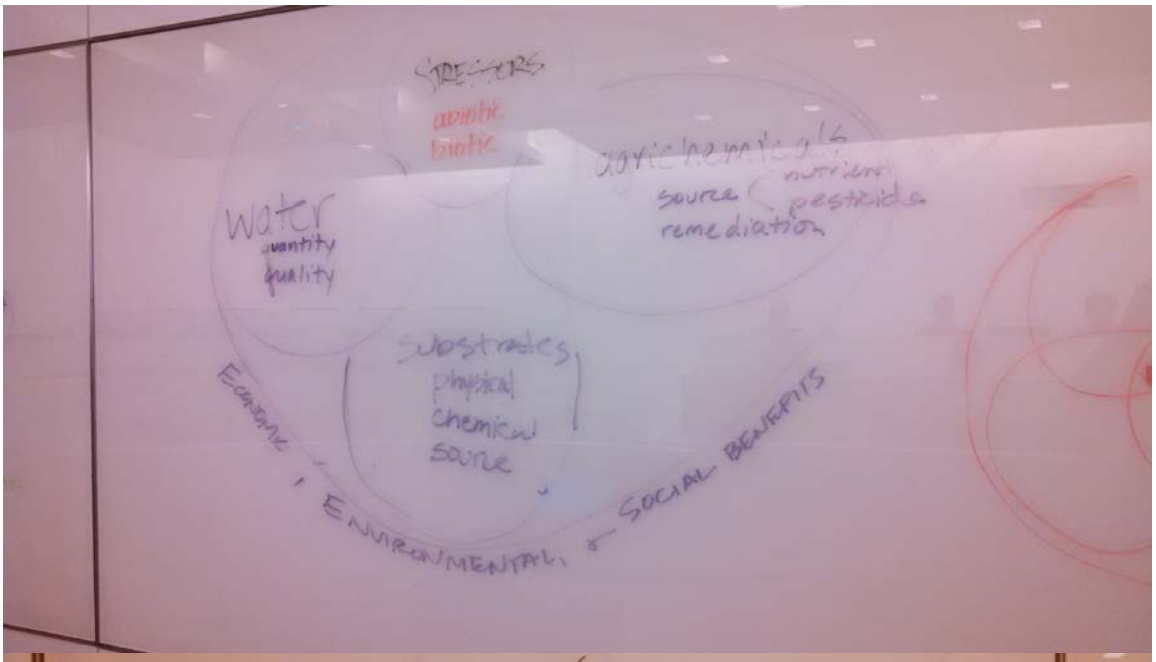
Tabled Agenda Items:
Summary of survey or focus groups results – Sarah
Report from Seeley Conference
Open discussion, sharing new ideas, other

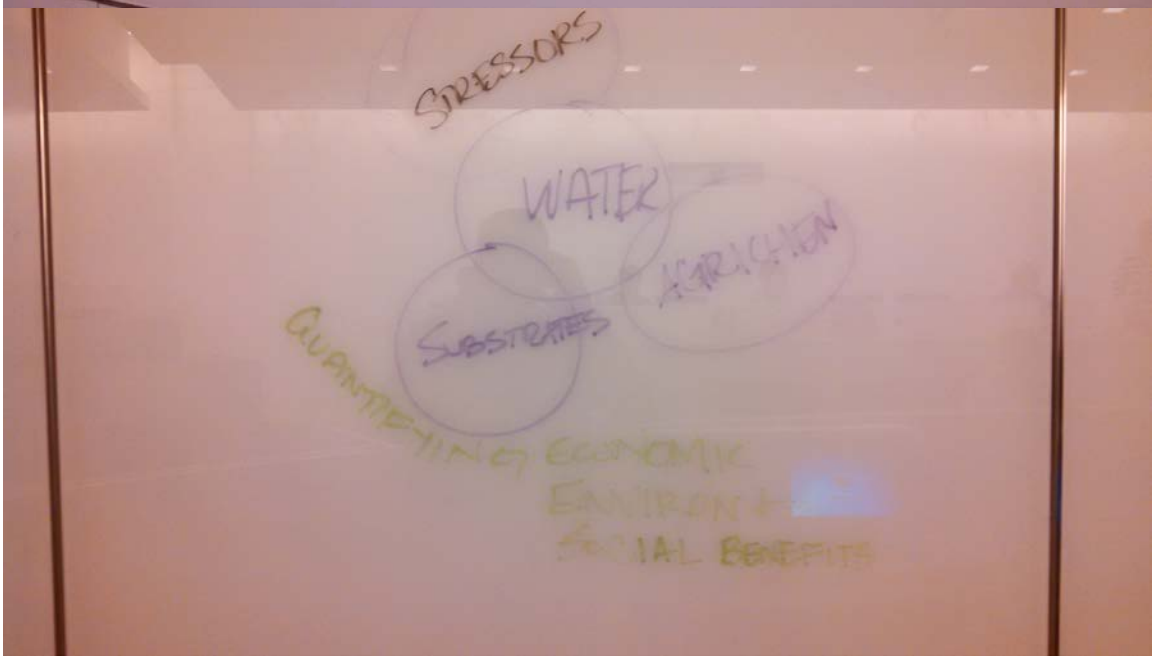
Notes on renewal from 2013 meetings minutes:

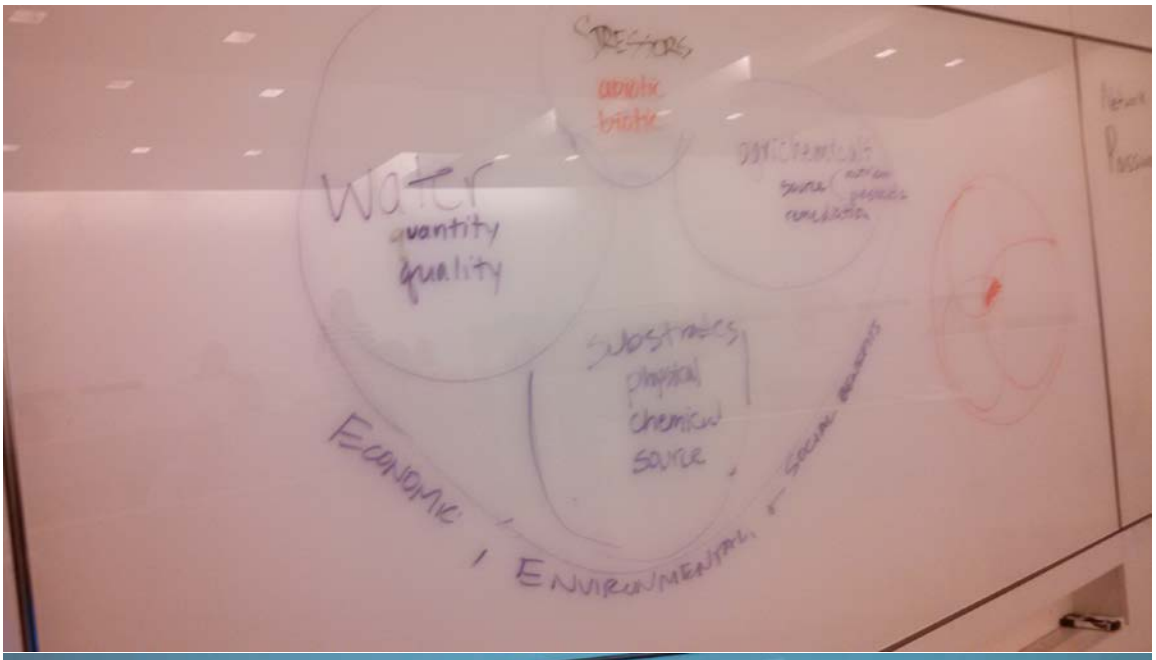
Genhua will provide overall coordination as chair the year of renewal.
John Lea-Cox will help Genhua with the submission.
Marc van Iersel– is excellent editor. Could be the executive editor of our document.
John Lea-Cox will be the water quantity team leader.
Sarah White will be the water quality team leader.
Jim Altland will be the substrates team leader, but may delegate
Doug Buhler has person in his office and also Chris at director's office can help. Send Doug the documents in word and his office will actually submit them.
Ronda Koski, Colorado State University, new member, volunteered to proofread the proposal.

John Lea-Cox – Suggests internal deadline 2 months in advance of real deadline.

Information for rewrite for Sarah:



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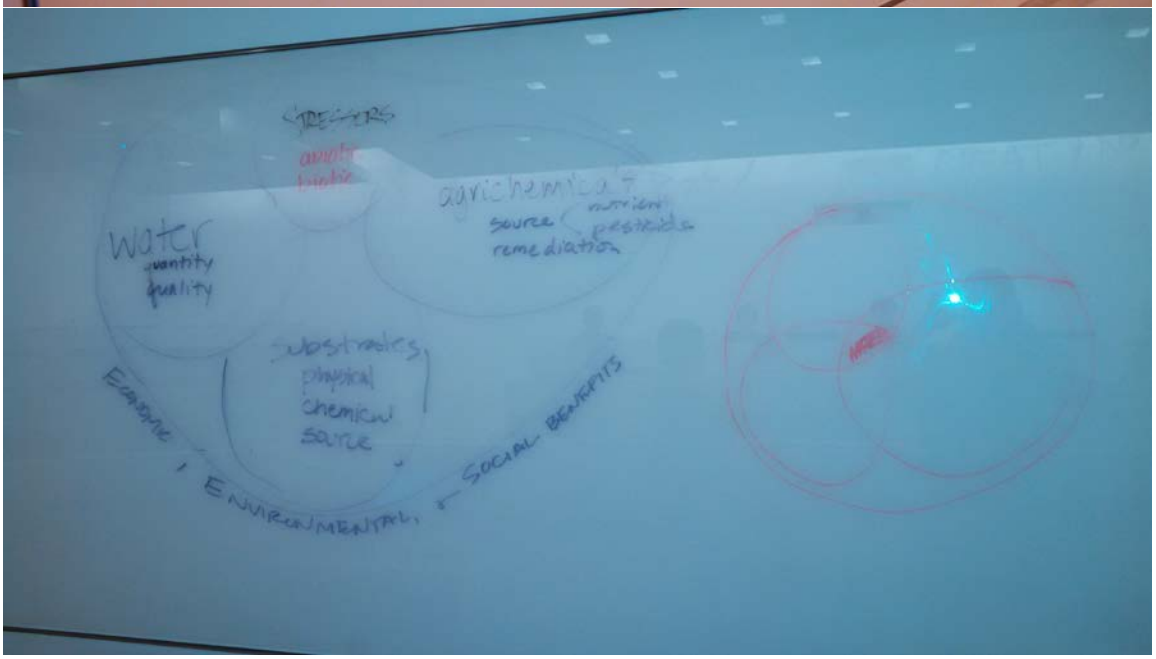
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source
ECONOMIC / ENVIRONMENTAL
SOCIAL BENEFITS


pesticide

Appendix V - NC1186 2014 Individual Station Reports

NC-1186 Station Report: ALABAMA

1. Impact Nugget: A concise statement of advancements, accomplishments and impacts. (Limit to 1-2 sentences)

Auburn University has developed recommendations for plant selection in rain gardens to increase nutrient removal from runoff.

Auburn University has identified selected landscape species tolerant of saline irrigation water.

2. New Facilities and Equipment. Include production areas, sensors, instruments, and control systems purchased/installed.

Eighteen rain gardens (6 ft x 6ft each) were constructed in two locations (total of 36 gardens) to be used for replicated rain garden research. The two locations provide two different soil types (coastal plain and piedmont). At each location there are six blocks with three rain gardens in each block. They are equipped with an underdrain that allows leachate exiting the rain garden to be captured, sampled, and analyzed chemically. Currently, rain gardens are planted with turf or landscape shrubs or unplanted (mulch only). Irrigation heads have been designed to apply water to mimic runoff that would enter a rain garden.

A new Green Infrastructure lab was completed in a new research facility on AU campus. This lab is equipped for water quality/quantity runoff experiments and can be used to evaluate the impact of surface cover (permeable, non-permeable, vegetated) on runoff and urban heat island effects.

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

In rain gardens, plants ultimately can be responsible for more nutrient removal from stormwater runoff than soil or substrate. Nutrient uptake by plants can occur year round and continue long term as plants continue to grow. When selecting plants for use in rain gardens, it is important to choose plants with diverse growth forms and habits to maximize nutrient uptake from stormwater runoff year-round.

Plants tolerant of saline irrigation water can potentially be irrigated with recycled water such as greywater or reclaimed wastewater. Irrigating plants with recycled water in production or in the landscape can reduce the demand for potable water.

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend.
NC-1186 Project area: Runoff water management and quality

Several plant species were identified to be tolerant to saline irrigation suggesting that these plants could be produced using recycled water in a nursery or included in saline or coastal landscapes. These species included *Portulaca oleracea, Muhlenbergia capillaris, Illicium parviflorum,* and *Begonia semperflorens-cultorum*. Three additional species were identified as being suitable for use in bioretention areas for filtration of pollutants (particularly phosphorus) from runoff. This suggests they would be suitable for use in water recycling facilities for production and in landscapes to capture stormwater runoff. These species included *Andropogon ternarius, Coreopsis verticillata,* and *Ilex vomitoria*.

5. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report.

NC-1186 Outcomes/Impacts: Mitigate nutrient runoff into the environment and better utilize limited water resources through increased use of secondary water sources instead of primary potable water sources.
Portulaca oleracea, Muhlenbergia capillaris, Illicium parviflorum, and *Begonia semperflorens-cultorum* were tolerant of daily saline irrigation up to at least 6000 ppm NaCl, suggesting tolerance of particularly high saline environments or saline recycled irrigation water.
Andropogon ternarius, Coreopsis verticillata, and *Ilex vomitoria* provided particularly effective phosphorus removal from bioretention areas when used in combination (polyculture) rather than alone (monoculture). Using a combination of growth habits provided more consistent year-round phosphorus removal.

6. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced.

Published Abstracts
Meder, A. and A. Wright. 2014. Phosphorus uptake and flooding tolerance of three native landscape plant species. HortScience 49:in press

Sluznis, R., A. Wright, and C. LeBleu. 2014. Greywater irrigation of two herbaceous landscape plant species. HortScience 49:in press

6. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

Meder, A. and A. Wright. 2014. Phosphorus uptake and flooding tolerance of three native landscape plant species. Oral presentation Southern Region American Society for Horticultural Science Annual Meeting.

Sluznis, R., A. Wright, and C. LeBleu. 2014. Greywater irrigation of two herbaceous landscape plant species. Oral presentation Southern Region American Society for Horticultural Science Annual Meeting.

7. Fund leveraging, specifically, collaborative grants between stations and members.

Wright, A., E. Brantley, and J. Howe. Evaluating Pollutant Removal Capabilities of Rain Gardens in Alabama**.** Alabama Agricultural Experiment Station.

8. Other relevant accomplishments and activities.

Initiated additional research to screen additional plant species for tolerance of repeated short-interval flooding like what would be expected in rain gardens. Plants being evaluated include *Illicium floridanum*, *Morella cerifera* (dwarf), *Lobelia cardinalis*, and *Chasmanthium latifolium*. New field research has been initiated to determine the effect of rain garden surface on rain garden uptake and leaching of phosphorus. Rain gardens are planted with turf only, landscape plants with mulch, or mulch only. Landscape plants include a polyculture of *Ilex verticillata, Ilex glabra*, *Chasmanthium latifolium,* and *Coreopsis verticillata*. Rain gardens were constructed in two locations to determine the effect of soil type on rain garden efficacy.

NC-1186 Report August 2014: FLORIDA

1. **Impact Nugget:** The Florida Department of Agriculture and Consumer Services administer a Best Management Practices (BMP) program. BMPs are developed in cooperation with Institute of Food and Agricultural Sciences at University of Florida. Nursery operations that voluntary implement and use BMPs receive a waiver of state imposed liability for ground and surface water contamination. In 2013, 39 container plant producers enrolled approximately 1000 acres in the BMP program.

2. **New Facilities and Equipment:** Funding has been allocated for construction of additional greenhouses at the University of Florida, Gainesville.

3. **Unique Water/Production Related Findings:** The objective of this research was to compare ET rates of plant species with containers spaced to achieve full canopy coverage. We evaluated uniform and marketable-sized plants grown in trade #3 (10-L) containers filled with pine bark-based substrates at nurseries in Florida and Virginia. Species tested in Florida were *Podocarpus macrophyllus*, *Rhaphiolepis indica* 'Alba', *Rosa* spp. Sunrosa® Pink, *Loropetalum chinense* var. *rubrum* 'Burgundy', *Ilex cornuta* 'Burfordii Nana', *Rhododendron* spp. 'Conversation Piece', *Viburnum odoratissimum* and in Virginia were *Rhododendron* spp. 'Girard's Crimson', *Spiraea japonica* 'Tracy' (Double Play® Big Bang), *Weigela florida* Wine & Roses®, *Hydrangea paniculata* PinkyWinky™, *Gardenia jasminoides* 'Frostproof', and *Berberis thunbergii* f. *atropurpurea* 'Rose Glow'.

In Florida, ET ranged from 0.77 cm for *Podocarpus* to 1.22 cm for *Viburnum* and ET of *Viburnum* greatly exceeded the ET of the other six species. In Virginia, ET ranged from 0.74 cm for *Rhododendron* to 1.15 cm for *Berberis* and ET of *Berberis* greatly exceeded the ET of the other five species. Excluding *Berberis* and *Viburnum*, differences in ET of 0.16 and 0.31 cm were determined for species tested in Virginia and Florida, respectively. These results indicated that differences in ET were small for most of the species evaluated. Thus, it is difficult for a production nursery to justify segregating these species by water needs.

4. **Accomplishment Summaries:** A significant accomplishment was the completion of a revised BMP manual (*Water Quality and Quantity Best Management Practices for Florida Nurseries*) that now encompasses content related to plants produced in native soils (http://www.freshfromflorida.com/content/download/37570/848371/NurseryBMP.pdf). The previous manual pertained to only container production. The container production content was revised. This achievement was the consummation of cooperation between governmental agencies, the nursery industry, and the University of Florida. A task force of representatives from these entities crafted BMPs that provide nursery plant producers using BMPs a waiver of state imposed liability from ground and surface water contamination. Videos developed by University of Florida and imbedded in the manual enhance the learning experience and help producers decide which BMPs are applicable to their operation.

5. **Impact Statement**: Irrigation water conservation is important for nurseries because of restrictions on allocations, competition for water resources, and the impact nutrient-laden runoff

water has on the environment. An ET based irrigation control system has been developed by University of Florida. Implementation of this system on a production area at a nursery in Florida resulted in a 20% reduction in overhead sprinkler water applied daily from March – July 2014. The amount of water applied to the ET based irrigated area was compared to an adjacent area of similar size with the same plants. The adjacent area was irrigated based on the Nursery Manager's decision regarding the amount of water to apply daily using a manual time setting. Plant growth was similar in both areas. Use of ET based irrigation is a BMP that not only provides a guide for irrigation management but results in a concomitant reduction of nutrients in runoff. At a nursery in Virginia, the owner indicated that nutritional amounts could be reduced 20% on some crops with implementation of the ET based irrigation BMP.

6. **Published Works:**

Book Chapter
Yeager, T. 2013. Best Management Practices for Field Production. In: Water Quality/Quantity Best Management Practices for Florida Nurseries. T. Pride, (ed.) Florida Department of Agriculture and Consumer Services, pp.17-21.
http://www.freshfromflorida.com/content/download/37570/848371/NurseryBMP.pdf

Refereed Journal Articles
Johnson, C.N., P.R. Fisher, J. Huang, T.H. Yeager, T.A. Obreza, R.P. Vetanovetz, W.R. Argo, and A. J. Bishko. 2013. Effect of fertilizer potential acidity and nitrogen form on the pH response in a peat-based substrate with three floricultural species. Scientia Horticulturae 162:135-143.

Yeager, T.H. and J.B. Million. 2013. Irrigation system capacity determined by container plant evapotranspiration. Acta Hort. 990:327-329.

Proceedings
Million, J. and T. Yeager. 2013. Effect of spacing on evapotranspiration rate of container-grown ornamentals. So. Nursery Assoc. Res. Conf. Proc. 58:302-307.

Poplar Article
Million, J.B. and T.H. Yeager. 2013. Online assessment of container production. American Nurseryman: July, 14-18 and 20-26.

Other Creative Works
Yeager, T. 2013. Nursery irrigation system checklist. Univ. Fla. Ext. Fact Sheet: ENH1208, 4 pages. http://edis.ifas.ufl.edu/pdffiles/EP/EP46900.pdf

7. **Scientific and Outreach Oral Presentations:**

Poster Presentation
Campoverde, E.V., P. Fisher, E. Skvarch, S. Steed, and T. Yeager. 2014. Educating Environmental Horticulture producers about water quality and conservation impacts on plant production. University of Florida Water Institute Conference, Sustainable Water Resources, Complex Challenges, Integrated Solutions, Gainesville, Florida (poster presentation).

Outreach Presentations
Yeager, T. 2014. Container plant irrigation considerations. Georgia Green Industry Research Update, Duluth, Georgia.

Yeager, T. 2014. Container plant irrigation management. Central Florida Extension Workshop Optimizing Profits by Controlling Resources, Eustis, Florida.

Yeager, T. 2014. Container plant irrigation considerations. Treasurer Coast Educational Program, Ft. Pierce, Florida.

8. NA

9. NA

NC-1186 Station Report Content: GEORGIA

1. Impact Nugget:
Low cost, but highly efficient, irrigation controllers have been developed. These controllers can help bring precision irrigation to homeowners and small farms.

2. New Facilities and Equipment.
We have developed a new low-cost irrigation controller, using open source prototype boards (Arduino). We used Arduino microcontrollers and soil moisture sensors to build an automated system to monitor and log substrate moisture content and to control irrigation based on real-time soil moisture measurements. The controller can control both 24VAC valves and latching 9VDC valves. The Arduino is programmed to read the raw output from the soil moisture sensors, convert it into VWC, log the data, send the results to a computer screen, and control irrigation based on the comparison of sensor readings and VWC thresholds. Thresholds varied from 0.2 to 0.5 m^3 m^{-3} and were applied to four pots with *Hibiscus acetosella* 'Panama Red'. The Arduino was reliable and successfully used to build an automated system to monitor substrate VWC and to control irrigation based on soil moisture sensors. The system worked properly during a 53-d trial, requiring little maintenance and irrigating the pots when the substrate VWC dropped below the set thresholds. The hardware cost of the irrigation control system, excluding the soil moisture sensor and valve is approximately $40.

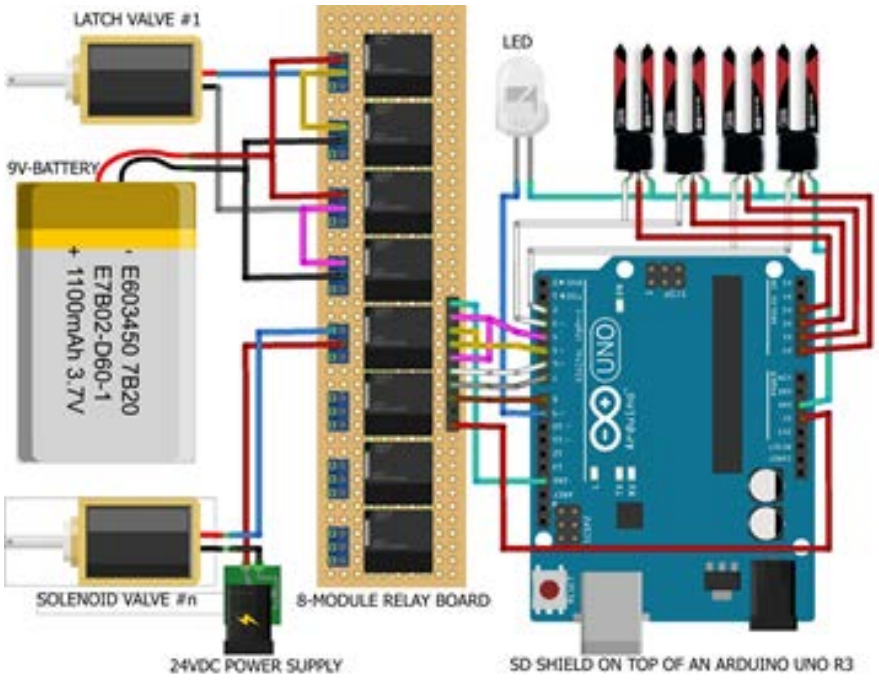

Figure 1. Diagram of a low-cost irrigation controller using an Arduino microcontroller. The controller can be used with both 24 VAC solenoids as well as latching 9 VDC solenoids.

3. Unique Water/Production Related Findings

Oxygen concentration in the rhizosphere

Anoxic conditions in soilless substrates have been implemented in disease development, reduced growth rates, and denitrification, but there is little quantitative information on oxygen concentrations in soilless substrates. We measured the partial pressure of oxygen (pO_2) in peat-perlite substrate planted with petunia (*Petunia* × *hybrida*). There are distinct diurnal fluctuations in substrate pO_2, and these can be largely explained by changes in substrate temperature, which increase the amount of water vapor in the air in the substrate, diluting oxygen and other gases. Barometric pressure (p_{air}) and substrate volumetric water content (θ) also affected substrate pO_2. Substrate pO_2 decreased with decreasing p_{air} and with increasing θ. Photosynthetic photon flux had a highly significant, but small effect on pO_2. Substrate density had no significant effect on pO_2. Overall, substrate pO_2 was between 19.1 and 20.6 kPa, even after watering the substrate to container capacity. The high air-filled porosity of the substrate (approximately 0.40 $m^3 \cdot m^{-3}$ after irrigation) may have prevented the development of anoxic conditions. Since such high levels of pO_2 are unlikely to induce any detrimental anoxic effects on plants, our data do not provide any supporting evidence for the idea that anoxia is an important potential problem in peat-perlite substrates.

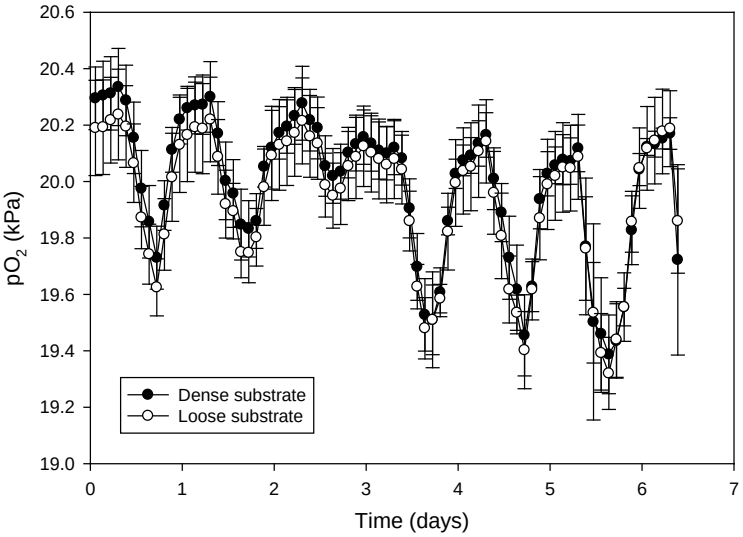

Figure 2. Temporal dynamics of the partial pressure of O_2 (pO_2) in a peat-perlite substrate in a loosely and densely packed substrate. There was no significance effect of substrate density on the partial pressure of oxygen. Diurnal fluctuations in $pO_2$are closely correlated with substrate temperature.

4. Accomplishment Summaries.

We have continued our testing of wireless sensor networks in commercial greenhouses and nurseries and found that soil moisture sensors can be very effective in automatically controlling irrigation. Growers see multiple benefits from these sensor networks, including water savings, shorter crop production cycles, less disease, and better quality. Based on estimates from the University of Maryland, implementation of these sensor networks by ornamental producers, assuming a 50% adoption rate, would result in annual water savings of 223 billion liters/year (enough for 400,000U.S. households) and reduce N and P discharges by 282,000 kg N and 182,000 kg P per year (Majsztrik et al., 2013). We expect a commercial release of the sensor networks in summer 2014.

There is a variety of automated irrigation controllers on the market, but many of them are either expensive or not designed for scientific research. Thus, we have develop an irrigation controller

that can trigger irrigation based on soil moisture sensor readings and store the soil moisture data, as well as information on how often different plots get irrigated. Using an Arduino Uno microcontroller, we can build a system that can control irrigation in four separate plots for about $40. The system can easily be scaled up to 14 plots using an Arduino Mega microcontroller (at a cost of $90). Cost estimates do not include the needed soil moisture sensors or irrigation systems. Prototype systems have been running successfully at the University of Georgia and Purdue University.

5. Impact Statements.

Wireless sensor networks can effectively control irrigation in commercial nurseries and greenhouses, based on soil moisture sensor readings. Growers have seen shorter production cycles, less disease, and better quality, along with large water savings. Implementation of this technology in greenhouses and nurseries will benefit both growers and society. Societal benefits include reduced water use and a decrease in agrochemical runoff.

6. Published Written Works.

Refereed Journal Articles

Bayer, A., I. Mahbub, M. Chappell, J. Ruter, and M.W. van Iersel. 2013. Water use and growth of *Hibiscus acetosella* 'Panama Red' grown with a soil moisture sensor controlled irrigation system. *HortScience* 48:980-987.

Chappell, M., S.K. Dove, M.W. van Iersel, P.A. Thomas and J. Ruter. 2013. Implementation of wireless sensor networks for irrigation control in three container nurseries. *HortTechnology* 23:747-753.

Lea-Cox, J.D., W.L. Bauerle, M.W. van Iersel, G.F. Kantor, T.L. Bauerle, E. Lichtenberg, D.M. King, and L. Crawford. 2013. Advancing wireless sensor networks for irrigation management of ornamental crops: an overview. *HortTechnology* 23:717-724.

O'Meara, L., M.R. Chappell, and M.W. van Iersel. 2014. Water use of *Hydrangea macrophylla* and *Gardenia jasminoides* in response to a gradually drying substrate. *HortScience* 49:493-498.

O'Meara, L., M.W. van Iersel, and M.R. Chappell. 2013. Daily water use of *Hydrangea macrophylla* and *Gardenia jasminoides* as affected by growth stage and environmental conditions. *HortScience* 48:1040-1046.

Starry, O., J.D. Lea-Cox, J. Kim, and M.W. van Iersel. 2014. Photosynthesis and water use by two *Sedum* species in green roof substrate. *Environmental and Experimental Botany* 107:105-112. DOI: 10.1016/j.envexpbot.2014.05.014.

van Iersel, M.W., M.R. Chappell, and J. Lea-Cox. 2013. Sensors for improved efficiency of irrigation in greenhouse and nursery production. *HortTechnology* 23:735-746.

Zhen, S., S.E. Burnett, M.E. Day, and M.W. van Iersel. 2014. Effects of substrate water content on morphology and physiology of rosemary, Canadian columbine, and cheddar pink. *HortScience* 49:486-492.

Symposium Proceedings

Alem, P.O., P.A. Thomas, and M.W. van Iersel. 2014. Irrigation volume and fertilizer concentration effects on leaching and growth of petunia. *Acta Horticulturae* 1034:143-148.

Bayer, A., J. Ruter and M. van Iersel. 2013. Automated irrigation control for improved growth and quality of *Gardenia jasminoides*. *Acta Horticulturae* 1014:407-411 (Proceedings of the International Plant Propagators' Society).

Bayer, A. K. Whitaker, M. Chappell, J. Ruter, and M. van Iersel. 2014. Effect of irrigation duration and fertilizer rate on plant growth, substrate solution EC, and leaching volume. *Acta Horticulturae* 1034: 477-484.

van Iersel, M.W. and S.K. Dove. 2014. Temporal dynamics of oxygen concentrations in a peat-perlite substrate. *Acta Horticulturae* 1034:355-361.

Abstracts

Alem, P.O., P.A. Thomas, and M.W. van Iersel. 2013. Control of poinsettia stem elongation: height limits using deficit irrigation. HortScience 48:S141-142 (abstract).

Bayer, A., and M. van Iersel. 2013. Using different teaching methods to enhance student learning of climate change. HortScience 48:S203 (abstract).

Bayer, A., J.M. Ruter, and M. van Iersel. 2013. Fertilizer rate and irrigation duration affect leachate volume, electrical conductivity, and growth of *Gardenia jasminoides*. HortScience 48:S182 (abstract).

Crawford, L., J.D. Lea-Cox, J. Majsztrik, W. Bauerle, M. van Iersel, T. Martin, and D. Kohanbash. 2013. Behind the curtain: The support component of wireless soil moisture networks. HortScience 48:S181-182 (abstract).

Ferrarezi, R.S., M.D. Ribeiro, M.W van Iersel, and R. Testezlaf. 2013. Subirrigation controlled by capacitance sensors for citrus rootstock production. HortScience 48:S142 (abstract).

Rivera, L.D., L. Crawford, M. van Iersel and S. Dove. 2013. Comparing hydraulic properties of soilless substrates with natural soils: a more detailed look at hydraulic properties and their impact on plant water availability. HortScience 48:S426-427 (abstract).

Starry, O., J. Kim, S. Dove, M. van Iersel, and J.D. Lea-Cox. 2013. Effects of water availability and temperature on CAM expression and water use efficiency by *Sedum album* and *Sedum kamtschaticum*. HortScience 48:S143 (abstract).

Thomas, P.T., M. Chappell, J.M. Ruter, E. Lichtenberg, and M.W. van Iersel. 2013. Wireless sensor networks for automated irrigation control in container nurseries: implementation and economic impact. HortScience 48:S179 (abstract).

7. Scientific and Outreach Oral Presentations.

Dinwiddie, J, M. van Iersel, B. Clegg, M. Nuccio, M. de Carbonnel, Y. Sun, A. Zhou, G. Crabb, J. Nichols, H. Zhaou, and Nic Bate. 2014. A whole-plant phenotyping approach leveraging Syngenta’s advanced crop laboratory at the research triangle park innovation center. 2014 Meeting of NCERA-101, Fairbanks, AK.

Dinwiddie, J., M. van Iersel, B. Clegg, M. Nuccio, M. de Carbonnel, Y. Suna, A. Zhoua, G. Crabb, J. Nichols, H. Zhou, and N. Bate. 2014. An automated whole plant phenotyping system for high resolution characterization of plant x environment interactions. Maize genetics conference, Bejing, China.

van Iersel, M.W., M. Chappell, and P.A. Thomas. 2014. Precision irrigation in greenhouses and nurseries: improving production and increasing profits. Horticulture Growers Short Course. Lower Mainland Horticulture Improvement Association, Pacific Agriculture Show, Abbotsford, BC.

8. Fund leveraging, specifically, collaborative grants between stations and members.
None

NC-1186 Station Report Content: HAWAI'I

1. Impact Nugget: A concise statement of advancements, accomplishments and impacts. (Limit to 1-2 sentences)

University of Hawaii has developed recommendations for the production of tropical ornamental plants using local substrate based on automated irrigation system that may reduce water use by 30%.

2. New Facilities and Equipment. Include production areas, sensors, instruments, and control systems purchased/installed.

University of Hawaii has set up sensor based irrigation systems for the research of water requirement of tropical ornamental plants.

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

Leucospermum performed better when grown with cinder based highly porous substrate compared to peat-based commercial potting mix. Higher water set point enhanced shoot growth of *Leucospermum* with more branches and more leaves, however, it significantly reduced root growth, resulting in lower root-to-shoot ratio. Therefore, applying more water during production may reduce plant resistance to multiple stresses during horticultural practices.

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend.

University of Hawaii at Manoa has developed substrate-moisture sensor based irrigation system to identify water requirement of tropical ornamental plants. Rooted cuttings of *Leucospermum* were grown with either commercial potting mix (CPM) or cinder-based potting mix (VCM), and irrigation was automatically controlled with substrate moisture sensors set at five set-points to provide different levels of volumetric water content (VWC, m^3/m^3). Daily irrigation volume gradually increased as plant size increased. Plants grown with VCM required higher irrigation frequency and higher daily irrigation volume, however, plants were significantly bigger and greener compared to the ones grown with CPM. Higher VWC enhanced shoot growth but reduced root growth, and generated higher leachate. Substrate seems to have more influence on plant quality and the irrigation frequency and volume, and the plant growth of *Leucospermum*. Optimizing potting substrates for crop production will help maximize crop quality and minimize water loss to the environment.

4. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report.

In order to determine water requirements of tropical ornamental plants, a sensor based irrigation system was used at University of Hawaii. Results indicate that substrate is the most important factor that affects irrigation frequency and volume, and plant quality of *Leucospermum*. When grown with highly porous substrate, plants performed better. Although higher irrigation frequency and volume increased shoot growth of *Leucospermum* by 40%, it reduced root growth by 20%, resulting in the reduction of root-to-shoot ratio by 50%. This information can be critical to optimize plant production systems.

5. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

Symposium Proceedings

Kim, H.J., P. Singleton, J. Lichty, and A. Kawabata. 2014. Water requirements of tropical ornamental crops. *Acta Horticulturae*. In Press.

Singleton, P., J. Lichty, and H.J. Kim. 2014. Anthurium productivity is limited by water and nutrient availability in volcanic cinder medium. *Acta Horticulturae*. In Press.

Poster Presentations

Kim, M.H., X.X. Li, A. Corpuz, D. Hunefeld, K. Leonhardt, and H.J. Kim. 2013. Substrate moisture sensor-based irrigation for the greenhouse production of protea. Landscape Industry Council of Hawai‘i (LICH) Conference 13(10): 1 (poster presentation).

Li, X.X., D. Hunefeld, A. Corpuz, M.H. Kim, H.J. Kim. 2013. Knowing the optimum phosphorus level for plant helps save cost and environment. Landscape Industry Council of Hawai‘i (LICH) Conference 13(10): 2 (poster presentation).

Kim, H.J., P. Singleton, J. Lichty, and A. Kawabata. 2013. Water requirements of tropical ornamental crops. International Society for Horticultural Science: Greensys 2013: 101 (oral presentation).

Singleton, P., J. Lichty, and H.J. Kim. 2013. Anthurium productivity is limited by water and nutrient availability in volcanic cinder medium. International Society for Horticultural Science: Greensys 2013: 179 (poster presentation).

6. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

Kim, H.J., P. Singleton, J. Lichty, and A. Kawabata. 2013. Water requirements of tropical ornamental crops. Greensys2013, International Society for Horticultural Science, Jeju, Korea.

7. Fund leveraging, specifically, collaborative grants between stations and members.

8. Other relevant accomplishments and activities.

NC-1186 Station Report: INDIANA

Impact Nugget:
Purdue University has developed methodology to determine nitrogen losses from container systems using stable isotopes.

Accomplishments:
Researchers at Purdue University grew red maple hybrids in containers and used fertilizers containing stable labeled isotopes of ammonium and nitrate nitrogen to determine the fate of all applied nitrogen. Major results are: 1) soilless media is biologically active and processes such as nitrification readily occur; 2) almost all ammonium applied to the media is nitrified; 3) nitrification likely accounts for the majority of N leaching that occurs; and 4) approximately 15% of the applied N was immobilized by the media.

Impact Statement:
The methodology developed at Purdue will allow researchers to better quantify N losses from container plants. This technique can now be used to conduct experiments on how environmental and management strategies affect the fate of N in container systems.

Poster Presentations

Raimann, S., W. Walters, S. Jame, M. Gosney, G. Michalski, and M. Mickelbart. 2005. Using stable isotopes to quantify nitrogen fates in container plants. Purdue Summer Undergraduate Research Fellowship (SURF) Sumposium (poster presentation).

NC-1186 Station Report: KENTUCKY

1. Impact Nugget: A concise statement of advancements, accomplishments and impacts.
A working model of a Prototype Programmable Logic Controller (PLC) System for Irrigation Automation has been tested and transferred to the field for trial controlling irrigation of container plants.

2. New Facilities and Equipment.
Programmable Logic Controller (PLC) System for Irrigation Automation Prototype System, Container Production Gravel bed expansion with run-off "Rain Garden", renovated city water field hydrant supply.

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

A working model of the PLC system has been developed and tested in the laboratory by Carey Grable, Extension Associate – Nursery Crops and systems specialist Thomas Turner.
http://www2.ca.uky.edu/HLA/Dunwell/PLCPoster_GrableTurner.pdf

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend. Include production areas, sensors, instruments, and control systems purchased/installed.

PLC Control Systems for Irrigation Automation:
This Prototype Irrigation system uses soil moisture probes to send a signal to a PLC controller at preset moisture levels. When the probe reaches a set low point, the PLC sends a signal to open the irrigation solenoid. After the irrigation has run long enough, and the probe reads the set high point, the PLC sends a signal to close the irrigation solenoid. A touch screen is used to monitor this system as well as make adjustments to the program on the fly.
West Kentucky has a manufacturing base that utilizes and has the expertise to program PLC. This system is designed to reduce water usage. This has many benefits: reduced chemical runoff, reduced disease pressure due to dryer conditions, as well as reduced amount of water used. This system has the capability to support automated fertilizer injection with minimal modification.

4. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report. Two examples are listed below.

The small UKREC Rain Gardens used to mitigate the run-off from gravel container research beds are the size that could be used by small local container production/retail nurseries that sell directly to the public. The Rain Garden/run-off control demonstrations are shared with the public via a June Open House.

5. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

Hagen, E, S. Nambuthiri, A. Fulcher, and R.L. Geneve. 2014. Comparing substrate moisture-based daily water use and on-demand irrigation regimes for oakleaf hydrangea grown in two container sizes. Scientia Horticulturae, in press.

Evans, M.R., A. Koeser, G. Bi, S. Nambuthiri, R.L. Geneve, K. Jacobsen, S. Lovell, and R. Stewart. 2014. Impact of biocontainers with and without shuttle trays on water use in the production of a containerized ornamental greenhouse crops. HortTechnology, in press.

Wang, X., R.T. Fernandez, B.M. Cregg, R. Auras, N. Gong, A. Fulcher, D.R. Cochran, G. Niu, Y. Sun, G. Bi, S. Nambuthiri and R.L. Geneve. 2014. Physical properties and compostability of alternative containers for nursery production. Scientia horticulturae, in preparation.

Wang, X., R.T. Fernandez, B.M. Cregg, R. Auras, A. Fulcher, D. Cochran, G. Niu, Y. Sun, G. Bi, S. Nambuthiri and R.L. Geneve. 2014. Multi-state Evaluation of Plant Growth and Water Use in Plastic Containers and Alternative Nursery Containers. HortTechology, submitted.

Li, T., G. Bi, G. Niu, S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, Y. Sun, X. Zhao, R.J. Stewart. 2014. Feasibility of using biocontainer in pot-in-pot system for a two-year nursery production of Betula nigra. HortTechnology, submitted.

Nambuthiri, S., R.L. Geneve, R.T. Fernandez, G. Bi, G. Niu, and X. Wang. 2014. Substrate temperature in black plastic, wood pulp, keratin, and fabric root pouch nursery containers. HortTechnology, submitted.

Susmitha Nambuthiri, Robert Geneve and Sharon Kester. 2014. Evaluating irrigation scheduling based on daily evapo-transpiration or plant demand of container grown woody plants. University of Kentucky Nursery Landscape Research Report, in press.

6. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

7. Fund leveraging, specifically, collaborative grants between stations and members.

LeBude, A., K. Braman, N.W. Gauthier, J. Neal, M. Chappell, A. Fulcher, W. Klingeman III, J. Derr, G. Knox, C. Adkins, J.-H. Chong, W. Dunwell, S. Frank, F. Hale, S.A. White, J. Williams-Woodward, and A. Windham. 2014. Experiential Nursery IPM Workshop Series to Enhance Grower Adoption and Extension Agent Facilitation. USDA-NIFA, SR-IPM, $39,982.

Bessin, Ric – PD: Co-PI: Winston C. Dunwell, C. Lee, Patricia Lucas, G. Schwab, and L. Murdock. 2013-2016. IPM in Kentucky-Integrated development and delivery. NIFA- Extension Integrated Pest Mangement Coordination and Support. $86,500 for 3 years starting October 2013. PI: (Winston C. Dunwell. 2013-2016. Kentucky Nursery Crops IPM Working Group. $34,036.)

8. Other relevant accomplishments and activities.

NC-1186 Station Report: LOUISIANA

1. Impact Nugget
    - A new irrigation and leaching control system has been designed by LSU AgCenter scientists to reduce irrigation water consumption and potential nutrient leaching during nursery container crop production (reported by Dr. Jeff Beasley).
    - A new substrate amendment has shown promising results to be used in container production of ornamental plants (reported by Dr. Yan Chen).

2. New Facilities and Equipment. The LSU AgCenter has recently hired irrigation research and extension faculty that will be housed at the Red River Research Station, Bossier City, LA. This water management initiative team includes an irrigation engineer, an irrigation economist, a water quality expert, and an irrigation agronomist (reported by Dr. Allen Owings).

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

    - The LSU AgCenter has recently completed a water and nutrient management knowledge/practice survey of nursery, landscape and garden center professionals. Results will be available this fall.
    - Hammond Research Station has been working with USDA-ARS Southern Horticulture Lab on a new substrate amendment, rice hull ash (RHA). Findings are promising that this material can be formulated into substrate mixes to increase water/nutrient use efficiency and at the same time as a supplemental fertilizer.
    - Louisiana Governor Bobby Jindal declared July as Smart Irrigation Month in Louisiana in cooperation with the Louisiana Irrigation Association and the Irrigation Association. This coincides with Smart Irrigation Month promoted nationally by the Irrigation Association.

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend.
    - We have conducted two experiments with rice hull ash, which showed promising properties as a wood-based substrate amendment to increase substrate water and nutrient retention capacity without negatively affecting plant growth. We have discussed these findings with local growers with the purpose to plan future on-site research plots.

5. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be

oriented towards the general public. This is perhaps the most difficult yet most important part of the report.

- Research and extension efforts are continuously being pursued at LSU AgCenter addressing irrigation management and water quality issues our industry is facing. Research on container substrate amendments and irrigation control with low leaching fractions are promising for further investigation.

6. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

7. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

8. Fund leveraging, specifically, collaborative grants between stations and members.
    - Collaborative agreement between USDA-ARS Southern Horticultural Laboratory and LSU AgCenter Hammond Research Station. $20,000. 2012 – 2017 (Chen).
    - HRI 2013 project: A new technology for reducing irrigation application and controlling leaching in greenhouse and nursery production. $17,350 (Beasley).

9. Other relevant accomplishments and activities.

NC-1186 Station Report: MICHIGAN

Impact Nugget:

Michigan State University and cooperators on an SCRI project determined that alternative (to petroleum-based polymer) containers constructed of wood pulp or woven fabric produced similar size and quality plants but required higher irrigation rates, indicating that any benefits in CO_2 reductions could be offset by increased water use. We also identified that consumers could be segmented in relation to production-, price-, or plant-orientation and the segment affected the price they were willing to pay for plants grown with water conserving, sustainable or conventional methods.

Accomplishments:

Michigan State University grew plants of the same size and quality of 3 taxa of ornamental plants in alternative containers but alternative containers with higher water vapor transmission rates could increase over-winter mortality in un-irrigated overwintering houses.

Impact Statement:

Plastic containers are produced using petroleum with a high carbon cost and are typically not recycled since they are contaminated with dirt and possibly pests after initial use. The goal of this project was to evaluate the ability of alternative to plastic containers in producing ornamental plants of the same size and quality. Field trials were conducted over the past 3 years to evaluate plant growth, quality and water use in several alternative containers. Containers were made of wood pulp, recycled and woven plastic, and keratin from chicken feathers. Plant growth and quality was unaffected providing irrigation was applied to replace the amount of water used but a higher number of some plants died overwinter due to water loss through porous sides of wood pulp and woven containers. The trade off between lower carbon inputs and higher water inputs is being evaluated.

New Facilities and Equipment

RFID readers, antennae and tags have been purchased for use at J. Frank Schmidt and Sons Nursery in Boring and Canby, OR and additional equipment will be used at 3 Michigan operations in 2014. RFID is currently being evaluated for performance and durability in nursery and greenhouse environments for simple inventory tasks but will be integrated into decision support systems for irrigation and nutrient management among other tasks.

Published Works:

Refereed Journal Articles

Behe, B.K., R.T. Fernandez, P.T. Huddleston, S. Minahan, K.L. Getter, L. Sage and A.M. Jones. 2013. Practical field use of eye-tracking devices for consumer research in the retail environment. HortTechnology 23:517-524

Campbell, B., B.K. Behe, H. Khachatryan, C. Hall, J. Dennis, P. Huddleston, and R.T. Fernandez. in-press. Incorporating eye tracking technology and conjoint analysis to better understand the green industry consumer. HortScience in- press.

Taylor, A.J., R.T. Fernandez, P. Nzokou, and B.M. Cregg. 2013. Carbon isotope discrimination, gas exchange, and growth of container-grown conifers under cyclic irrigation. HortScience 48:848-854.

Theses/Dissertations

Wang, X. 2013. Irrigation management and alternative containers for more sustainable nursery production. **M.S. Thesis**. Department of Horticulture, Michigan State University, East Lansing, MI.

In-review or In-preparation

Li, T., G. Bi, G. Niu, S.S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, Y. Sun, X. Zhao. In-review. Feasibility of Using Biocontainers in a Pot-in-Pot System for Nursery Production of Betula nigra. HortTechnology

Nambuthiri, S., R.L. Geneve, Y. Sun, X. Wang, R.T. Fernandez, G. Niu, G. Bi, A. Fulcher. In-review. Substrate temperature in black plastic, wood pulp, keratin, and fabric nursery containers. HortTechnology

Pershey, N.A., R.T. Fernandez, B.M. Cregg and J.A. Andresen. In-review. Irrigating based on daily water use reduces nursery effluent volume and nutrient load without reducing growth of four conifers. Submitted to Agricultural Water Management

Pershey, N.A. in-preparation. Reducing Water Use, Runoff Volume, and Nutrient Movement for Container Nursery Production by Scheduling Irrigation Based on Plant Daily Water Use. **M.S. Thesis**. Department of Horticulture, Michigan State University, East Lansing, MI.

Wang, X., R.T. Fernandez, B.M. Cregg, R. Auras, A. Fulcher, G. Niu, Y. Sun, G. Bi, S. Nambuthiri, R.L.Geneve. in-preparation. Multi-state evaluation of plant growth and water use in plastic and alternative nursery containers. HortTechnology

Wang, X., R.T. Fernandez, B.M. Cregg, R. Auras, N. Gong, A. Fulcher, D.R. Cochran, G. Niu, Y. Sun, G. Bi, S. Nambuthiri, R.L. Geneve. in-preparation. Physical Properties and Compostability of Alternative Containers for Nursery Production. HortTechnology

Yuan, S., P. Huddleston, B.K. Behe, R.T. Fernandez, C. Hall, and M. Palma. in-preparation. The effect of product expertise and involvement on consumers' information seeking and decision making process. J. Consumer Psychology

Symposium Proceedings

Behe, B. K., Campbell, B., Khachatryan, H., Hall, C., Dennis, J., Fernandez, T. and Huddleston, P. T. 2013. Consumers look at what is important. Paper presented at the 1st International

Symposium on Horticulture, Economics, Marketing and Consumer Research. August 19-21, 2013. Portland, OR

Huddleston, P.T., B.K. Behe, A. Jones and R.T. Fernandez. in-press. Can you read the sign? Consumers' attention to water conservation information as an extrinsic cue. 2014 Academy of Marketing Science 17th World Marketing Congress, Lima Peru.

Popular Articles

Fernandez, R.T. 2014. The future of water quality. American Nurseryman. June 2014, p. 18-21.

Fulcher, A., G. Niu, G. Bi, M. Evans, R.T. Fernandez, R. Geneve, A. Koeser, S. Nambuthiri, N. Pershey, J.R. Stewart, S. Verlinden, X. Wang. 2013. Pulp or Plastic? Research comparing plastic to pulp containers. American Nurseryman. February 2013, p. 20-24.

Professional/Outreach Publications

Cregg, B. and D. Ellison. 2013. Urban tree selection in a changing climate. *The Michigan landscape 56(6):28-30.*

Cregg, B. 2013. Weather 2012: One for the record books. *The Michigan Landscape 56(1):29-31*.

Dudek, T.A. and R.T. Fernandez. 2013. Is plastic better than pulp containers for nursery plants? http://msue.anr.msu.edu/news/is_plastic_better_than_pulp_containers_for_nursery_plants

Fulcher, A. and R.T. Fernandez. 2013. Sustainable nursery irrigation management: Part 1. Water use in nursery production. Univ. TN CES W278, https://utextension.tennessee.edu/publications/Documents/W278.pdf

Fulcher, A. and R.T. Fernandez. 2013. Sustainable nursery irrigation management: Part 2. Strategies to increase efficiency. Univ. TN CES W 279, https://utextension.tennessee.edu/publications/Documents/W279.pdf

Fulcher, A. and R.T. Fernandez. 2013. Sustainable nursery irrigation management: Part 3. Strategies to manage nursery runoff. Univ. TN CES W280, https://utextension.tennessee.edu/publications/Documents/W280.pdf

Stelzer, H. and B. Cregg. 2013. FAQ's for helping your tree survive during a drought. Extension Disaster Education Network (EDEN) 6 pp.

Scientific and Outreach Presentations

Brumfield, R.G., G. Bi, D. Cochran, R.T. Fernandez, A.F. Fulcher, R.L. Geneve, A. Koeser, G. Niu, J.R. Stewart, and X. Wang. 2014. Economics of utilizing biodegradable containers in ornamental crop production systems. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. (Abstr.)

Cregg, B, and D. Ellison. 2013. Urban tree selection in a changing climate. Presented at ASHS-2013, Annual Conference, July 22-25, Palm Desert, CA. (Abstr.)

Cregg, B. 2013. Research in Real Time: Integrating Social Media and Landscape Research. Presented at ASHS-2013, Annual Conference, July 22-25, Palm Desert, CA. (Abstr.)

Cregg, B. 2013. Weather 2012. Looking back: Looking Forward. Michigan Nursery and Landscape Association Great Lakes Trade EXPO. Grand Rapids, MI. January 7, 2013.

Cregg, B. 2013.Urban tree selection in a changing climate. Minnesota Shade Tree Short Course. March 13, 2013.

Fernandez, R.T., X. Wang, Ingrao, A., Bi, G., Fulcher, A., Geneve, R., Niu, G., Sun, Y., Verlinden, S., Cregg, B., Ngouajio, M., Auras, R., Nambuthiri, S. and Conneway, R. 2014. Water use and performance of plants grown in alternative nursery containers. ISHS IHC 2014, Brisbane, Australia. (Abstr.)

Fernandez, R.T., H.M. Stoven, S. Doane. 2014. Using RFID for inventory tracking in container and field nursery operations. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. (Abstr.)

Fernandez, R.T., X. Wang, G. Bi, G. Niu, R.L. Geneve, A.F. Fulcher, D. Cochran. 2014. Water use of nursery plants grown in alternative containers: Implications for sustainability. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. (Abstr.) Invited Workshop Presentation

Fernandez, R.T. 2014. Not just another pretty plant: Using plants for improving water resources. Meadow Brook Garden Club. April 25, 2014

Fernandez, R.T. 2014. Phytoremediation: Putting plants to work. Kalamazoo Area interested citizens. Portage, MI April 15, 2014

Fernandez, R.T. 2014. Do your plants have a drinking problem? Managing irrigation to improve plant growth and quality. Idaho Horticulture Expo, Boise, ID. January 23, 2014

Fernandez, R.T. 2014. Stemming the off-site tide: Managing nursery irrigation and runoff. Ohio Nursery Short Course, Columbus OH. January 13, 2014

Fernandez, R.T. 2014. How water quality, substrates and irrigation management affects container plant production and movement of nutrients and pesticides. MNLA GLTE, Grand Rapids, MI January 6, 2014

Fernandez, R.T. 2013. Irrigating substrates to improve nutrient retention and plant growth. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S100 (Abstr.) Invited Workshop Presentation

Fernandez, R.T. 2013. Pesticides in recycled water: What are the issues? 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S101 (Abstr.) Invited Workshop Presentation

Li, T., G. Bi, G. Niu, S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, A.F. Fulcher, Y. Sun, and X. Zhao. 2014. Use of fiber containers in pot-in-pot system for a two-year nursery production of birch. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. (Abstr.)

Li, T., G. Bi, G. Niu, S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, A. Fulcher, Y. Sun. 2013. Use of biocontainers in pot-in-pot nursery production system. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S48 (Abstr.)

Nambuthiri, S., R.L. Geneve, Y. Sun, X. Wang, G. Bi, R.T. Fernandez, and G. Niu. 2014. Impact of alternative materials on container physical properties and substrate temperature. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. (Abstr.)

Nambuthiri, S., R.L. Geneve, G. Niu, Y. Sun, G. Bi, R.T. Fernandez, X. Wang. 2013. Impact of container material on substrate heat buildup in an outdoor nursery. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S45 (Abstr.)

Wang, X., R.T. Fernandez, B.M. Cregg, M. Ngouajio, R. Auras, J.P. Albano. 2013. Sensor integrated automatic irrigation system to reduce runoff and nutrient loss without affecting plant growth. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S259 (Abstr.)

Wang, X., R.T. Fernandez, G. Bi, A. Fulcher, R.L. Geneve, G. Niu, S. Verlinden, B.M. Cregg, M. Ngouajio. 2013. Plant growth and water use in plastic, fiber, keratin, and Root Pouch containers. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S108 (Abstr.)

White, S.A., J.S. Owen, Jr., J. Majsztrick, R.T. Fernandez, P.R. Fisher, C.R. Hall, T.A. Irani, J.D. Lea-Cox, J. Newman, L.R. Oki. 2013. Containment, remediation, and recycling of irrigation water for sustainable ornamental crop production: Results of a SCRI Planning Grant. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S264 (Abstr.)

Funding:

Behe, B.K., P. Huddleston, R.T. Fernandez, T. Dudek, K. Getter, H. Wollager. 2014. Does the role of branding on plant quality perceptions vary by age cohort? Project GREEEN $35,000

Cregg, B.M. 2013. Utility of Plant Growth Regulators in Christmas Tree and Conifer Nursery Production. USDA SCRI Block Grant $69,241

Cregg, B.M. 2013. Urban tree selection in changing climate. Project GREEEN $70,000

Cregg, B.M. 2013. Urban tree selection in a changing climate. Michigan Department of Agriculture and Rural Development. $9,518

Cregg, B.M. 2013. Urban tree selection in a changing climate. Michigan Nursery and landscape Association. $5,000

Cregg, B.M., B. Crain, P. Nzokou, J. O'Donnell, and B. Bishop. 2013. Environmental control of coning in Fraser fir. Michigan Department of Agriculture and Rural Development. $9,235

Cregg, B.M. 2013. Environmental control of cone production in Fraser fir Christmas tree plantations. Michigan Christmas Tree Association $4,652

Fernandez, R.T., B.K. Behe, and T.A. Dudek. 2014. RFID for decision support and logistics management for the container plant value chain. Project GREEEN $39,150

Warnock, D.F., G. Bi, R. Brumfield, R.T. Fernandez, A. Fulcher, B. Geneve, D. Ingram, J. Wesley, G. Niu, R. Schnelle, S. Verlinden. 2010. Impact and social acceptance of selected sustainable practices in ornamental crop production systems. USDA SCRI $1,548,793 (Final Year, FY2013).

Pending

Bauerle, W.L., J.D. Lea-Cox, R.T. Fernandez, A.G. Ristvey, G.A. Kantor, T.L. Bauerle, M. van Iersel, P. Thomas, M. Chappell, C. Campbell, L. Crawford, C. Lund, E. Lichtenberg, S. Kim. 2014. Maximizing the value of wireless sensor networks through sensor-based fertilization and scaled up irrigation control. USDA-NIFA-SCRI. $5,999,802 over 4 years (PENDING)

Fernandez, R.T. 2014. Maximizing the value of wireless sensor networks through sensor-based fertilization and scaled up irrigation control. MSU Project GREEEN $160,000 (PENDING and tied to Bauerle et al., SCRI)

Fernandez, R.T., B.K. Behe, J.D. Lea-Cox, and E. Lichtenberg. 2014. RFID for nursery and greenhouse cost of production, logistics, and decision support. Horticulture Research Institute $90,000 over 2 years (PENDING)

Fernandez, R.T., B.M. Cregg, and B.K. Behe. 2014. Clean WateR^3 - Reduce, Remediate, Recycle: Informed Decision-Making to Facilitate Use of Alternative Water Resources and

Promote Sustainable Specialty Crop Production. $200,000 (PENDING and tied to White et al., SCRI)

White, S.A., J.S. Owen, B. Behe, B. Cregg, R.T. Fernandez, P. Fisher, C.R. Hall, D. Haver, D. Hitchcock, D.L. Ingram, S. Kumar, A. Lamm, J. Lea-Cox, L.R. Oki, J.L. Parke, A. Ristvey, D. Sample, L.S. Warner. 2014. Clean WateR^3 - Reduce, Remediate, Recycle: Informed Decision-Making to Facilitate Use of Alternative Water Resources and Promote Sustainable Specialty Crop Production. USDA-NIFA-SCRI. $8,734,103 over 5 years (PENDING)

NC-1186 STATION REPORT: MISSISSIPPI

1. Impact Nugget

Graduate student Anthony Witcher reported in an article published in HortTechnology that a range of plant species can be propagated from stem cuttings in an alternative substrate composed of processed whole pine trees alone or combined with peat moss.

2. New Facilities and Equipment

A greenhouse container irrigation and leachate collection system has been installed for use in collaborative projects with Dr. John Adamczyk (Research Leader) and Anthony Witcher (Support Scientist) at the USDA-ARS Thad Cochran Southern Horticultural Laboratory, and Dr. Eugene Blythe at the South Mississippi Branch Experiment Station in Poplarville, Mississippi. These projects will examine irrigation efficiency in alternative soilless substrates, as well as the binding and leaching potential of soil-incorporated insecticides used in container-grown crops.

3. Unique Water/Production Related Findings

In light of the increasing use of alternative substrate materials as replacements for pine bark, a collaborative project among University of Southern Mississippi, Mississippi State University, Auburn University, and USDA-ARS evaluated cutting propagation substrates prepared with processed whole pine trees and found that such material could be used successfully, particularly when blended with peat moss.

4. Accomplishment Summary

Wood-based substrates have been extensively evaluated for greenhouse and nursery crop production, yet these substrates have not been evaluated for propagation. The objective of a collaborative study among University of Southern Mississippi, Mississippi State University, Auburn University, and USDA-ARS was to evaluate processed whole pine trees as a rooting substrate for stem cutting propagation of a range of ornamental crops, the pine substrate used alone and in combination with peat moss. Physical and chemical properties were determined for all substrates. Rooting and initial shoot growth responses were determined for eight species in the two-year study. Rooting percentage was similar among substrates within each species in both experiments. The addition of peat moss resulted in significantly greater total root length in substrates containing pine bark and whole pine tree compared with the latter two alone, for five of the eight species.

5. Impact Statement

The supply of pine bark as a component of nursery and greenhouse growing media has become more limited in the Southeastern U.S. due to reduced forestry production and increased use of bark as a fuel source. Although previous studies has shown that growing media containing processed whole pine trees are a viable substitute for pine bark, this renewable material had not previously been tested for use in cutting propagation. Graduate student Anthony Witcher determined that processed whole pine trees can be used successfully for rooting cuttings of horticultural crops, and is best used blended with peat moss. Results of this study will provide additional, sustainable substrate options for commercial nursery producers.

6. Published Written Works

Witcher, A.L, E.K. Blythe, G.B. Fain, and K.J. Curry. 2014. Stem cutting propagation in whole pine tree substrates. HortTechnology 24:30-37.

Merhaut, D.J., E.K. Blythe, J.P. Albano, and J.P. Newman. 2013. Nutrient release from controlled-release fertilizers in nursery production systems. UNCFA News: Vol. 17, No. 3, Fall 2013. University of California, Agriculture and Natural Resources, Nursery and Floriculture Alliance. (Posted at: http://ucanr.edu/sites/UCNFAnews/Feature_Stories/Nutrient_Release_from_Controlled-Release_ Fertilizers_in_Nursery_Production_Systems/).

7. Scientific and Outreach Oral Presentations

None during this period.

8. Fund Leveraging

Mississippi Agricultural and Forestry Experiment Station. Nutrient release and plant nutrient use efficiency using controlled-release and water-soluble fertilizers in container nursery production systems. 2014. E.K. Blythe. $10,000.00. (In support of collaborative projects with University of California, Riverside and with USDA-ARS.

9. Other

Data analysis and manuscript preparation is underway for a study examining the effect of controlled-release fertilizer type on nutrient leaching and nutrient uptake in outdoor-grown Texas privet and greenhouse-grown azalea by Donald J. Merhaut (University of California, Riverside), Eugene K. Blythe (Mississippi State University), and Joseph P. Albano (formerly USDA-ARS). In these studies, we are quantifying nutrients lost through leaching and nutrients taken up by plants during an 11-month growing period using four different types of controlled-release fertilizers and standard nursery production procedures.

NC1186 Station report: NORTH CAROLINA (LeBude)

Impact Nugget:

The Southern Nursery IPM (SNIPM) Working Group presented three two-day workshops to growers in three southeastern states and improved knowledge about irrigation management by 20%. After the workshop, growers felt that they were 40% more likely to adopt the techniques presented to them and manage their irrigation by increasing its efficiency of application.

Accomplishment Summaries

The Southern Nursery IPM (SNIPM) working group received funding from the Southern IPM Center to conduct three two-day workshops that included hands-on experiential learning for growers and Extension agents in three nursery dense areas in the south. Attendees were instructed on irrigation management techniques and substrate and nutrition management, for example, measuring water availability using sensors, measuring irrigation application and uniformity, and measuring pH and electrical conductivity in leachate in containers. After the workshops, all attendees improved their knowledge about irrigation management techniques and substrate and nutrition management, sharpened their skills to successfully monitor and measure these factors, and became more confident of their ability to adopt the practices and integrate them at their nursery operation.

Impact Statements

Application of irrigation to nursery crops affects growth, health, and the amount of nutrients available to plants, as well as the nutrients lost in production runoff water. Because water, nutrients, and plant health are limited resources that affect environmental health, it is imperative that they are used judiciously. The Southern Nursery IPM (SNIPM) Working Group with funding from the Southern IPM Center provided training for growers on measuring irrigation efficiency. Approximately 75 growers in three different areas of the southeast U.S. learned how to measure irrigation application rate and its uniformity. By adopting these techniques that reduce water use, growers could reduce production costs while maintaining plant quality.

Refereed Publications

Fulcher, A., S.A. White, J.-H. (JC) Chong, J.C. Neal, J.L. Williams-Woodward, C.R. Adkins, S.K. Braman, M.R. Chappell, J.F. Derr, W.C. Dunwell, S.D. Frank, S.A. Gill, F.A. Hale, W.E. Klingeman, A.V. LeBude, K. Rane, and A.S. Windham. 2013. Testing, promoting, and launching a mobile application as an extension tool: A case study with IPMPro. HortTechnology 23:407-410.

Fulcher, A., J.-H. (JC) Chong, S.A. White, J.C. Neal, J.L. Williams-Woodward, C.R. Adkins, S.K. Braman, M.R. Chappell, J.F. Derr, W.C. Dunwell, S.D. Frank, S.A. Gill, F.A. Hale, W.E. Klingeman, A.V. LeBude, K. Rane, and A.S. Windham. 2013. Developing a mobile application as an extension education tool: A case study using IPMPro. HortTechnology 23:402-406.

Trade Journal

Fulcher, A., A. LeBude, S. White, J-H Chong, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, S. Gill, F. Hale, W. Klingeman, G. Knox, J. Neal, M. Paret, K. Rane, N. Ward, J. Williams-Woodward, and A. Windham. 2013. IPM in action. Nursery Management 29(12):30-33.

Websites

LeBude, A.V. 2013. Nurserycropscience.info. The Nursery Crop Science website is an outreach project of the Department of Horticultural Science at NC State University and is dedicated to providing current information for Extension field faculty, students, researchers, and growers of commercial horticultural products. Between January and December 2013, the site has had 6000 page visits, 5000 were unique visitors that viewed over 13,000 pages. The bounce rate was 66%, which indicates that approximately 2040 visitors interacted with the site beyond the home page. According to Google Analytics, approximately 1500 people stayed more than a minute and viewed 11,332 pages of content. Those would be considered users who are interested in nursery crop science information and not casual "googlers" who stopped by the site by accident or by looking for corollary information but were drawn to the website first.

Fund leveraging

LeBude, A.V., S.A. White, A. Fulcher, J.-H. Chong, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, F. Hale, W. Klingeman, G. Knox, J. Neal, N. Ward, A. Windham, and J. Williams-Woodward. Experiential Nursery IPM Workshop Series to Enhance Grower Adoption and Extension Agent Facilitation Southern Region IPM Center (Prime--US Dept. of Agriculture (USDA) - National Institute of Food and Agriculture) $39,982.00 awarded.

White, S.A., A. Fulcher, J.-H. Chong, A. LeBude, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, F. Hale, W. Klingeman, G. Knox, J. Neal, N. Ward, A. Windham, and J. Williams-Woodward. 2013. IPM for Shrubs in Southeastern U.S. Nursery Production (Vol. I), a SNIPM Working Group Effort. Southern Region IPM Center – IPM Enhancement Program. $29,983 awarded.

NC-1186 Station Report: NEW JERSEY

NC-1186 Station Report Content:

1. Impact Nugget: A concise statement of advancements, accomplishments and impacts. (Limit to 1-2 sentences)

Rutgers University continues education of New Jersey's plant nursery and greenhouse industries on topics of water pollution prevention and water conservation. We continue to work under grant funding to implement specific conservation practices at participating nurseries in New Jersey.

2. New Facilities and Equipment. Include production areas, sensors, instruments, and control systems purchased/installed.

None.

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

None.

4a. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend.

Rutgers University is working with grant funding to implement conservation practices at plant nurseries and agricultural operations. Planned practices include improved irrigation systems, grassed waterways, rainwater harvesting, and water channel stabilization.

Rutgers University continues education and outreach activities for New Jersey's nursery and greenhouse industries. Methods include presentations to agricultural clientele, stakeholders from non-governmental organizations, and government agency representatives.

4b. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report. Two examples are listed below.

The implementation of conservation practices will prevent water pollution or improve water quality in streams and lakes in the targeted watershed in New Jersey. Benefits include the reduction of sediment and phosphorus to the Cohansey River, water conservation in areas of stressed aquifers, reduction of soils erosion, and the improvement of sustainability of New Jersey's plant nurseries and agricultural operations.

Educational activities which focus on water concerns of the plant nursery and greenhouse industries reduce soil erosion, prevent water pollution in New Jersey's waterways, conserve water, and further the sustainability of the industries.

5. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

None.

6. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

<u>Presentations delivered to agricultural clientele and relevant stakeholders</u>:

Mangiafico, S.S. 2013. State of Our Watersheds: Salem River and Oldmans Creek. South Jersey Land and Water Trust Landowner Workshops. Harrisonville, NJ.

Mangiafico, S.S. 2014. Reducing Pesticides in Agricultural Runoff: Update on Local Conservation Practices to Prevent Pesticide Runoff. 2014 Salem County Pesticide Safety Meeting. Woodstown, NJ.

Mangiafico, S.S. 2014. Optimizing Productivity and Protecting the Environment with Cumberland County Soils. 2014 South Jersey Nursery Meeting. Millville, NJ.

7. Fund leveraging, specifically, collaborative grants between stations and members.

None.

8. Other relevant accomplishments and activities.

None.

NC-1186 Station Report: OHIO

1. Impact Nugget:

USDA-ARS in Wooster, OH, developed pH response curves for greenhouse and nursery substrates amended with steel slag, a cost-effective alternative to dolomitic lime that both elevates substrate pH and provides silicon for plant uptake.

USDA-ARS in Wooster, OH, documented the impact of particle size and substrate pH on cation exchange capacity in pine bark substrates, improving fertilizer management decisions.

USDA-ARS in Wooster, OH, documented the phosphorus released from gasified rice hull biochar in soilless substrates. Substrates amended with 10% (by volume) of this biochar have sufficient phosphorus to meet floriculture crop needs without additional phosphorus fertilizer.

USDA-ARS in Wooster, OH, developed best management practices for using rice hulls as an alternative to herbicides for weed control in container-grown crops.

2. New Facilities and Equipment.

USDA-ARS recently completed construction of new, climate-controlled nursery production hoophouse. The hoophouse is being fitted with environmental sensors, and will be used to conduct irrigation and light quality research.

3. Unique Water/Production Related Findings.

Steel slag, comprised primarily of calcium oxide (CaO), offers greater pH reaction than dolomitic lime in soilless substrates.

Cation exchange capacity in pine bark varies greatly by source, and is influenced by particle size distribution, but not pH, of the bark.

Gasified rice hull biochar, amended at 10% by volume, provides the total phosphorus needs of potted floriculture crops.

Rice hulls applied as a mulch to the container surface provides greater than 16 weeks of weed control.

4. Accomplishment Summaries.

USDA-ARS in Wooster, OH, measured the acid neutralizing ability of steel slag in soilless substrates. Steel slag is a byproduct of the steel manufacturing industry. Steel slag has a high concentration of calcium oxide, as well as other nutrients and micronutrients including iron, silicon, and manganese. Steel slag has greater pH neutralizing ability than dolomitic limestone, provides high concentrations of plant-available silicon, and provides low levels of other plant-essential micronutrients. Steel slag is being marketed for horticultural use, and should cost less than dolomitic lime.

Cation exchange capacity (CEC) describes a substrate's ability to retain cation nutrients. Higher CEC values for a substrate generally result in greater amounts of nutrients retained in the substrate and available for plant uptake, and greater buffering against change in pH over time. We determined that particle size of the pine bark had the greatest effect on CEC. Substrate pH and peatmoss amendment had little or no effect on CEC. Nursery producers should choose a bark source with the greatest percentage of fine particles to maximize CEC.

Biochar is the charred organic matter that remains after pyrolysis (burning) of biomass or manure. Biochars from different feedstocks yield different properties as a result of their differing particle sizes at the time of pyrolysis, inherent ash content of the feedstock, pyrolysis conditions, and storage conditions after processing. We measured nitrate, phosphate, and potassium retention and leaching in a typical greenhouse soilless substrate amended with one of three biochar types including: gasified rice hull biochar (GRHB), sawdust biochar (SDB), and a bark and wood biochar (BWB). All biochar amendments affected nitrate release by temporarily absorbing nitrate and releasing it slowly. This could result in less drastic and fewer spikes between high and low nitrate availability in the soil solution. The GRHB was a net source of phosphates and potassium, and when incorporated into a greenhouse substrate at 10% by volume, provides enough of these two nutrients without the need to provide additional phosphorus or potassium fertilizers.

Preemergence herbicides are the primary tool for controlling weeds in containers. However, preemergence herbicides cannot be used on all crops, nor are they labeled for use in enclosed structures. Alternatives are needed for managing weeds where preemergence herbicides are either not labeled or cannot be used with a wide margin of safety. In particular, there are needs for weed control alternatives in propagation, hoophouses and other enclosed structures, and herbaceous perennials and other sensitive crops. We demonstrated that parboiled rice hulls applied at a depth of 0.5 to 1.0 in over the substrate surface prevented establishment of bittercress and liverwort from seeds or gemmae, respectively.

5. Impact Statements.

USDA-ARS in Wooster, OH developed BMP guidelines for substrate amendment with steel slag as an alternative to dolomitic lime. Substrate pH response curves were generated for greenhouse and nursery substrates, as a function of steel slag rate. Growers can use this information to determine the specific rate needed for their substrates and crops.

USDA-ARS in Wooster, OH gathered information on what has been published on cation exchange capacity for pine bark substrates used in the northern U.S. There was virtually no science based information on this topic, yet substrate management decisions are being made based on assumptions of how pine bark CEC affects plant nutrition. Our research showed that particle size of the pine bark does influence CEC, but pH and peatmoss amendment have little impact.

USDA-ARS in Wooster, OH assessed physical and chemical properties of greenhouse and nursery substrates amended with gasified rice hull biochar (GRHB), and its impact on plant

health and nutrient levels in leachates. GRHB affected nitrate release by temporarily absorbing nitrate and releasing it slowly. This could result in less drastic and fewer spikes between high and low nitrate availability in the soil solution. The GRHB was a net source of phosphates and potassium, and when incorporated into a greenhouse substrate at 10% by volume, provides enough of these two nutrients without the need to provide additional phosphorus or potassium fertilizers. Growers can reduce fertilizer costs by 33% using GRHB instead of traditional fertilizers.

USDA-ARS in Wooster, OH developed new best management practices for weed management that improves crop health and reduces the amount of pesticides returning to runoff irrigation reservoirs. By using rice hulls as an alternative to chemical herbicides for weed control, fewer herbicides are needed to produce healthy crops. This best management practice is especially relevant in enclosed production spaces such as greenhouses and hoophouses where use of chemical herbicides is limited by label restrictions. Nursery growers can reduce weed control costs by as much as 75% with the use of rice hulls.

6. Published Written Works.

Locke, J.C., J.E. Altland, and C.W. Ford. 2013. Gasified rice hull biochar affects nutrition and growth of horticultural crops in container substrates. J. Environ. Hort. 31:195-202.

Altland, J.E. and J.C. Locke. 2013. Effect of biochar type on macronutrient retention and release from soilless substrate. HortScience 48:1397-1402.

Altland, J.E. and C. Krause. 2014. Parboiled rice hull mulch in containers reduces liverwort and bittercress growth. J. Environ. Hort. (Accpted, in press).

Altland, J.E., J.C. Locke, and C. Krause. 2014. Influence of pine bark particle size and pH on cation exchange capacity. HortTechnology. (Accepted, in press).

7. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

Altland, J.E. 2013. Weed control in herbicide-sensitive crops. Floriculture Research Alliance, Seattle, WA.

Altland, J.E. 2014. Weed control alternatives to herbicides. Maumee Valley Growers Association Annual Meeting, Toledo, OH.

7. Fund leveraging, specifically, collaborative grants between stations and members.

8. Other relevant accomplishments and activities.

NC1186 Station Report: PENNSYLVANIA

1. Impact Nugget

Pythium species frequently isolated by Penn State from recycled irrigation water in two commercial greenhouses are not highly pathogenic but appear to be truly aquatic in nature. Highly plant pathogenic species of *Pythium* are very rarely isolated from recycled irrigation water and may pose minimal threat to potted greenhouse crops through water dissemination.

2. New Facilities and Equipment

Nothing to report

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

Penn State's continuous baiting of recycled irrigation water in two commercial potted plant greenhouses revealed that there is a complex community of mostly non-plant pathogenic species of *Pythium* constantly present in the water. The species in the two greenhouses differ from one another even though it is known that the two greenhouses purchase plants from each other.

4. Accomplishment Summaries.

Penn State determined that the recycled irrigation water holding tanks of two commercial greenhouses continuously monitored to detect *Pythium* harbored numerous different isolates characterized by filamentous, non-inflated sporangia (Group F). In addition, one greenhouse habored *Pythium helicoides, P. middletonii, P. rostratifigens* and two species that are new to science while the second greenhouse harbored *Pythium chamaehyphon* and one species that is new to science. In greenhouse experiments where these isolates were used to inoculate geraniums each separately and in combination with the highly pathogenic *Pythium aphanidermatum*, *P. irregulare*, and *P. cryptoirregulare* there did not appear to be disease inhibitory or enhancement effects between *Pythium* species.

4. Impact Statements.

No quantitative data to report.

5. Published Written Works.

Book Chapters

Moorman, G. W., A. J. Gevens, L.L. Granke, M. K. Hausbeck, K. Hendricks, P. D. Roberts, and T. R. Pettitt. 2014. Sources and Distribution Systems of Irrigation Water and Their Potential Risks for Crop Health. Pages 3-11 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

Moorman, G. W. 2014. Irrigation Water and the Health of Greenhouse Crops. Pages 23-29 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

Ivors, K. L. and G. W. Moorman. 2014. Oomycete Plant Pathogens in Irrigation Water. Pages 57-64 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

Ristvey, A. G. and G. W. Moorman. 2014. An Integrated Approach to Minimizing Plant Pathogens in Runoff Water from Containerized Production Systems. Pages 365-375 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

6. Scientific and Outreach Oral Presentations.

Moorman, G. W. What plant pathogens could be in irrigation water? 12/3/2013. 85 logged in.
Recorded presentation: https://connect.extension.iastate.edu/p3u8rvp77kf/

Moorman, G. W. How do plant pathogens get into and move in irrigation water? 1/7/2014. 70 logged in.
Recorded presentation: https://connect.extension.iastate.edu/p5k9xrwl0vb/

Moorman, G. W. How do we determine irrigation water is clean or contaminated? 2/4/2014. 79 logged in.
Recorded presentation: https://connect.extension.iastate.edu/p6g6f7h6dj2/

7. Other relevant accomplishments and activities.

NC-1186 Station Report: SOUTH CAROLINA

1. Impact Nugget:

Clemson University has identified 2 aquatic plants (*Canna flaccida,* and *Canna ×generalis* 'Bird of Paradise') that can reduce viability of *Phytophthora* zoospore inocula in aqueous systems by 18-46%.

2. New Facilities and Equipment. None

3. Unique Water/Production Related Findings.

Results from our plant susceptibility trials indicate that two aquatic plant species (*Canna flaccida* and *Canna ×generalis* 'Bird of Paradise' may not only be non-susceptible to species of *Phytophthora*, but also actively suppressed (18 - 46%) zoospore activity in aqueous systems.

4. Accomplishment Summaries.

Researchers at Clemson University evaluated aquatic plants species for their susceptibility to plant pathogens by (1) surveying multiple plant species in constructed wetlands and vegetative channels directly receiving runoff from nursery production areas and (2) by screening seven aquatic plant species in repeated laboratory trials to evaluate susceptibility to plant pathogens. *Canna flaccida, Canna ×generalis* 'Bird of Paradise,' *Hydrocotyle umbellata, Pontederia cordata, Sagittaria latifolia,* and *Typha latifolia* support limited or no growth and reproduction of examined *Phytophthora* spp.

Researchers at Clemson University, Virginia Tech, University of Maryland, Michigan State University, University of California-Davis, Texas A&M, Oregon State University and the University of Florida developed and submitted a Specialty Crops Research Initiative Coordinated Agricultural Proposal planning to develop a decision-support tool to help growers' select treatment technologies and best management practices to facilitate recycling of irrigation runoff water.

Researchers at Virginia Tech, Clemson University, North Carolina State University, and University of New Hampshire collaborated with PureSense to begin developing a comprehensive crop production tool to help the technology-savvy grower manage water and fertilizer. This research funded by the Horticulture Research Institute and the American Floral Endowment will assist nursery and floriculture producers The "app" will assist growers in making on-the-go decisions, providing them with historical records, saving time and money.

5. Impact Statements.

During the past five years, researchers at Clemson University have monitored the efficacy of two constructed wetlands to facilitate removal of nutrient and pathogen contaminants from runoff. The wetlands reduced export of total nitrogen by 69%, phosphorus by 39%, and *Phytophthora* spp. (a pathogen) by 80%. Over 630,000 gallons of water flow through these wetlands each day, and an average of 143 lbs. of nitrogen and 0.12 lbs. of phosphorus are removed from runoff on a daily basis. Given that it takes only 0.02 ppm phosphorus to contribute to nutrient enrichment and potential impairment of surface waters[2], optimizing best management practices to reduce nutrient export into surface waters is critical. This technology to filter contaminants from runoff

not only helps to protect our surface waters, but can also be applied to increase re-use of irrigation runoff to save potable water sources for other uses.

6. Published Written Works.

Refereed Journal Articles

Nyberg, ET, SA White, SN Jeffers, WC Bridges. 2014. Removal of Zoospores of Phytophthora nicotianae from Irrigation Runoff using Slow Filtration Systems: Quantifying Physical and Biological Components. Water, Air, & Soil Pollution. 225:1999 11pp.

Ridge, GA, SN Jeffers, WC Bridges, Jr., SA White. 2014. In situ production of zoospores by five species of Phytophthora in aqueous environments for use as inocula. Plant Disease. 98(4): 501-508. doi.org/10.1094/PDIS-06-13-0591-RE.

White, SA and MM Cousins. 2013. Floating treatment wetland aided remediation of nitrogen and phosphorus from simulated stormwater runoff. Ecological Engineering, 61:207-215.

White, SA. 2013. Wetland Technologies for Nursery and Greenhouse Compliance with Nutrient Regulations. HortScience, 48(9): 1103-1108.

White, SA. 2013. Regulating Water Quality: Current Legislation, Future Impacts: Introduction to the Colloquium. HortScience, 48(9): 1095-1096.

Symposium Proceedings

White, SA, JS Owen, JC Majsztrik, RT Fernandez, P Fisher, CR Hall, T Irani, JD Lea-Cox, JP Newman, LR Oki. 2013. "Grower identified priorities for water research in ornamental crops." SNA Research Conference Proceedings, 58, 299-301.

Tyrpak, DR, K Van Kampen, SA White. 2013. "Phosphorus removal and accumulation by Swiss Chard (Beta vulgaris) grown in floating treatment wetlands." SNA Research Conference Proceedings, 58, 275-281.

Van Kampen, K, SN Jeffers, D Tyrpak, SA White. 2013. "Inoculation of Canna flaccida with zoospores from two species of Phytophthora." SNA Research Conference Proceedings, 58, 344-349.

Van Kampen, K, N Brinton, SA White. 2013. "Phosphorus removal and accumulation by sweet basil (Ocimum basilicum) grown in floating treatment wetlands. SNA Research Conference Proceedings, 58, 293-298.

Extension Bulletins

Park, DM, SA White, LB McCarty, N Menchyk. 2014. "Interpreting Irrigation Water Quality Reports." Clemson Cooperative Extension – Water Resources. CU-2014-700.

Popular Articles

Park, DM, SA White. 2014. "Navigating the Sea of Salinity Part 3: Managing Salinity Issues in Turfgrasses and Soils." Carolinas Green. May/June: 22-23.

Park, DM, SA White. 2014. "Navigating the Sea of Salinity Part 2: Water Sources." Carolinas Green. March/April: 22-23.

White, SA, DM Park. 2014 . "Salinity Sense Part III: Managing Salinity Issues – Soil and Plants." SC Nurseryman. March/April: 28-29.

Park, DM, SA White. 2014. "Navigating the Sea of Salinity Part 1: Measurements." Carolinas Green. January/February: 22-23.

White, SA, DM Park. 2014 . “Salinity Sense Part II: Know Your Water Source” SC Nurseryman. January/February: 28-29.

Park, DM, SA White. 2013. “Don’t get salt stress from measuring salinity.” SportsTurf Management. November. 29(11): 32.

White, SA, DM Park. 2013. “Salinity Sense Part I: How Do We Measure Salinity.” SC Nurseryman. November/December: 33.

White, SA, JS Owen, J Majsztrik, J Lea-Cox. 2013. Water Quality: Salts, Pests, and Pesticides - The State of Water Part III." Greenhouse Management. October. 33(10): 40, 42-46. http://www.greenhousemag.com/gm1013-water-quality-monitor.aspx

Majsztrik, J, JS Owen, SA White, J Lea-Cox. 2013. “Efficient Irrigation: The State of Water II.” Greenhouse Management. September. 33(9): 22-25. http://www.greenhousemag.com/gm0913-water-efficiency-irrigation.aspx

Majsztrik, J, SA White, JS Owen, J Lea-Cox. 2013. “Water Smarts: The State of Water I.” Greenhouse Management. August. 33(8): 24-26. http://www.greenhousemag.com/gm0813-water-smarts.aspx

6. Scientific and Outreach Oral Presentations.

Van Kampen, K., SA White, SN Jeffers. 2014. “Exposure of *Canna flaccida* and two *Canna* hybrids to five species of *Phytophthora*.” *Southern Region-American Society for Horticultural Science*, Dallas, TX.

White, SA, JS Owen, Jr., JC Majsztrik, RT Fernandez, P Fisher, CR Hall, T Irani, JD Lea-Cox, JP Newman, LR Oki. 2014. “Grower Priorities for Water Research: Results of a SCRI Planning Grant.” *Southern Region-American Society for Horticultural Science*, Dallas, TX

White, SA. 2014. “Plant-based remediation systems to manage agricultural contaminants.” University of Georgia. Department of Environmental Health Science. Athens, GA.

White, SA. 2013. “Evaluation of Floating Treatment Wetland Plant Nutrient Uptake with Varied Nutrient Loading Rates.” Floating Treatment Wetland Expert Panel. Chesapeake Bay Program. Annapolis, MD.

White, SA. 2013. “Nursery BMPs.” Horticultural Inspection Society - Southern Chapter, Greenville, SC.

7. Other relevant accomplishments and activities.

None

NC-1186 Station Report: TENNESSEE

1. Impact Nugget: A concise statement of advancements, accomplishments and impacts. (Limit to 1-2 sentences)

University of Tennessee developed procedures for elevating and lowering dissolved oxygen levels of irrigation water and began preliminary experiments to determine the best way to inoculate seedlings with pythium in this controlled oxygen level system.

University of Tennessee, investigated the importance of probe placement in estimating whole container moisture content, the effect of one substantial drying event on accuracy of probe measurements, and evaluated daily water use and on demand basis for scheduling irrigation.

2. New Facilities and Equipment. Include production areas, sensors, instruments, and control systems purchased/installed.

N/A

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

The University of Tennessee found that probe position was not important for EC-5 sensor accuracy in 11.4 L containers filled with 85% pine bark and 25% peat but cultural practices may dictate the most ideal placement. For example a surface placement may be east to install and remove and a side placement through the container sidewall may be more secure during hand weeding and less affected during pesticide applications. A single severe drying event reduced sensor accuracy for 4 out of 5 positions and reduced the amount of water the container could hold. OD generally used less water than DWU and had either no or a positive impact on biomass in all but one trial. For 3.8 L plants, photosynthesis and stomatal conductance were consistently greater when irrigated by the OD program. Both treatments used significantly less water than the industry standard of 2.5 cm per day.

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend.

By oxygenating irrigation water, container-grown plants would be exposed to more oxygen in the root zone, potentially reducing pathogenicity and providing an alternative to chemical control. We designed an automatic irrigation system that minimized the loss in dissolved oxygen levels and cost less than $900.00. We targeted 5.0 $mg \cdot L^{-1}$, 7.0 $mg \cdot L^{-1}$, 11.0 $mg \cdot L^{-1}$, and 13.0 $mg \cdot L^{-1}$. Actual dissolved oxygen levels varied across the three trials and average measurements were 4.9 $mg \cdot L^{-1}$ to 13.2 $mg \cdot L^{-1}$. As much as a 20% increase in dissolved oxygen level and 17.3% decrease from the initial level to the last emitter was observed, depending on target level. The results presented here suggest that the automatic irrigation system is one of several factors contributing to the increased or decreased dissolved oxygen levels.

We conducted an experiment to determine which of five substrate-moisture sensor placements best estimates volumetric water content (VWC) for 11.4 L containers filled with 85% pine bark: 15% sphagnum peat moss substrate by volume and planted with *Hibiscus moscheutos* 'Pink Elephant' as well as the effect of low VWC on sensor measurements. Five sensor placements were tested; three sensors were horizontally inserted into the sidewall at 5 cm, 10 cm, and 15 cm from the base of the container and the other two placements were inserted into the substrate surface either vertically or diagonally. All positions showed a strong linear relationship (r^2> 0.92) with VWC determined gravimetrically, indicating they all are appropriate models of container substrate moisture. The substrate was dried to 0.11 $m^3 \cdot m^{-3}$ and became hydrophobic. This substantially decreased the amount of water that could be held at effective container capacity and decreased sensor accuracy.

Independently controlled irrigation plots were designed to test two container nursery irrigation regimes on oakleaf hydrangea (*Hydrangea quercifolia* 'Alice'). Plants were automatically irrigated by one of two soil moisture sensor-based regimes: 1) a daily water use (DWU) system that delivered the exact amount of water that had been lost in the previous 24 h and 2) an on-demand (OD) irrigation system based on a specific substrate moisture content derived from the relationship between substrate moisture and photosynthetic rate. OD generally used less water than DWU and had either no or a positive impact on biomass in all but one trial. For 3.8 L plants, photosynthesis and stomatal conductance were consistently greater when irrigated by the OD program. Both treatments used significantly less water than the industry standard of 2.5 cm per day. This research demonstrated that both DWU and OD are a dramatic improvement over conventional irrigation scheduling and could be adopted as conservative irrigation systems for nursery production.

5. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report. Two examples are listed below.

Increasing regulation, public interest in sustainable practices, and droughts have increased nursery producer awareness of the need to more conservatively use natural resources such as water during agricultural production. The University of Tennessee has shown that substrate moisture probe placement does not matter for scheduling irrigation, for 11.4 L container filled with 75% pine bark and 25% peat moss. A severe drying event, 11% VWC reduces sensor accuracy due to the substrate holding less water. The University of Tennessee also showed that in Southern locations scheduling irrigation based on an on demand (OD) or daily water use (DWU) regime reduced water use. OD generally used less water than DWU and had either no or a positive impact on biomass in all but one trial.

Root rot pathogens lead to economic costs due to loss of crop and use of expensive fungicides. The University of Tennessee developed a system to apply irrigation water with a range of dissolved oxygen levels from approximately 5.0 $mg \cdot L^{-1}$, 7.0 $mg \cdot L^{-1}$, 11.0 $mg \cdot L^{-1}$, and 13.0 $mg \cdot L^{-1}$, approximately double the ambient concentration. This system will allow us to test if elevating oxygen levels will reduce pathogenicity of root rot pathogens and/or bolster plant health allowing plants to resist infection.

6. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

Book and Manual Chapters

Mattson, N.S. and A. Fulcher. 2014 (in press). pp. XYZ-XYZ. Substrates and containers for seed and cutting propagation and transplanting. In: Beyl, C.A. and R.N. Trigiano, eds. Plant Propagation Concepts and Exercises, CRC Press, Boca Raton, FL. in press.

Nambuthiri, S., A. Fulcher, and R. Geneve. 2014 (in press). pp.XYZ_XYZ. Micro-irrigation Systems for Pot-in-Pot Ornamental Nursery Production: Concepts and a Case Study. In: Goyal,M. (Ed.), Micro-irrigation management in trees and vines. Apple Academic Press. Waretown, NJ.

UT-UK IPM for Shrub Production Manual. 2013. A. Fulcher, ed. University of Tennessee, Knoxville, TN. 80pp. (electronic version) http://plantsciences.utk.edu/tnsustainablenurserycrops.htm

Refereed Journal Articles

Hagen, E.[M], S. Nambuthiri, A. Fulcher, and R. Geneve. 20XX. Growth and water consumption of *Hydrangea quercifolia* irrigated by on demand and daily water use irrigation regimes. Accepted with revisions. Sciencia Horticulturae.

Hagen, E.[M], A. Fulcher and X. Sun. Determining optimum sensor orientation and depth within an 11.4 L container to estimate whole container volumetric water content. Applied Engineering in Agriculture. In review.

Nambuthiri, S., A. Fulcher, A. Koeser, R. Geneve, G. Niu. 20XX. Moving towards sustainability with alternative containers for greenhouse and nursery crop production: A review and research update. Accepted HortTechnology: Special Biocontainer Issue Expected Winter 2014/15.

Hagen, E.[M], A. Fulcher and X. Sun. Determining optimum sensor orientation and depth within an 11.4 L container to estimate whole container volumetric water content. Applied Engineering in Agriculture. In review.

Multimedia

"Systems-based Pest Management: Irrigation Practices" 2014.
Produced by: H. Jones and D. Cochran, edited by A. Fulcher. Videos created in collaboration with F. Hale and A. Windham. Funded by the Southern Risk Management Education Center.
http://www.youtube.com/watch?v=X4LlfYJIjvs

Proceedings

Cochran, D.[M] and A. Fulcher. 2013. Plant establishment and degradation of biocontainers. Turf and Ornamental Field Day Proceedings. p. 36.

Cochran, D.[M] and A. Fulcher. 2013. Development of a cost-effective automated oxygenated irrigation system. Proc. Southern Nursery Association Research Conference. 58:XX. In press.

Nambuthiri, S., R. Geneve, and A. Fulcher. 2013. Evaluating irrigation scheduling based on daily evapo-transpiration or plant demand of container grown woody plants. Proc. Southern Nursery Association Research Conference. 58:XX. In press.

7. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

Fulcher, A.* and D. Cochran. Exploring Oxygenation of Irrigation Water. Annual SCRI meeting of Integrated Management of Zoosporic Pathogens and Irrigation Water Quality for A Sustainable Green Industry, November 14, 2013, Virginia Beach, VA.

Li, T.*, G. Bi, G. Niu, S. Nambuthiri, R. Geneve, X. Wang, R.T. Fernandez, A. Fulcher, and Y. Sun. Use of Biocontainers in Pot-in-Pot Nursery Production System. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

Wilson, S.E.[M], D. Cochran[M]*, and A. Fulcher. Container-grown Lavender Affected by Oxygenated Irrigation Water. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

Nambuthiri, S.*, R. Geneve, and A. Fulcher. Comparison of Irrigation Scheduling Based on Daily Water Use or Plant Water Demand of Container Grown Woody Plants. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

Wang, X.*, T. Fernandez, G. Bi, A. Fulcher, R. Geneve, G. Niu, S. Verlinden, B. Cregg, M. Ngouajio, T. Kijchavengku, R. Auras, S. Nambuthiri, R. Conneway and Y. Sun. Plant Growth and Water Use in Plastic, Fiber, Keratin and Root Pouch Containers. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

8. Fund leveraging, specifically, collaborative grants between stations and members.

Funding from the Southern Region Systems–based Pest Management

LeBude, A., K. Braman, N.W. Gauthier, J. Neal, M. Chappell, A. Fulcher, W. Klingeman III, J. Derr, G. Knox, C. Adkins, J.-H. Chong, W. Dunwell, S. Frank, F. Hale, S.A. White, J.

Williams-Woodward, and A. Windham. 2014-2015. Experiential Nursery IPM Workshop Series to Enhance Grower Adoption and Extension Agent Facilitation. IPM Working Group and Capstone. $39,982 (Fulcher $0, no subawards permitted by agency).

Stewart, R., G. Bi, R. Brumfield, M. Evans, T. Fernandez, A. Fulcher. R. Geneve, D. Kovacic, D. Lindsey, G. Niu, R. Schnelle, and S. Verlinden. 2010-2014. Impact and Social Acceptance of Selected Sustainable Practices in Ornamental Crop Production Systems. USDA Specialty Crops Research Initiative. $1,548,793 (Fulcher: $32,950). http://www.reeis.usda.gov/web/crisprojectpages/222423.html

White, S.A., A. Fulcher, J.-H. Chong, A. LeBude, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, F. Hale, W. Klingeman, G. Knox, J. Neal, N. Ward, A. Windham, and J. Williams-Woodward. 2013-2014. IPM for Shrubs in Southeastern U.S. Nursery Production (Vol. I), a SNIPM Working Group Effort. Southern Region IPM Center, IPM Enhancement Program. $29,983. (Fulcher $0, no subawards permitted by agency).

9. Other relevant accomplishments and activities.

NC 1186 Station Report: TEXAS

1. Impact Nugget

2. New Facilities and Equipment.
N/A

3. Unique Water/Production Related Findings.

4. Accomplishment Summaries.

A greenhouse study evaluated the short-term effects of irrigation with laundry graywater on the growth and aesthetic performance of selected landscape plants. Initial results indicate that graywater containing detergents and softeners produces similar plant growth and quality responses as in plants irrigated with tap water. Graywater containing bleaching agents, however, reduced the aesthetic quality of some species. Tissues are being analyzed for mineral nutrient status and later will be evaluated against growth performance and the major chemical properties of the graywaters employed in the study. These preliminary observations are being shared in local and regional meetings dealing with urban landscape water conservation issues.

A field study to evaluate the long-term effects of graywater irrigation on landscape plants has been planted. Twelve species of herbaceous perennials and woody plants were transplanted in replicated rows, and once established, the plants will be subjected to irrigation with various graywater treatments over a three-year period to evaluate their effect on plant growth, aesthetics and the physical, chemical and biological properties of the landscape soil beneath each treatment.

Greenhouse studies were conducted to evaluate garden roses including Earth-Kind® rose cultivars in response to a range of elevated salinity level in irrigation water. Based on their growth, visual quality, and leaf mineral concentrations, the relative salt tolerance of the selected rose cultivars was determined and classified as sensitive, moderately sensitive, moderately tolerant groups. Another greenhouse study was carried out to evaluate the salt tolerance of Texas Superstar® landscape plants. Both Earth-Kind® roses and Texas Superstar® landscape plants are specially designated by Texas AgriLife Extension with superior stress tolerance and outstanding landscape performance under Texas growing conditions. However, their responses to salinity were unknown. Our results indicated that drought tolerant plants are not necessarily tolerant to salinity. This additional information on salt tolerance will help landscape professionals and home owners select appropriate plants for areas where poor quality water may be used for irrigation to prevent salt damage and landscape aesthetic appearance.

5. Impact Statements.

Severe drought and stiff competition for high-quality water supplies are forcing the green industry, particularly those located in urban areas, to consider the use of alternative irrigation sources like reclaimed, stormwater and graywater. An effective use of these

sources could reduce municipal potable water dependence in urban areas. Research at Texas A&M AgriLife-Uvalde indicates that laundry-derived graywater, without bleach residues, can be used to satisfactorily grow annual and herbaceous perennials plants used for urban landscaping applications.

Salt tolerance of garden roses, including 18 Earth-Kind® roses and 15 Texas Superstar® landscape plants were evaluated in several greenhouse studies. The results of salt tolerance of these landscape plants will help nursery and landscape professionals and home owners to choose appropriate plants for landscapes where low quality water may be used.

6. Published Written Works.

Refereed Journal Articles

Cabrera, R.I., K.L. Wagner and B. Wherley. 2013. An evaluation of urban landscape water use in Texas. Texas Water Journal 4(2): 14–27.

Cai, X., Y. Sun, T. Starman, C. Hall, and G. Niu. 2014. Response of 18 Earth-Kind® Rose Cultivars to Salt Stress. HortScience 49(5):544–549.Cai, X., T. Starman, G. Niu, and C. Hall. 2014. The effect of substrate moisture content on growth and physiological responses of two landscape roses (*Rosa x hybrid* L.). HortScience 49(6):741–745.

Cai, X., G. Niu, T. Starman, and C. Hall. 2014. Response of six garden roses (*Rosa x hybrid* L.) to salt stress. Scientia Horticulturae 168:27-32.

Niu, G., T. Starman, and D. Byrne. 2013. Responses of growth and mineral nutrition of garden roses to saline water irrigation. HortScience 48(6):756–761.

Book Chapters

Cabrera, R.I. and A.R. Solís-Pérez. 2013. Tolerancia y manejo de salinidad, pH y alcalinidad en el cultivo de flores, p. 65-72. In: Avances en Nutrición de Flores de Corte (Memorias). Centro de Innovación de la Floricultura Colombiana (CENIFLORES), Colombia. ISBN 978-958-98993-3-5.

Technical Articles

Cabrera, R.I., K.L. Wagner and B. Wherley. 2013. An evaluation of urban landscape water use in Texas. Texas Water Journal 4 (2): 14–27.

Cabrera, R.I. 2013. Optimizing rose crop nutrient status and productivity through balanced cation and anion ratios: Leachate properties and mineral nutrition relations with productivity and quality. International Cut Flower Growers Assn. Bulletin, July-Dec. Issue. pp. 7-11.

Cabrera, R.I. 2013. Optimizing rose crop nutrient status and productivity through balanced cation and anion ratios: Flower productivity and quality. International Cut Flower Growers Assn. Bulletin, Apr.-Jun. Issue. p. 10-13.

Sun, Y., G. Niu, C. Perez, and P. Osuna. 2014. Salt Tolerance of Garden Rose Cultivars. Proceedings of Southern Nursery Association.

Sun, Y., G. Niu, C. Perez, and P. Osuna. 2014. Salt Tolerance of *Artemesia schmidtiana*, *Buddleia davidii*, and *Lantana* Sp. Proceedings of Southern Nursery Association.

Abstracts

Cabrera, R.I. and D. I. Leskovar. 2013. Alternative irrigation sources for urban landscape water conservation. HortScience 48(9): S28. (Abstract)

Cabrera, R.I. 2013. The challenges of graywater as an alternative water source for landscape irrigation. HortScience 48(9):S105. (Abstract)

Cabrera, R.I. D.I. Leskovar, M. Martin, M. Koch and D. Rodriguez. 2013. Water use and conservation in urban landscaping activities: The case for graywater utilization. The National and International Conference on Groundwater, 2013 NGWA Summit. April 28-May 2, 2013, San Antonio, TX. (Abstract).

Leskovar, D.I., M. Palma and R.I. Cabrera. 2013. Deficit irrigation strategies for high-value crops in South Texas. The National and International Conference on Groundwater, 2013 NGWA Summit. April 28-May 2, 2013, San Antonio, TX. (Abstract).

7. Scientific and Outreach Oral Presentations.

Cabrera, R.I. 2013. Irrigation Water Quality and its Effects on Urban Trees. 2013 Texas Tree Conference. Sponsored by the Texas Chapter of the International Society of Arboriculture. Convention Center in Waco, TX. October 2-4, 2013.

Cabrera, R.I. 2013. Coping with Drought. 2013 Texas Master Gardener Conference. Sponsored by the Texas Master Gardener Association. Held at the Convention Center in McAllen, TX. October 17-19, 2013.

Cabrera, R.I. 2013. Native and Adaptive Plants as Solutions for Drought and Landscape Irrigation Restrictions. Texas Native Plant Week. Sponsored by the Uvalde Chapter of the Texas Native Plant Society. Held at Progreso Library, Uvalde, TX. October 26, 2013.

Cabrera, R.I. 2013. Water Quality for Ornamental Plants/Landscaping. 2013 Irrigation Show & Education Conference. Sponsored by the Irrigation Association. Convention Center, Austin, TX. November 08, 2013.

Cabrera, R.I. 2014. Landscape Plant Disorders related to Weather, Soil and Water (In Spanish). 2014 Winter Workshop on Landscape Management- TNLA Region II. United Way Bldg., 50 Waugh Dr., Houston, TX. January 31, 2014.

Cabrera, R.I. 2014. Short-term evaluation of graywater irrigation on selected ornamental species. 95th Annual Meeting of the Southern Region-ASHS. Dallas, TX. Jan. 31 - Feb. 2, 2014.

Cabrera, R.I. 2014. Water quantity and quality issues for arboriculture and landscape horticulture. South Texas Urban Forestry Conference on Planning and Growing Healthy Green Space. Sponsored by the San Antonio Arborist Assn. and the Texas Forest Service. Laredo, TX. February 20, 2014.

Cabrera, R.I. 2014. Short Course on "Nutrition, Fertilization and Plant Physiology Applied to Flower Crops". Escuela de Floricultura, EXPOFLORES (Asociación Nacional de Productores y Exportadores de Flores del Ecuador), Quito, Ecuador. March 27-29 4, 2014.

Cabrera, R.I. 2014. Coping with drought and landscape irrigation restrictions. Uvalde Green Garden Club Monthly Meeting. Patricia Lane, Uvalde, TX. April 3, 2014.

Cabrera, R.I. 2014. Water conservation in urban landscaping activities. Laredo EcoFestival, Sponsored by Rio Grande International Study Center. Alexander Crossings, Laredo, TX. April 12, 2014.

Niu, G., Y. Sun, and C. Perez. 2014. Growth and physiological responses of selected ornamental plants to salinity stress. Proc. International Salinity Forum. Riverside, CA.

Sun, Y. G. Niu*, and C. Perez. 2014. 95th Annual Meeting of the Southern Region-ASHS. Dallas, TX. Jan. 31 - Feb. 2, 2014.

8. Fund leveraging, specifically, collaborative grants between stations and members.

9. Other relevant accomplishments and activities.

Ph.D. student, Xiaoya Cai will graduate in August 2014, co-advised by Dr. Terri Starman and Dr. Genhua Niu. Xiaoya Cai's dissertation is "The responses of selected garden roses (*Rosa* × *hybrida*) to drought and salt stresses".

NC-1186 Station Report: VIRGINIA

1. Impact Nugget: A concise statement of advancements, accomplishments and impacts. (Limit to 1-2 sentences)

Research on new controlled release fertilizers conducted at Virginia Tech has resulted in an industry leader/manufacturer to alter protocol when assessing fertilizer release by increasing incubation temperatures 10F; therefore, better matching release of mineral nutrients to labeled longevities and ornamental crop need.

Virginia Tech, while investigating solute transport in soilless substrates, discovered a 16% increase in leached nitrate during an irrigation events and a 44% increase in overall release of controlled fertilizers when incorporated throughout the substrate profile versus being top-dressed. Continued research on fertilizer application has the potential to reduce fertilizer application rates by 25% while producing an equivalent size plant.

Virginia Tech held a water management workshop in cooperation with the Water Education Alliance for Horticulture to share knowledge and strategies for (1) understanding regulation in Virginia, (2) implementing Best Management Practices (BMPs), (3) monitoring water quality and (4) managing irrigation. Participants increased knowledge in all learning areas and indicated they currently perform “little” of the specific practices introduced, however they would do “some” or “much” in the future. A nursery operation in Virginia has begun to adopt sensor technology to manage irrigation in an effort to reduce water application and subsequent runoff. Another nursery operation is investigating the use of a central controller to manage irrigation based on daily environmental parameters to more efficiently apply water.

2. New Facilities and Equipment. Include production areas, sensors, instruments, and control systems purchased/installed.

In 2013/2014 the Virginia Tech nursery research program began to monitor substrate moisture content, bulk electrical conductivity and temperature using a combination of GS3 sensors and thermo-misters. Data was recorded using a solar powered Campbell Scientific data logger with expanded input capability via an analog multiplexer.

In 2013 Virginia Tech began investigating the use of a modified evaporative method measured via the HyProp (Decagon Devices, Inc.) to determine hydrological properties of soilless substrates. This method has proven to provide greater data density and additional hydrological information within moisture content ranges occurring in soilless substrates.

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

Virginia Tech identified methodology on solute transport in soilless substrates and found that mineral nutrients channeled through soilless substrates, fingered flow (i.e. channeling) is prevalent wen irrigating and controlled release fertilizer effects nutrient leaching from a given

irrigation event. Research is currently being published in by the American Society for Horticultural Science and will be presented to stakeholders.

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend.

See Literature cited and presentations.

5. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report. Two examples are listed below.

See answers to previous questions.

6. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

Contreras R.C., J.S. Owen, W. Hanna, B. Schwartz. 2013. Evaluation of seven complex Pennisetum hybrids for container and landscape performance in the Pacific Northwestern United State States. HortTechnology 23:525-528.

Contreras R.C., J. Ruter, J. Owen, A. Hoegh. 2013. Chlorophyll, cartenoid and visual color rating of Japanese-cedar grown in the Southeastern United States. HortScience 48:1452-1456.

Bailey D., J.S. Owen, J. Selker, J. Wagner. 2013. In-situ performance and usability of a distributed, wireless sensor network via mesh connectivity at a production container nursery. Applied Engineering in Agriculture 29:779-782. (DOI: 10.13031/aea.29.10006)

Landgren C., J.S. Owen and R.C. Contreras. 2013. Evaluating soil and foliar fertilization of *Abies nordmanniana* under container and field production. Scandinavian Journal of Forest Research 28:419-427. (DOI:10.1080/02827581.2012.762939)

Owen Jr., J.S., H.M.Stoven, D.M Sullivan and R.C. Costello. 2014. Effect of compost amendment feedstock and source on containerized azalea production in bark-based substrate. Acta Hort. 1018:533-540.

She Y., R. Ehsani, J.S. Owen, J. Robbins. 2013. Application of small unmanned aerial vehicle for inventory management. Proceedings of the 5th Asian Conference on Precision Agriculture. pp. 104-112.

Hoskins T., J.S. Owen, A. Niemiera and J. Brindley. 2013. Nutrient movement in a bark-based substrate during irrigation. Proc. Southern Nursery Assoc. Res. Conf. 58:7-12.

White S., J.S. Owen, J. Majsztrik, R. Fernandez, P. Fisher, C. Hall, T. Irani, J. Lea-cox, J. Newman, L. Oki. Grower identified priorities for water research in ornamental crops. 2013. Proc. Southern Nursery Assoc. Res. Conf. 58:299-301. (poster presentation)

Leiva J., R. Ehsani, J. Owen, J. Robbins. 2013. Plant count for container-grown plants using an aerial boom and object-based software. Proc. Southern Nursery Assoc. Res. Conf. 58:89-91.

Robbins J., J. Leiva, Y. She, R. Ehsani, J. Owen, D. Saraswat, J. Maja, H. Stoven, C. Landgren. 2014. Count on this: Object-based software provides an automated inventory process for growers. January. Nursery Management 30 (1):26-30.

Hensey A., J. Owen. 2013. The profitable side of green growing: The climate friendly nurseries project turns up new ways to save money and energy. August. Digger 57(8):120-124.

Majsztrik J., S. White, J. Owen, J. Lea-cox. 2013. Water smarts: The state of water I. Greenhouse Management. August. 33(8):24-26.

Majsztrik J., J. Owen, S. White, J. Lea-cox. 2013. Efficient irrigation: The state of water II. Greenhouse Management. September. 33(9):22-25.

White S., J. Owen, J. Majsztrik, J. Lea-cox. 2013. Water quality: Salts, pests, and pesticides. The state of water III. Greenhouse Management. October. 33(10):40, 42-46.

Majsztrik J., S. White, J. Owen, J. Lea-cox. 2013. The state of water in the green industry I: Water resource availability. Nursery Management. June. 29(6):28, 30-32.

Majsztrik J., J. Owen, S. White, J. Lea-cox. 2013. The state of water in the green industry II: Water use efficiency. Nursery Management. July. 29(7):24, 26, 28.

Majsztrik J., S. White, J. Owen, J. Lea-cox. 2013. The state of water in the green industry III: Water quality. Nursery Management. August. 29(8):20-21, 23-25.

7. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

Hao, W. and C.X. Hong. Heat treatment induced bacterial changes in irrigation water and their implications for plant disease management. World Journal of Microbiology and Biotechnology.

Hong, C. X., Richardson, P. A., Kong, P., and Cafa, G. Tracking water quality dynamics in a multi-basin agricultural water recycling system, 2013 AWRA Spring Specialty Conference on Agricultural Hydrology and Water Quality II, St. Louis, MO, March 25-27, 2013

Hong, C. X., Richardson, P. A., Kong, P., Cafa, G., Lea-Cox, J. D., Belayneh, B. E., and Ristvey, A. G. Dramatic fluctuations of water quality in agricultural runoff containment basins. 2013

AWRA Spring Specialty Conference on Agricultural Hydrology and Water Quality II, St. Louis, MO, March 25-27, 2013

Hong, C. X., and Moorman. Diversity and significance of plant pathogens as agricultural water contaminants. 2013 AWRA Spring Specialty Conference on Agricultural Hydrology and Water Quality II, St. Louis, MO, March 25-27, 2013

Owen, J.S., Jr. 2014. Water and Nutrient-use Efficiency for Commercial Nursery Crops. "Kicking off the Season" Specialist Day!, Eastern Shore AREC, Painter, VA. March 7. Audience Size: 12. Hours of Instruction: 1.0.

Owen, J.S., Jr. 2014. Utilizing best management practices today to help prepare for water quality regulations of tomorrow. Shenandoah Nursery and Greenhouse Association, Blueridge Community College, Weyers Cave, VA. February 12. Audience Size: 42. Hours of Instruction: 1.0.

Owen, J.S., Jr. 2014. Opportunities utilizing unmanned aerial vehicles in agriculture, Farm Bureau, Suffolk, VA. February 10. Audience Size: 138. Hours of Instruction: 0.5.

Owen, J.S., Jr., J. Latimer, L. Fox. C. Hong 2013. Water management for ornamental crops workshop and in-service training, Virginia Beach, VA. October 29-30. Audience Size: 28. Hours of Instruction: 14.0.

Owen, J.S., Jr. 2013. Properly scheduling irrigation for smarter water use. Water Management for Ornamental Crops Workshop, Virginia Beach, VA. October 29. Audience Size: 28. Hours of Instruction: 1.0.

Owen, J.S., Jr. 2013. Nursery automation: Tree counter demonstration. Nursery Works, Kansas State University, Manhattan, KS. July 18. Audience Size: 65. Hours of Instruction: 1.0. *Invited*

Owen, J.S., Jr. 2013. Increasing nursery efficiency and profits with automation. Nursery Works, Kansas State University, Manhattan, KS. July 17. Audience Size: 65. Hours of Instruction: 1.0. *Invited*

Owen, J.S., Jr. 2013. Understanding nursery production: From propagule to tree. Trees: The Dirty Truth, Virginia Western Community College, Roanoke, VA. May 22. Audience Size: 65. Hours of Instruction: 1.0.

Owen, J.S.. Jr., K.A. Williams and H.M. Stoven[#]. 2013. Bluing of hydrangea 'Endless Summer' sepals is influenced by timing of aluminum sulfate drenches or aluminum chelate foliar sprays in three different locations and production systems. HortScience 48:S382-S383 (poster)

Pistininzi, M., E. Weiss, L. Achtemeier, and C.X. Hong. Zoospore production biology of pythiaceous plant pathogens. Journal of Phytopathology doi: 10.1111/jph.12154

White, S., J.S. Owen, Jr., J. Majsztrik, T. Fernandez, P. Fisher, C. Hall, T. Irani, J. Lea-Cox, J. Newman and L. Oki. 2013. Containment, remediation, and recycling of irrigation water for sustainable ornamental crop production: results of a SCRI planning grant. HortScience 48:S427-S428 (poster)

Owen, J.S. Methods for Analysis of Soilless substrate physical and hydraulic properties. HortScience 48:S104. (invited oral presentation In: Horticultural Substrates: Current Research, Development, and Characterization for Improved Crop Production Workshop)

8. Fund leveraging, specifically, collaborative grants between stations and members.

Owen, J.S., Jr. and J.S. Fields. 2014. Modeling soilless substrate to maximize plant available water for containerized nursery crop production. Center for Applied Nursery Research. $2,500.

Owen J.S., Jr. and J. Brindley*. 2014. Evaluating compost filter socks for agrichemical remediation of runoff in ornamental nurseries as a cost-effective means to effectively treat water. Oregon Department of Agriculture / Oregon Association of Nurseries. $14,991.

Owen, J.S., Jr., S. White, B. Krug and B. Whipker. 2014. Managing water and fertilizer: A comprehensive crop production tool for the mobile grower. Horticultural Research Institute. $14,498.

Owen, J.S., Jr. and J. Brindley*. 2013. Economical and efficient water treatment: Evaluating compost filter socks for agrichemical remediation of runoff in ornamental nurseries. J. Frank Schmidt Family Charitable Foundation. $8,794.

9. Other relevant accomplishments and activities.

Appendix VI - NC1186 2014 Compiled Station Reports
Report period: from last meeting to the current meeting

NC-1186 Station Report Content:
1. Impact Nugget: A concise statement of advancements, accomplishments and impacts. (Limit to 1-2 sentences)

Auburn University has developed recommendations for plant selection in rain gardens to increase nutrient removal from runoff.

Auburn University has identified selected landscape species tolerant of saline irrigation water.

The Florida Department of Agriculture and Consumer Services administer a Best Management Practices (BMP) program. BMPs are developed in cooperation with Institute of Food and Agricultural Sciences at University of Florida. Nursery operations that voluntary implement and use BMPs receive a waiver of state imposed liability for ground and surface water contamination. In 2013, 39 container plant producers enrolled approximately 1000 acres in the BMP program.

Low cost, but highly efficient, irrigation controllers have been developed by the University of Georgia. These controllers can help bring precision irrigation to homeowners and small farms.

University of Hawaii has developed recommendations for the production of tropical ornamental plants using local substrate based on automated irrigation system that may reduce water use by 30%.

Purdue University has developed methodology to determine nitrogen losses from container systems using stable isotopes.

A working model of a Prototype Programmable Logic Controller (PLC) System for Irrigation Automation has been tested and transferred to the field by the University of Kentucky for trial controlling irrigation of container plants.

A new irrigation and leaching control system has been designed by LSU AgCenter scientists to reduce irrigation water consumption and potential nutrient leaching during nursery container crop production (reported by Dr. Jeff Beasley).

At LSU, a new substrate amendment has shown promising results to be used in container production of ornamental plants (reported by Dr. Yan Chen).

Michigan State University and cooperators, including NC1186 members from Texas, Mississippi, and Tennessee, on an SCRI project determined that alternative (to petroleum-based polymer) containers constructed of wood pulp or woven fabric produced similar size and quality plants but required higher irrigation rates, indicating that any benefits in CO_2 reductions could be

offset by increased water use. MSU also identified that consumers could be segmented in relation to production-, price-, or plant-orientation and the segment affected the price they were willing to pay for plants grown with water conserving, sustainable or conventional methods.

At Mississippi State University, graduate student Anthony Witcher reported in an article published in HortTechnology that a range of plant species can be propagated from stem cuttings in an alternative substrate composed of processed whole pine trees alone or combined with peat moss.

Rutgers University continues education of New Jersey's plant nursery and greenhouse industries on topics of water pollution prevention and water conservation. Rutgers continues to work under grant funding to implement specific conservation practices at participating nurseries in New Jersey.

At North Carolina State University, the Southern Nursery IPM (SNIPM) Working Group presented three two-day workshops to growers in three southeastern states and improved knowledge about irrigation management by 20%. After the workshop, growers felt that they were 40% more likely to adopt the techniques presented to them and manage their irrigation by increasing its efficiency of application.

USDA-ARS in Wooster, OH, developed pH response curves for greenhouse and nursery substrates amended with steel slag, a cost-effective alternative to dolomitic lime that both elevates substrate pH and provides silicon for plant uptake.

USDA-ARS in Wooster, OH, documented the impact of particle size and substrate pH on cation exchange capacity in pine bark substrates, improving fertilizer management decisions.

USDA-ARS in Wooster, OH, documented the phosphorus released from gasified rice hull biochar in soilless substrates. Substrates amended with 10% (by volume) of this biochar have sufficient phosphorus to meet floriculture crop needs without additional phosphorus fertilizer.

USDA-ARS in Wooster, OH, developed best management practices for using rice hulls as an alternative to herbicides for weed control in container-grown crops.

Pythium species frequently isolated by Penn State from recycled irrigation water in two commercial greenhouses are not highly pathogenic but appear to be truly aquatic in nature. Highly plant pathogenic species of *Pythium* are very rarely isolated from recycled irrigation water and may pose minimal threat to potted greenhouse crops through water dissemination.

Clemson University has identified 2 aquatic plants (*Canna flaccida*, and *Canna* ×*generalis* 'Bird of Paradise') that can reduce viability of *Phytophthora* zoospore inocula in aqueous systems by 18-46%.

University of Tennessee developed procedures for elevating and lowering dissolved oxygen levels of irrigation water and began preliminary experiments to determine the best way to inoculate seedlings with pythium in this controlled oxygen level system.

University of Tennessee investigated the importance of probe placement in estimating whole container moisture content, the effect of one substantial drying event on accuracy of probe measurements, and evaluated daily water use and on demand basis for scheduling irrigation.

Research on new controlled release fertilizers conducted at Virginia Tech has resulted in an industry leader/manufacturer to alter protocol when assessing fertilizer release by increasing incubation temperatures 10F; therefore, better matching release of mineral nutrients to labeled longevities and ornamental crop need.

Virginia Tech, while investigating solute transport in soilless substrates, discovered a 16% increase in leached nitrate during an irrigation events and a 44% increase in overall release of controlled fertilizers when incorporated throughout the substrate profile versus being top-dressed. Continued research on fertilizer application has the potential to reduce fertilizer application rates by 25% while producing an equivalent size plant.

Virginia Tech held a water management workshop in cooperation with the Water Education Alliance for Horticulture to share knowledge and strategies for (1) understanding regulation in Virginia, (2) implementing Best Management Practices (BMPs), (3) monitoring water quality and (4) managing irrigation. Participants increased knowledge in all learning areas and indicated they currently perform “little” of the specific practices introduced, however they would do “some” or “much” in the future. A nursery operation in Virginia has begun to adopt sensor technology to manage irrigation in an effort to reduce water application and subsequent runoff. Another nursery operation is investigating the use of a central controller to manage irrigation based on daily environmental parameters to more efficiently apply water.

In collaboration with Dr. G. Moorman at Penn State, Drs. J. Lea-Cox and A. Ristvey at Uniersity of Maryland, and Dr. W. Copes at the USDA ARS, Dr. Hong investigated the biology and management of zoosporic pathogens and recycled water quality at commercial horticultural production facilities.

2. New Facilities and Equipment. Include production areas, sensors, instruments, and control systems purchased/installed.

At Auburn University, eighteen rain gardens (6 ft x 6ft each) were constructed in two locations (total of 36 gardens) to be used for replicated rain garden research. The two locations provide two different soil types (coastal plain and piedmont). At each location there are six blocks with three rain gardens in each block. They are equipped with an underdrain that allows leachate exiting the rain garden to be captured, sampled, and analyzed chemically. Currently, rain

gardens are planted with turf or landscape shrubs or unplanted (mulch only). Irrigation heads have been designed to apply water to mimic runoff that would enter a rain garden.

A new Green Infrastructure lab was completed in a new research facility on AU campus. This lab is equipped for water quality/quantity runoff experiments and can be used to evaluate the impact of surface cover (permeable, non-permeable, vegetated) on runoff and urban heat island effects.

Funding has been allocated for construction of additional greenhouses at the University of Florida, Gainesville.

The University of Georgia has developed a new low-cost irrigation controller, using open source prototype boards (Arduino). UGA used Arduino microcontrollers and soil moisture sensors to build an automated system to monitor and log substrate moisture content and to control irrigation based on real-time soil moisture measurements. The controller can control both 24VAC valves and latching 9VDC valves. The Arduino is programmed to read the raw output from the soil moisture sensors, convert it into VWC, log the data, send the results to a computer screen, and control irrigation based on the comparison of sensor readings and VWC thresholds. Thresholds varied from 0.2 to 0.5 m^3 m^{-3} and were applied to four pots with *Hibiscus acetosella* 'Panama Red'. The Arduino was reliable and successfully used to build an automated system to monitor substrate VWC and to control irrigation based on soil moisture sensors. The system worked properly during a 53-d trial, requiring little maintenance and irrigating the pots when the substrate VWC dropped below the set thresholds. The hardware cost of the irrigation control system, excluding the soil moisture sensor and valve is approximately $40.

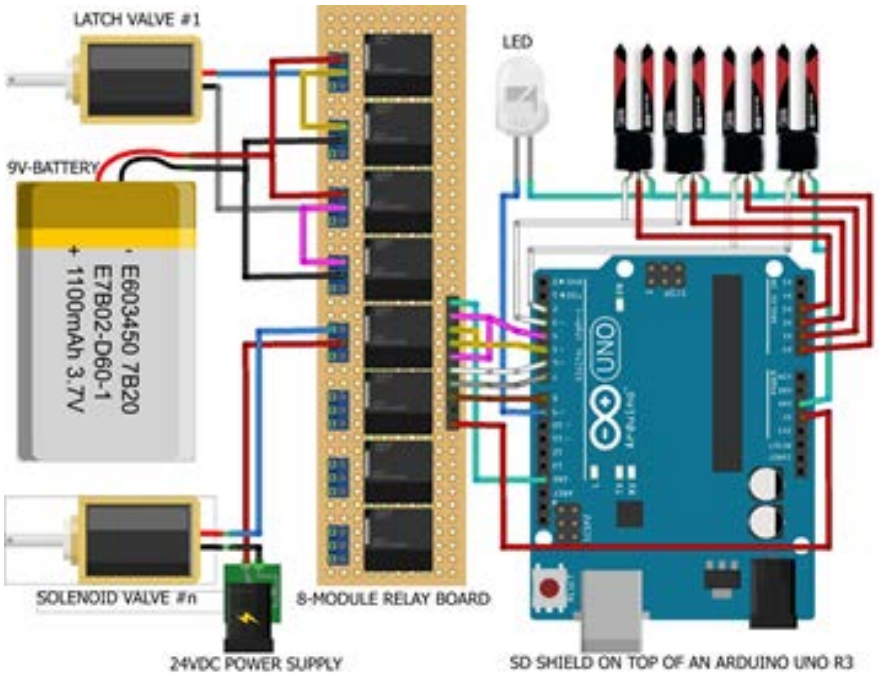

Figure 2. Diagram of a low-cost irrigation controller using an Arduino microcontroller. The controller can be used with both 24 VAC solenoids as well as latching 9 VDC solenoids.

University of Hawaii has set up sensor based irrigation systems for the research of water requirement of tropical ornamental plants.

Programmable Logic Controller (PLC) System for Irrigation Automation Prototype System, Container Production Gravel bed expansion with run-off "Rain Garden", renovated city water field hydrant supply at the University of Kentucky.

The LSU AgCenter has recently hired irrigation research and extension faculty that will be housed at the Red River Research Station, Bossier City, LA. This water management initiative team includes an irrigation engineer, an irrigation economist, a water quality expert, and an irrigation agronomist (reported by Dr. Allen Owings).

RFID readers, antennae and tags have been purchased for use at J. Frank Schmidt and Sons Nursery in Boring and Canby, OR and additional equipment will be used at 3 Michigan operations in 2014. RFID is currently being evaluated for performance and durability in nursery and greenhouse environments for simple inventory tasks but will be integrated into decision support systems for irrigation and nutrient management among other tasks.

A greenhouse container irrigation and leachate collection system has been installed for use in collaborative projects with Dr. John Adamczyk (Research Leader) and Anthony Witcher (Support Scientist) at the USDA-ARS Thad Cochran Southern Horticultural Laboratory, and Dr. Eugene Blythe at the South Mississippi Branch Experiment Station in Poplarville, Mississippi. These projects will examine irrigation efficiency in alternative soilless substrates, as well as the binding and leaching potential of soil-incorporated insecticides used in container-grown crops.

USDA-ARS recently completed construction of new, climate-controlled nursery production hoophouse in Ohio. The hoophouse is being fitted with environmental sensors and will be used to conduct irrigation and light quality research.

In 2013/2014, the Virginia Tech nursery research program began to monitor substrate moisture content, bulk electrical conductivity and temperature using a combination of GS3 sensors and thermo-misters. Data was recorded using a solar powered Campbell Scientific data logger with expanded input capability via an analog multiplexer.

In 2013, Virginia Tech began investigating the use of a modified evaporative method measured via the HyProp (Decagon Devices, Inc.) to determine hydrological properties of soilless substrates. This method has proven to provide greater data density and additional hydrological information within moisture content ranges occurring in soilless substrates.

3. Unique Water/Production Related Findings. Include noteworthy findings in water management and quality for crop production & health.

In rain gardens, plants ultimately can be responsible for more nutrient removal from stormwater runoff than soil or substrate says Auburn University. Nutrient uptake by plants can occur year round and continue long term as plants continue to grow. When selecting plants for use in rain gardens, it is important to choose plants with diverse growth forms and habits to maximize nutrient uptake from stormwater runoff year-round.

Plants tolerant of saline irrigation water can potentially be irrigated with recycled water such as greywater or reclaimed wastewater says Auburn University. Irrigating plants with recycled water in production or in the landscape can reduce the demand for potable water.

The objective of this research was to compare ET rates of plant species with containers spaced to achieve full canopy coverage says the University of Florida. UF evaluated uniform and marketable-sized plants grown in trade #3 (10-L) containers filled with pine bark-based substrates at nurseries in Florida and Virginia. Species tested in Florida were *Podocarpus macrophyllus*, *Rhaphiolepis indica* 'Alba', *Rosa* spp. Sunrosa® Pink, *Loropetalum chinense* var. *rubrum* 'Burgundy', *Ilex cornuta* 'Burfordii Nana', *Rhododendron* spp. 'Conversation Piece', *Viburnum odoratissimum* and in Virginia were *Rhododendron* spp. 'Girard's Crimson', *Spiraea japonica* 'Tracy' (Double Play® Big Bang), *Weigela florida* Wine & Roses®, *Hydrangea paniculata* PinkyWinky™, *Gardenia jasminoides* 'Frostproof', and *Berberis thunbergii* f. *atropurpurea* 'Rose Glow'.

In Florida, ET ranged from 0.77 cm for *Podocarpus* to 1.22 cm for *Viburnum* and ET of *Viburnum* greatly exceeded the ET of the other six species. In Virginia, ET ranged from 0.74 cm for *Rhododendron* to 1.15 cm for *Berberis* and ET of *Berberis* greatly exceeded the ET of the other five species. Excluding *Berberis* and *Viburnum*, differences in ET of 0.16 and 0.31 cm were determined for species tested in Virginia and Florida, respectively. These results indicated that differences in ET were small for most of the species evaluated. Thus, it is difficult for a production nursery to justify segregating these species by water needs.

Oxygen concentration in the rhizosphere

At the University of Georgia, anoxic conditions in soilless substrates have been implemented in disease development, reduced growth rates, and denitrification, but there is little quantitative information on oxygen concentrations in soilless substrates. UGA measured the partial pressure of oxygen (pO_2) in peat-perlite substrate planted with petunia (*Petunia* ×

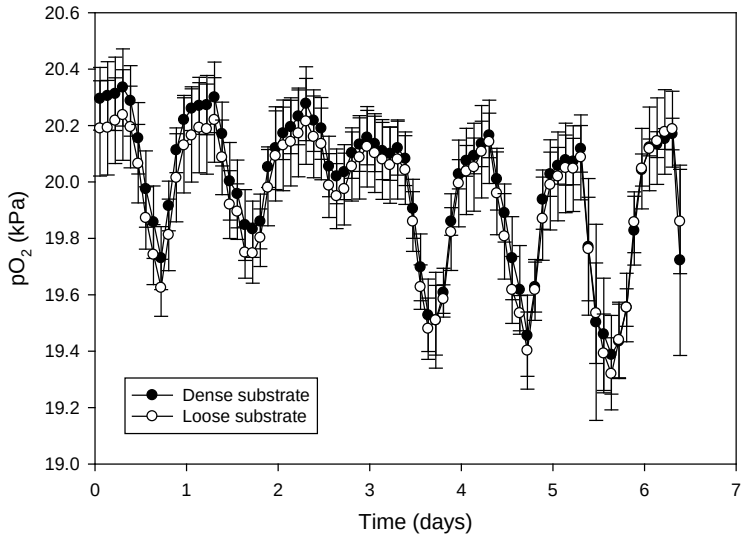

Figure 2. Temporal dynamics of the partial pressure of O_2 (pO_2) in a peat-perlite substrate in a loosely and densely packed substrate. There was no significance effect of substrate density on the partial pressure of oxygen. Diurnal fluctuations in $pO_2$are closely correlated with substrate temperature.

hybrida). There are distinct diurnal fluctuations in substrate pO_2, and these can be largely explained by changes in substrate temperature, which increase the amount of water vapor in the air in the substrate, diluting oxygen and other gases. Barometric pressure (p_{air}) and substrate volumetric water content (θ) also affected substrate pO_2. Substrate pO_2 decreased with decreasing p_{air} and with increasing θ. Photosynthetic photon flux had a highly significant, but small effect on pO_2. Substrate density had no significant effect on pO_2. Overall, substrate pO_2 was between 19.1 and 20.6 kPa, even after watering the substrate to container capacity. The high air-filled porosity of the substrate (approximately 0.40 $m^3 \cdot m^{-3}$ after irrigation) may have prevented the development of anoxic conditions. Since such high levels of pO_2 are unlikely to induce any detrimental anoxic effects on plants, UGA data does not provide any supporting evidence for the idea that anoxia is an important potential problem in peat-perlite substrates.

The University of Hawaii found that *Leucospermum* performed better when grown with cinder based highly porous substrate compared to peat-based commercial potting mix. Higher water set point enhanced shoot growth of *Leucospermum* with more branches and more leaves. However, it significantly reduced root growth, resulting in lower root-to-shoot ratio. Therefore, applying more water during production may reduce plant resistance to multiple stresses during horticultural practices.

A working model of the PLC system has been developed and tested in the laboratory by Carey Grable, Extension Associate – Nursery Crops and systems specialist Thomas Turner at the University of Kentucky. http://www2.ca.uky.edu/HLA/Dunwell/PLCPoster_GrableTurner.pdf

The LSU AgCenter has recently completed a water and nutrient management knowledge/practice survey of nursery, landscape and garden center professionals. Results will be available this fall.

Hammond Research Station has been working with USDA-ARS Southern Horticulture Lab on a new substrate amendment, rice hull ash (RHA). Findings are promising that this material can be formulated into substrate mixes to increase water/nutrient use efficiency and, at the same time, as a supplemental fertilizer.

Louisiana Governor Bobby Jindal declared July as Smart Irrigation Month in Louisiana in cooperation with the Louisiana Irrigation Association and the Irrigation Association. This coincides with Smart Irrigation Month promoted nationally by the Irrigation Association.

In light of the increasing use of alternative substrate materials as replacements for pine bark, a collaborative project among University of Southern Mississippi, Mississippi State University, Auburn University, and USDA-ARS evaluated cutting propagation substrates prepared with processed whole pine trees and found that such material could be used successfully, particularly when blended with peat moss.

The Ohio ARS station found that steel slag, comprised primarily of calcium oxide (CaO), offers greater pH reaction than dolomitic lime in soilless substrates.

Cation exchange capacity in pine bark varies greatly by source and is influenced by particle size distribution, but it is not influenced by pH of the bark.

Gasified rice hull biochar, amended at 10% by volume, provides the total phosphorus needs of potted floriculture crops.

Rice hulls applied as a mulch to the container surface provides greater than 16 weeks of weed control.

Penn State's continuous baiting of recycled irrigation water in two commercial potted plant greenhouses revealed that there is a complex community of mostly non-plant pathogenic species of *Pythium* constantly present in the water. The species in the two greenhouses differ from one another even though it is known that the two greenhouses purchase plants from each other. Results from Penn State's plant susceptibility trials indicate that two aquatic plant species (*Canna flaccida* and *Canna* ×*generalis* 'Bird of Paradise' may not only be non-susceptible to species of *Phytophthora*, but also actively suppressed (18 - 46%) zoospore activity in aqueous systems.

The University of Tennessee found that probe position was not important for EC-5 sensor accuracy in 11.4 L containers filled with 85% pine bark and 25% peat but cultural practices may affect the most ideal placement. For example, a surface placement may be easy to install and remove, and a side placement through the container sidewall may be more secure during hand weeding and less affected during pesticide applications. A single severe drying event reduced sensor accuracy for 4 out of 5 positions and reduced the amount of water the container could hold. In another study on demand irrigation generally used less water than daily water use and had either no or a positive impact on biomass in all but one trial. For 3.8 L plants, photosynthesis and stomatal conductance were consistently greater when irrigated by the on demand program. Both treatments used significantly less water than the industry standard of 2.5 cm per day.

Virginia Tech identified methodology on solute transport in soilless substrates and found that mineral nutrients channeled through soilless substrates, fingered flow (i.e. channeling) is prevalent wen irrigating and controlled release fertilizer effects nutrient leaching from a given irrigation event. Research is currently being published in by the American Society for Horticultural Science and will be presented to stakeholders.

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the NC-1186 objectives (see below). Please use language that the general public can readily comprehend.

NC-1186 Project area: Runoff water management and quality
Several plant species were identified by Auburn University to be tolerant to saline irrigation suggesting that these plants could be produced using recycled water in a nursery or included in saline or coastal landscapes. These species included *Portulaca oleracea, Muhlenbergia capillaris, Illicium parviflorum,* and *Begonia semperflorens-cultorum*. Three additional species

were identified as being suitable for use in bioretention areas for filtration of pollutants (particularly phosphorus) from runoff. This suggests they would be suitable for use in water recycling facilities for production and in landscapes to capture stormwater runoff. These species included *Andropogon ternarius, Coreopsis verticillata,* and *Ilex vomitoria*.

A significant accomplishment was the completion of a revised BMP manual (*Water Quality and Quantity Best Management Practices for Florida Nurseries*) that now encompasses content related to plants produced in native soils (http://www.freshfromflorida.com/content/download/37570/848371/NurseryBMP.pdf). The previous manual pertained to only container production. The container production content was revised. This achievement was the consummation of cooperation between governmental agencies, the nursery industry, and the University of Florida. A task force of representatives from these entities crafted BMPs that provide nursery plant producers using BMPs a waiver of state imposed liability from ground and surface water contamination. Videos developed by University of Florida and imbedded in the manual enhance the learning experience and help producers decide which BMPs are applicable to their operation.

UGA has continued their testing of wireless sensor networks in commercial greenhouses and nurseries and found that soil moisture sensors can be very effective in automatically controlling irrigation. Growers see multiple benefits from these sensor networks, including water savings, shorter crop production cycles, less disease, and better quality. Based on estimates from the University of Maryland, implementation of these sensor networks by ornamental producers, assuming a 50% adoption rate, would result in annual water savings of 223 billion liters/year (enough for 400,000U.S. households) and reduce N and P discharges by 282,000 kg N and 182,000 kg P per year (Majsztrik et al., 2013). UGA expects a commercial release of the sensor networks in summer 2014.

There is a variety of automated irrigation controllers on the market, but many of them are either expensive or not designed for scientific research. Thus, UGA has developed an irrigation controller that can trigger irrigation based on soil moisture sensor readings and store the soil moisture data, as well as information on how often different plots get irrigated. Using an Arduino Uno microcontroller, UGA can build a system that can control irrigation in four separate plots for about $40. The system can easily be scaled up to 14 plots using an Arduino Mega microcontroller (at a cost of $90). Cost estimates do not include the needed soil moisture sensors or irrigation systems. Prototype systems have been running successfully at the University of Georgia and Purdue University.

University of Hawaii at Manoa has developed substrate-moisture sensor based irrigation system to identify water requirement of tropical ornamental plants. Rooted cuttings of *Leucospermum* were grown with either commercial potting mix (CPM) or cinder-based potting mix (VCM), and irrigation was automatically controlled with substrate moisture sensors set at five set-points to provide different levels of volumetric water content (VWC, m^3/m^3). Daily irrigation volume gradually increased as plant size increased. Plants grown with VCM required higher irrigation frequency and higher daily irrigation volume, however, plants were significantly bigger and greener compared to the ones grown with CPM. Higher VWC enhanced shoot growth but reduced root growth, and generated higher leachate. Substrate seems to have more influence on plant quality and the irrigation frequency and volume, and the plant growth of *Leucospermum*.

Optimizing potting substrates for crop production will help maximize crop quality and minimize water loss to the environment.

Researchers at Purdue University grew red maple hybrids in containers and used fertilizers containing stable labeled isotopes of ammonium and nitrate nitrogen to determine the fate of all applied nitrogen. Major results are: 1) soilless media is biologically active and processes such as nitrification readily occur; 2) almost all ammonium applied to the media is nitrified; 3) nitrification likely accounts for the majority of N leaching that occurs; and 4) approximately 15% of the applied N was immobilized by the media.

PLC Control Systems for Irrigation Automation at the University of Kentucky:
This Prototype Irrigation system uses soil moisture probes to send a signal to a PLC controller at preset moisture levels. When the probe reaches a set low point, the PLC sends a signal to open the irrigation solenoid. After the irrigation has run long enough, and the probe reads the set high point, the PLC sends a signal to close the irrigation solenoid. A touch screen is used to monitor this system as well as make adjustments to the program on the fly.
West Kentucky has a manufacturing base that utilizes and has the expertise to program PLC. This system is designed to reduce water usage. This has many benefits: reduced chemical runoff, reduced disease pressure due to dryer conditions, as well as reduced amount of water used. This system has the capability to support automated fertilizer injection with minimal modification.

LSU has conducted two experiments with rice hull ash, which showed promising properties as a wood-based substrate amendment to increase substrate water and nutrient retention capacity without negatively affecting plant growth. LSU has discussed these findings with local growers with the purpose to plan future on-site research plots.

Michigan State University grew plants of the same size and quality of 3 taxa of ornamental plants in alternative containers but alternative containers with higher water vapor transmission rates could increase over-winter mortality in un-irrigated overwintering houses.

Wood-based substrates have been extensively evaluated for greenhouse and nursery crop production, yet these substrates have not been evaluated for propagation. The objective of a collaborative study among University of Southern Mississippi, Mississippi State University, Auburn University, and USDA-ARS was to evaluate processed whole pine trees as a rooting substrate for stem cutting propagation of a range of ornamental crops: the pine substrate used alone and in combination with peat moss. Physical and chemical properties were determined for all substrates. Rooting and initial shoot growth responses were determined for eight species in the two-year study. Rooting percentage was similar among substrates within each species in both experiments. The addition of peat moss resulted in significantly greater total root length in substrates containing pine bark and whole pine tree compared with the latter two alone for five of the eight species.

Rutgers University is working with grant funding to implement conservation practices at plant nurseries and agricultural operations. Planned practices include improved irrigation systems, grassed waterways, rainwater harvesting, and water channel stabilization.

Rutgers University continues education and outreach activities for New Jersey's nursery and greenhouse industries. Methods include presentations to agricultural clientele, stakeholders from non-governmental organizations, and government agency representatives.

At North Carolina State University, the Southern Nursery IPM (SNIPM) working group received funding from the Southern IPM Center to conduct three two-day workshops that included hands-on experiential learning for growers and Extension agents in three nursery dense areas in the south. Attendees were instructed on irrigation management techniques and substrate and nutrition management, for example, measuring water availability using sensors, measuring irrigation application and uniformity, and measuring pH and electrical conductivity in leachate in containers. After the workshops, all attendees improved their knowledge about irrigation management techniques and substrate and nutrition management, sharpened their skills to successfully monitor and measure these factors, and became more confident of their ability to adopt the practices and integrate them at their nursery operation.

USDA-ARS in Wooster, OH, measured the acid neutralizing ability of steel slag in soilless substrates. Steel slag is a byproduct of the steel manufacturing industry. Steel slag has a high concentration of calcium oxide, as well as other nutrients and micronutrients including iron, silicon, and manganese. Steel slag has greater pH neutralizing ability than dolomitic limestone, provides high concentrations of plant-available silicon, and provides low levels of other plant-essential micronutrients. Steel slag is being marketed for horticultural use and should cost less than dolomitic lime.

Cation exchange capacity (CEC) describes a substrate's ability to retain cation nutrients. Higher CEC values for a substrate generally result in greater amounts of nutrients retained in the substrate and available for plant uptake and greater buffering against change in pH over time. USDA-ARS in Wooster, OH determined that particle size of the pine bark had the greatest effect on CEC. Substrate pH and peat moss amendment had little or no effect on CEC. Nursery producers should choose a bark source with the greatest percentage of fine particles to maximize CEC.

Biochar is the charred organic matter that remains after pyrolysis (burning) of biomass or manure. Biochars from different feedstocks yield different properties as a result of their differing particle sizes at the time of pyrolysis, inherent ash content of the feedstock, pyrolysis conditions, and storage conditions after processing. USDA-ARS in Wooster, OH measured nitrate, phosphate, and potassium retention and leaching in a typical greenhouse soilless substrate amended with one of three biochar types including: gasified rice hull biochar (GRHB), sawdust biochar (SDB), and a bark and wood biochar (BWB). All biochar amendments affected nitrate release by temporarily absorbing nitrate and releasing it slowly. This could result in less drastic and fewer spikes between high and low nitrate availability in the soil solution. The GRHB was a net source of phosphates and potassium and when incorporated into a greenhouse substrate at 10% by volume, provides enough of these two nutrients without the need to provide additional phosphorus or potassium fertilizers.

Preemergence herbicides are the primary tool for controlling weeds in containers. However, preemergence herbicides cannot be used on all crops nor are they labeled for use in enclosed

structures. Alternatives are needed for managing weeds where preemergence herbicides are either not labeled or cannot be used with a wide margin of safety. In particular, there are needs for weed control alternatives in propagation, hoophouses and other enclosed structures, and herbaceous perennials and other sensitive crops. USDA-ARS in Wooster, OH demonstrated that parboiled rice hulls applied at a depth of 0.5 to 1.0 in over the substrate surface prevented establishment of bittercress and liverwort from seeds or gemmae, respectively.

Penn State determined that the recycled irrigation water holding tanks of two commercial greenhouses continuously monitored to detect *Pythium* harbored numerous different isolates characterized by filamentous, non-inflated sporangia (Group F). In addition, one greenhouse habored *Pythium helicoides, P. middletonii, P. rostratifigens* and two species that are new to science while the second greenhouse harbored *Pythium chamaehyphon* and one species that is new to science. In greenhouse experiments where these isolates were used to inoculate geraniums each separately and in combination with the highly pathogenic *Pythium aphanidermatum*, *P. irregulare*, and *P. cryptoirregulare* there did not appear to be disease inhibitory or enhancement effects between *Pythium* species.

Researchers at Clemson University evaluated aquatic plants species for their susceptibility to plant pathogens by (1) surveying multiple plant species in constructed wetlands and vegetative channels directly receiving runoff from nursery production areas and (2) by screening seven aquatic plant species in repeated laboratory trials to evaluate susceptibility to plant pathogens. *Canna flaccida, Canna ×generalis* 'Bird of Paradise,' *Hydrocotyle umbellata, Pontederia cordata, Sagittaria latifolia,* and *Typha latifolia* support limited or no growth and reproduction of examined *Phytophthora* spp.

Researchers at Clemson University, Virginia Tech, University of Maryland, Michigan State University, University of California-Davis, Texas A&M, Oregon State University and the University of Florida developed and submitted a Specialty Crops Research Initiative Coordinated Agricultural Proposal planning to develop a decision-support tool to help growers' select treatment technologies and best management practices to facilitate recycling of irrigation runoff water.

Researchers at Virginia Tech, Clemson University, North Carolina State University, and University of New Hampshire collaborated with PureSense to begin developing a comprehensive crop production tool to help the technology-savvy grower manage water and fertilizer. This research funded by the Horticulture Research Institute and the American Floral Endowment will assist nursery and floriculture producers. The "app" will assist growers in making on-the-go decisions, providing them with historical records, saving time and money.

By oxygenating irrigation water, container-grown plants would be exposed to more oxygen in the root zone, potentially reducing pathogenicity and providing an alternative to chemical control. The University of Tennessee designed an automatic irrigation system that minimized the loss in dissolved oxygen levels and cost less than $900.00. UT targeted 5.0 $mg \cdot L^{-1}$, 7.0 $mg \cdot L^{-1}$, 11.0 $mg \cdot L^{-1}$, and 13.0 $mg \cdot L^{-1}$. Actual dissolved oxygen levels varied across the three trials and average measurements were 4.9 $mg \cdot L^{-1}$ to 13.2 $mg \cdot L^{-1}$. As much as a 20% increase in dissolved oxygen level and 17.3% decrease from the initial level to the last emitter was observed,

depending on target level. The results presented here suggest that the automatic irrigation system is one of several factors contributing to the increased or decreased dissolved oxygen levels.

UT conducted an experiment to determine which of five substrate-moisture sensor placements best estimates volumetric water content (VWC) for 11.4 L containers filled with 85% pine bark: 15% sphagnum peat moss substrate by volume and planted with *Hibiscus moscheutos* 'Pink Elephant' as well as the effect of low VWC on sensor measurements. Five sensor placements were tested; three sensors were horizontally inserted into the sidewall at 5 cm, 10 cm, and 15 cm from the base of the container and the other two placements were inserted into the substrate surface either vertically or diagonally. All positions showed a strong linear relationship (r^2> 0.92) with VWC determined gravimetrically, indicating they all are appropriate models of container substrate moisture. The substrate was dried to 0.11 $m^3 \cdot m^{-3}$ and became hydrophobic. This substantially decreased the amount of water that could be held at effective container capacity and decreased sensor accuracy.

At the University of Tennessee, independently controlled irrigation plots were designed to test two container nursery irrigation regimes on oakleaf hydrangea (*Hydrangea quercifolia* 'Alice'). Plants were automatically irrigated by one of two soil moisture sensor-based regimes: 1) a daily water use (DWU) system that delivered the exact amount of water that had been lost in the previous 24 h and 2) an on-demand (OD) irrigation system based on a specific substrate moisture content derived from the relationship between substrate moisture and photosynthetic rate. OD generally used less water than DWU and had either no or a positive impact on biomass in all but one trial. For 3.8 L plants, photosynthesis and stomatal conductance were consistently greater when irrigated by the OD program. Both treatments used significantly less water than the industry standard of 2.5 cm per day. This research demonstrated that both DWU and OD are a dramatic improvement over conventional irrigation scheduling and could be adopted as conservative irrigation systems for nursery production.

At Texas A&M, a greenhouse study evaluated the short-term effects of irrigation with laundry gray water on the growth and aesthetic performance of selected landscape plants. Initial results indicate that gray water containing detergents and softeners produces similar plant growth and quality responses as in plants irrigated with tap water. Gray water containing bleaching agents, however, reduced the aesthetic quality of some species. Tissues are being analyzed for mineral nutrient status and later will be evaluated against growth performance and the major chemical properties of the gray waters employed in the study. These preliminary observations are being shared in local and regional meetings dealing with urban landscape water conservation issues.

At Texas A&M, a field study to evaluate the long-term effects of gray water irrigation on landscape plants has been planted. Twelve species of herbaceous perennials and woody plants were transplanted in replicated rows, and once established, the plants will be subjected to irrigation with various gray water treatments over a three-year period to evaluate their effect on plant growth, aesthetics and the physical, chemical and biological properties of the landscape soil beneath each treatment.

Greenhouse studies were conducted to evaluate garden roses including Earth-Kind® rose cultivars in response to a range of elevated salinity level in irrigation water. Based on their growth, visual quality, and leaf mineral concentrations, the relative salt tolerance of the selected rose cultivars was determined and classified as sensitive, moderately sensitive, moderately tolerant groups. Another greenhouse study was carried out to evaluate the salt tolerance of Texas Superstar® landscape plants. Both Earth-Kind® roses and Texas Superstar® landscape plants are specially designated by Texas AgriLife Extension with superior stress tolerance and outstanding landscape performance under Texas growing conditions. However, their responses to salinity were unknown. Texas A&M's results indicated that drought tolerant plants are not necessarily tolerant to salinity. This additional information on salt tolerance will help landscape professionals and home owners select appropriate plants for areas where poor quality water may be used for irrigation to prevent salt damage and landscape aesthetic appearance.

According to research conducted in Virginia, plant pathogens in irrigation water pose a constant threat to ornamental crops and surrounding natural forests. This project is to identify major knowledge gaps and develop science-based, economically-viable and environmentally-sustainable management strategies for the ornamental horticultural industry. Specifically, we will develop protocols to guide farmers in recycling irrigation system design for minimal inoculums intake and crop health risk. We also will revamp the heat pasteurization protocol to reduce energy consumption and cost without compromise of water decontamination efficacy.

5. Impact Statements. Please draft 2 or 3 impact statement summaries related to the NC-1186 objectives (listed below). Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report. Two examples are listed below.

NC-1186 Outcomes/Impacts: Auburn University found that mitigate nutrient runoff into the environment and better utilize limited water resources through increased use of secondary water sources instead of primary potable water sources. *Portulaca oleracea*, *Muhlenbergia capillaris*, *Illicium parviflorum*, and *Begonia semperflorens-cultorum* were tolerant of daily saline irrigation up to at least 6000 ppm NaCl, suggesting tolerance of particularly high saline environments or saline recycled irrigation water. *Andropogon ternarius*, *Coreopsis verticillata*, and *Ilex vomitoria* provided particularly effective phosphorus removal from bioretention areas when used in combination (polyculture) rather than alone (monoculture). Using a combination of growth habits provided more consistent year-round phosphorus removal.

Irrigation water conservation is important for nurseries because of restrictions on allocations, competition for water resources, and the impact nutrient-laden runoff water has on the environment. An ET based irrigation control system has been developed by University of Florida. Implementation of this system on a production area at a nursery in Florida resulted in a 20% reduction in overhead sprinkler water applied daily from March – July 2014. The amount of water applied to the ET based irrigated area was compared to an adjacent area of similar size with the same plants. The adjacent area was irrigated based on the Nursery Manager's decision regarding the amount of water to apply daily using a manual time setting. Plant growth was similar in both areas. Use of ET based irrigation is a BMP that not only provides a guide for

irrigation management but results in a concomitant reduction of nutrients in runoff. At a nursery in Virginia, the owner indicated that nutritional amounts could be reduced 20% on some crops with implementation of the ET based irrigation BMP.

University of Georgia found that wireless sensor networks can effectively control irrigation in commercial nurseries and greenhouses, based on soil moisture sensor readings. Growers have seen shorter production cycles, less disease, and better quality, along with large water savings. Implementation of this technology in greenhouses and nurseries will benefit both growers and society. Societal benefits include reduced water use and a decrease in agrochemical runoff.

In order to determine water requirements of tropical ornamental plants, a sensor based irrigation system was used at University of Hawaii. Results indicate that substrate is the most important factor that affects irrigation frequency and volume and plant quality of *Leucospermum*. When grown with highly porous substrate, plants performed better. Although higher irrigation frequency and volume increased shoot growth of *Leucospermum* by 40%, it reduced root growth by 20%, resulting in the reduction of root-to-shoot ratio by 50%. This information can be critical to optimize plant production systems.

The methodology developed at Purdue will allow researchers to better quantify N losses from container plants. This technique can now be used to conduct experiments on how environmental and management strategies affect the fate of N in container systems.

At the University of Kentucky, the small UKREC Rain Gardens used to mitigate the run-off from gravel container research beds are the size that could be used by small local container production/retail nurseries that sell directly to the public. The Rain Garden/run-off control demonstrations are shared with the public via a June Open House.

Research and extension efforts are continuously being pursued at LSU AgCenter addressing irrigation management and water quality issues our industry is facing. Research on container substrate amendments and irrigation control with low leaching fractions are promising for further investigation.

Plastic containers are produced using petroleum with a high carbon cost and are typically not recycled since they are contaminated with dirt and possibly pests after initial use. The goal of this project was to evaluate the ability of alternative to plastic containers in producing ornamental plants of the same size and quality. Field trials were conducted over the past 3 years to evaluate plant growth, quality and water use in several alternative containers. Containers were made of wood pulp, recycled and woven plastic, and keratin from chicken feathers. Plant growth and quality was unaffected providing irrigation was applied to replace the amount of water used but a higher number of some plants died overwinter due to water loss through porous sides of wood pulp and woven containers. The tradeoff between lower carbon inputs and higher water inputs is being evaluated.

Mississippi State University found that the supply of pine bark as a component of nursery and greenhouse growing media has become more limited in the Southeastern U.S. due to reduced forestry production and increased use of bark as a fuel source. Although previous studies has

shown that growing media containing processed whole pine trees are a viable substitute for pine bark, this renewable material had not previously been tested for use in cutting propagation. Graduate student Anthony Witcher determined that processed whole pine trees can be used successfully for rooting cuttings of horticultural crops and is best used blended with peat moss. Results of this study will provide additional, sustainable substrate options for commercial nursery producers.

The implementation of conservation practices will prevent water pollution or improve water quality in streams and lakes in the targeted watershed in New Jersey. Benefits include the reduction of sediment and phosphorus to the Cohansey River, water conservation in areas of stressed aquifers, reduction of soils erosion, and the improvement of sustainability of New Jersey's plant nurseries and agricultural operations.

Educational activities, which focus on water concerns of the plant nursery and greenhouse industries reduce soil erosion, prevent water pollution in New Jersey's waterways, conserve water, and further the sustainability of the industries.

North Carolina State University found that the application of irrigation to nursery crops affects growth, health, and the amount of nutrients available to plants, as well as the nutrients lost in production runoff water. Because water, nutrients, and plant health are limited resources that affect environmental health, it is imperative that they are used judiciously. The Southern Nursery IPM (SNIPM) Working Group with funding from the Southern IPM Center provided training for growers on measuring irrigation efficiency. Approximately 75 growers in three different areas of the southeast U.S. learned how to measure irrigation application rate and its uniformity. By adopting these techniques that reduce water use, growers could reduce production costs while maintaining plant quality.

USDA-ARS in Wooster, OH developed BMP guidelines for substrate amendment with steel slag as an alternative to dolomitic lime. Substrate pH response curves were generated for greenhouse and nursery substrates, as a function of steel slag rate. Growers can use this information to determine the specific rate needed for their substrates and crops.

USDA-ARS in Wooster, OH gathered information on what has been published on cation exchange capacity for pine bark substrates used in the northern U.S. There was virtually no science based information on this topic, yet substrate management decisions are being made based on assumptions of how pine bark CEC affects plant nutrition. USDA-ARS's research showed that particle size of the pine bark does influence CEC, but pH and peatmoss amendment have little impact.

USDA-ARS in Wooster, OH assessed physical and chemical properties of greenhouse and nursery substrates amended with gasified rice hull biochar (GRHB) and its impact on plant health and nutrient levels in leachates. GRHB affected nitrate release by temporarily absorbing nitrate and releasing it slowly. This could result in less drastic and fewer spikes between high and low nitrate availability in the soil solution. The GRHB was a net source of phosphates and potassium and, when incorporated into a greenhouse substrate at 10% by volume, provides enough of these two nutrients without the need to provide additional phosphorus or potassium

fertilizers. Growers can reduce fertilizer costs by 33% using GRHB instead of traditional fertilizers.

USDA-ARS in Wooster, OH developed new best management practices for weed management that improves crop health and reduces the amount of pesticides returning to runoff irrigation reservoirs. By using rice hulls as an alternative to chemical herbicides for weed control, fewer herbicides are needed to produce healthy crops. This best management practice is especially relevant in enclosed production spaces such as greenhouses and hoophouses where use of chemical herbicides is limited by label restrictions. Nursery growers can reduce weed control costs by as much as 75% with the use of rice hulls.

During the past five years, researchers at Clemson University have monitored the efficacy of two constructed wetlands to facilitate removal of nutrient and pathogen contaminants from runoff. The wetlands reduced export of total nitrogen by 69%, phosphorus by 39%, and *Phytophthora* spp. (a pathogen) by 80%. Over 630,000 gallons of water flow through these wetlands each day, and an average of 143 lbs. of nitrogen and 0.12 lbs. of phosphorus are removed from runoff on a daily basis. Given that it takes only 0.02 ppm phosphorus to contribute to nutrient enrichment and potential impairment of surface waters[2], optimizing best management practices to reduce nutrient export into surface waters is critical. This technology to filter contaminants from runoff not only helps to protect our surface waters but can also be applied to increase re-use of irrigation runoff to save potable water sources for other uses.

Increasing regulation, public interest in sustainable practices, and droughts have increased nursery producer awareness of the need to more conservatively use natural resources such as water during agricultural production. The University of Tennessee has shown that substrate moisture probe placement does not matter for scheduling irrigation, for 11.4 L container filled with 75% pine bark and 25% peat moss. A severe drying event, 11% VWC reduces sensor accuracy due to the substrate holding less water. The University of Tennessee also showed that in Southern locations scheduling irrigation based on an on demand (OD) or daily water use (DWU) regime reduced water use. OD generally used less water than DWU and had either no or a positive impact on biomass in all but one trial.

Root rot pathogens lead to economic costs due to loss of crop and use of expensive fungicides. The University of Tennessee developed a system to apply irrigation water with a range of dissolved oxygen levels from approximately 5.0 $mg \cdot L^{-1}$, 7.0 $mg \cdot L^{-1}$, 11.0 $mg \cdot L^{-1}$, and 13.0 $mg \cdot L^{-1}$, approximately double the ambient concentration. This system will allow UT to test if elevating oxygen levels will reduce pathogenicity of root rot pathogens and/or bolster plant health allowing plants to resist infection.

Severe drought and stiff competition for high-quality water supplies are forcing the green industry, particularly those located in urban areas, to consider the use of alternative irrigation sources like reclaimed, stormwater and graywater. An effective use of these sources could reduce municipal potable water dependence in urban areas. Research at Texas A&M AgriLife-Uvalde indicates that laundry-derived graywater, without bleach residues, can be used to satisfactorily grow annual and herbaceous perennials plants used for urban landscaping applications.

Salt tolerance of garden roses, including 18 Earth-Kind® roses and 15 Texas Superstar® landscape plants were evaluated in several greenhouse studies. The results of salt tolerance of these landscape plants will help nursery and landscape professionals and home owners to choose appropriate plants for landscapes where low quality water may be used.

Virginia developed and launched a monthly webinar series: Irrigation Pathogens and Water Quality on October 8, 2013 . This series is a key component of our SCRI project educational program and has attracted national and international audience. Also, a workshop on Water Management for Ornamental Crops was held in Virginia Beach, Virginia in October 2013 with participants from green industry and water treatment companies from several states.

6. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

Book Chapter

Cabrera, R.I. and A.R. Solís-Pérez. 2013. Tolerancia y manejo de salinidad, pH y alcalinidad en el cultivo de flores, p. 65-72. In: Avances en Nutrición de Flores de Corte (Memorias). Centro de Innovación de la Floricultura Colombiana (CENIFLORES), Colombia. ISBN 978-958-98993-3-5.

Chappell, M.R., J.S. Owen, S.A., White and J. Lea-cox. Irrigation management practices. In: T. Yeager, T. Bilderback, D. Fare, C. Gilliam, J. Lea-Cox, A. Niemiera, J. Ruter, K. Tilt, S. Warren, T. Whitwell and R. Wright (eds.) Best management practices: Guide for producing nursery crops. 3rd edition. Southern Nursery Association, Atlanta, GA. In press in English and Spanish.

Ivors, K. L. and G. W. Moorman. 2014. Oomycete Plant Pathogens in Irrigation Water. Pages 57-64 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

Mattson, N.S. and A. Fulcher. 2014 (in press). pp. XYZ-XYZ. Substrates and containers for seed and cutting propagation and transplanting. In: Beyl, C.A. and R.N. Trigiano, eds. Plant Propagation Concepts and Exercises, CRC Press, Boca Raton, FL. in press.

Moorman, G. W., A. J. Gevens, L.L. Granke, M. K. Hausbeck, K. Hendricks, P. D. Roberts, and T. R. Pettitt. 2014. Sources and Distribution Systems of Irrigation Water and Their Potential Risks for Crop Health. Pages 3-11 in: Biology, Detection, and Management of

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UT-UK IPM for Shrub Production Manual. 2013. A. Fulcher, ed. University of Tennessee, Knoxville, TN. 80pp. (electronic version) http://plantsciences.utk.edu/tnsustainablenurserycrops.htm

Yeager, T. 2013. Best Management Practices for Field Production. In: Water Quality/Quantity Best Management Practices for Florida Nurseries. T. Pride, (ed.) Florida Department of Agriculture and Consumer Services, pp.17-21. http://www.freshfromflorida.com/content/download/37570/848371/NurseryBMP.pdf

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Hong, C. X., Richardson, P. A., Kong, P., and Cafa, G. Tracking water quality dynamics in a multi-basin agricultural water recycling system, 2013 AWRA Spring Specialty Conference on Agricultural Hydrology and Water Quality II, St. Louis, MO, March 25-27, 2013

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Produced by: H. Jones and D. Cochran, edited by A. Fulcher. Videos created in collaboration with F. Hale and A. Windham. Funded by the Southern Risk Management Education Center.
http://www.youtube.com/watch?v=X4LlfYJIjvs

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Cabrera, R.I. and D.I. Leskovar. 2013. Alternative irrigation sources for urban landscape water conservation. HortScience 48(9): S28. (abstract).

Cabrera, R.I. 2013. The challenges of graywater as an alternative water source for landscape irrigation. HortScience 48(9):S105. (abstract).

Cabrera, R.I. D.I. Leskovar, M. Martin, M. Koch and D. Rodriguez. 2013. Water use and conservation in urban landscaping activities: The case for graywater utilization. The National and International Conference on Groundwater, 2013 NGWA Summit. April 28-May 2, 2013, San Antonio, TX. (abstract).

Crawford, L., J.D. Lea-Cox, J. Majsztrik, W. Bauerle, M. van Iersel, T. Martin, and D. Kohanbash. 2013. Behind the curtain: The support component of wireless soil moisture networks. HortScience 48:S181-182 (abstract).

Ferrarezi, R.S., M.D. Ribeiro, M.W van Iersel, and R. Testezlaf. 2013. Subirrigation controlled by capacitance sensors for citrus rootstock production. HortScience 48:S142 (abstract).

Leskovar, D.I., M. Palma and R.I. Cabrera. 2013. Deficit irrigation strategies for high-value crops in South Texas. The National and International Conference on Groundwater, 2013 NGWA Summit. April 28-May 2, 2013, San Antonio, TX. (abstract).

Li, T., G. Bi, G. Niu, S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, A. Fulcher, Y. Sun. 2013. Use of biocontainers in pot-in-pot nursery production system. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S48 (abstract.)

Meder, A. and A. Wright. 2014. Phosphorus uptake and flooding tolerance of three native landscape plant species. HortScience 49:in press.

Nambuthiri, S., R.L. Geneve, Y. Sun, X. Wang, G. Bi, R.T. Fernandez, and G. Niu. 2014. Impact of alternative materials on container physical properties and substrate temperature. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. (abstract).

Nambuthiri, S., R.L. Geneve, G. Niu, Y. Sun, G. Bi, R.T. Fernandez, and X. Wang. 2013. Impact of container material on substrate heat buildup in an outdoor nursery. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S45 (abstract).

Owen, J.S.. Jr., K.A. Williams and H.M. Stoven. 2013. Bluing of hydrangea 'Endless Summer' sepals is influenced by timing of aluminum sulfate drenches or aluminum chelate foliar sprays in three different locations and production systems. HortScience 48:S382-S383.

Rivera, L.D., L. Crawford, M. van Iersel and S. Dove. 2013. Comparing hydraulic properties of soilless substrates with natural soils: a more detailed look at hydraulic properties and their impact on plant water availability. HortScience 48:S426-427 (abstract).

Sluznis, R., A. Wright, and C. LeBleu. 2014. Greywater irrigation of two herbaceous landscape plant species. HortScience 49:in press

Starry, O., J. Kim, S. Dove, M. van Iersel, and J.D. Lea-Cox. 2013. Effects of water availability and temperature on CAM expression and water use efficiency by *Sedum album* and *Sedum kamtschaticum*. HortScience 48:S143 (abstract).

Thomas, P.T., M. Chappell, J.M. Ruter, E. Lichtenberg, and M.W. van Iersel. 2013. Wireless sensor networks for automated irrigation control in container nurseries: implementation and economic impact. HortScience 48:S179 (abstract).

Wang, X., R.T. Fernandez, B.M. Cregg, M. Ngouajio, R. Auras, and J.P. Albano. 2013. Sensor integrated automatic irrigation system to reduce runoff and nutrient loss without affecting

plant growth. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S259 (abstract).

Wang, X., R.T. Fernandez, G. Bi, A. Fulcher, R.L. Geneve, G. Niu, S. Verlinden, B.M. Cregg, M. Ngouajio. 2013. Plant growth and water use in plastic, fiber, keratin, and Root Pouch containers. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S108 (abstract).

White, S.A., J.S. Owen, Jr., J. Majsztrick, R.T. Fernandez, P.R. Fisher, C.R. Hall, T.A. Irani, J.D. Lea-Cox, J. Newman, and L.R. Oki. 2013. Containment, remediation, and recycling of irrigation water for sustainable ornamental crop production: Results of a SCRI Planning Grant. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S264 (abstract).

Theses/Dissertations

Wang, X. 2013. Irrigation management and alternative containers for more sustainable nursery production. M.S. Thesis. Department of Horticulture, Michigan State University, East Lansing, MI.

In-review or In-preparation

Hagen, E., A. Fulcher and X. Sun. Determining optimum sensor orientation and depth within an 11.4 L container to estimate whole container volumetric water content. Applied Engineering in Agriculture. In review.

Li, T., G. Bi, G. Niu, S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, Y. Sun, and X. Zhao. Feasibility of Using Biocontainers in a Pot-in-Pot System for Nursery Production of Betula nigra. HortTechnology. In review.

Nambuthiri, S., R.L. Geneve, Y. Sun, X. Wang, R.T. Fernandez, G. Niu, G. Bi, and A. Fulcher. Substrate temperature in black plastic, wood pulp, keratin, and fabric nursery containers. HortTechnology. In review.

Pershey, N.A., R.T. Fernandez, B.M. Cregg and J.A. Andresen. Irrigating based on daily water use reduces nursery effluent volume and nutrient load without reducing growth of four conifers. Agricultural Water Management. In review.

Pershey, N.A. Reducing Water Use, Runoff Volume, and Nutrient Movement for Container Nursery Production by Scheduling Irrigation Based on Plant Daily Water Use. M.S. Thesis. Department of Horticulture, Michigan State University, East Lansing, MI. In preparation.

Wang, X., R.T. Fernandez, B.M. Cregg, R. Auras, A. Fulcher, G. Niu, Y. Sun, G. Bi, S. Nambuthiri, and R.L. Geneve. Multi-state evaluation of plant growth and water use in plastic and alternative nursery containers. HortTechnology. In preparation.

Wang, X., R.T. Fernandez, B.M. Cregg, R. Auras, N. Gong, A. Fulcher, D.R. Cochran, G. Niu, Y. Sun, G. Bi, S. Nambuthiri and R.L. Geneve. 2014. Physical properties and compostability of alternative containers for nursery production. Scientia Horticulturae. In preparation.

Yuan, S., P. Huddleston, B.K. Behe, R.T. Fernandez, C. Hall, and M. Palma. The effect of product expertise and involvement on consumers' information seeking and decision making process. J. Consumer Psychology. In preparation.

Websites

LeBude, A.V. 2013. Nurserycropscience.info. The Nursery Crop Science website is an outreach project of the Department of Horticultural Science at NC State University and is dedicated to providing current information for Extension field faculty, students, researchers, and growers of commercial horticultural products. Between January and December 2013, the site has had 6000 page visits, 5000 were unique visitors that viewed over 13,000 pages. The bounce rate was 66%, which indicates that approximately 2040 visitors interacted with the site beyond the home page. According to Google Analytics, approximately 1500 people stayed more than a minute and viewed 11,332 pages of content. Those would be considered users who are interested in nursery crop science information and not casual "googlers" who stopped by the site by accident or by looking for corollary information but were drawn to the website first.

Other Creative Works

Fulcher, A., A. LeBude, S. White, J-H Chong, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, S. Gill, F. Hale, W. Klingeman, G. Knox, J. Neal, M. Paret, K. Rane,

N. Ward, J. Williams-Woodward, and A. Windham. 2013. IPM in action. Nursery Management 29(12):30-33.

Yeager, T. 2013. Nursery irrigation system checklist. Univ. Fla. Ext. Fact Sheet: ENH1208, 4 pages. http://edis.ifas.ufl.edu/pdffiles/EP/EP46900.pdf

7. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

Altland, J.E. 2013. Weed control in herbicide-sensitive crops. Floriculture Research Alliance, Seattle, WA.

Altland, J.E. 2014. Weed control alternatives to herbicides. Maumee Valley Growers Association Annual Meeting, Toledo, OH.

Cabrera, R.I. 2013. Irrigation Water Quality and its Effects on Urban Trees. 2013 Texas Tree Conference. Sponsored by the Texas Chapter of the International Society of Arboriculture. Convention Center in Waco, TX. October 2-4, 2013.

Cabrera, R.I. 2013. Coping with Drought. 2013 Texas Master Gardener Conference. Sponsored by the Texas Master Gardener Association. Held at the Convention Center in McAllen, TX. October 17-19, 2013.

Cabrera, R.I. 2013. Native and Adaptive Plants as Solutions for Drought and Landscape Irrigation Restrictions. Texas Native Plant Week. Sponsored by the Uvalde Chapter of the Texas Native Plant Society. Held at Progreso Library, Uvalde, TX. October 26, 2013.

Cabrera, R.I. 2013. Water Quality for Ornamental Plants/Landscaping. 2013 Irrigation Show & Education Conference. Sponsored by the Irrigation Association. Convention Center, Austin, TX. November 08, 2013.

Cabrera, R.I. 2014. Landscape Plant Disorders related to Weather, Soil and Water (In Spanish). 2014 Winter Workshop on Landscape Management- TNLA Region II. United Way Bldg., 50 Waugh Dr., Houston, TX. January 31, 2014.

Cabrera, R.I. 2014. Short-term evaluation of graywater irrigation on selected ornamental species. 95th Annual Meeting of the Southern Region-ASHS. Dallas, TX. Jan. 31 - Feb. 2, 2014.

Cabrera, R.I. 2014. Water quantity and quality issues for arboriculture and landscape horticulture. South Texas Urban Forestry Conference on Planning and Growing Healthy Green Space. Sponsored by the San Antonio Arborist Assn. and the Texas Forest Service. Laredo, TX. February 20, 2014.

Cabrera, R.I. 2014. Short Course on Nutrition, Fertilization and Plant Physiology Applied to Flower Crops. Escuela de Floricultura, EXPOFLORES (Asociación Nacional de Productores y Exportadores de Flores del Ecuador), Quito, Ecuador. March 27-29 4, 2014.

Cabrera, R.I. 2014. Coping with drought and landscape irrigation restrictions. Uvalde Green Garden Club Monthly Meeting. Patricia Lane, Uvalde, TX. April 3, 2014.

Cabrera, R.I. 2014. Water conservation in urban landscaping activities. Laredo EcoFestival, Sponsored by Rio Grande International Study Center. Alexander Crossings, Laredo, TX. April 12, 2014.

Campoverde, E.V., P. Fisher, E. Skvarch, S. Steed, and T. Yeager. 2014. Educating Environmental Horticulture producers about water quality and conservation impacts on plant production. University of Florida Water Institute Conference, Sustainable Water Resources, Complex Challenges, Integrated Solutions, Gainesville, Florida (poster presentation).

Cregg, B, and D. Ellison. 2013. Urban tree selection in a changing climate. Presented at ASHS-2013, Annual Conference, July 22-25, Palm Desert, CA.

Cregg, B. 2013. Research in Real Time: Integrating Social Media and Landscape Research. Presented at ASHS-2013, Annual Conference, July 22-25, Palm Desert, CA.

Cregg, B. 2013. Weather 2012. Looking back: Looking Forward. Michigan Nursery and Landscape Association Great Lakes Trade EXPO. Grand Rapids, MI. January 7, 2013.

Cregg, B. 2013.Urban tree selection in a changing climate. Minnesota Shade Tree Short Course. March 13, 2013.

Dinwiddie, J, M. van Iersel, B. Clegg, M. Nuccio, M. de Carbonnel, Y. Sun, A. Zhou, G. Crabb, J. Nichols, H. Zhaou, and N. Bate. 2014. A whole-plant phenotyping approach leveraging Syngenta's advanced crop laboratory at the research triangle park innovation center. 2014 Meeting of NCERA-101, Fairbanks, AK.

Dinwiddie, J., M. van Iersel, B. Clegg, M. Nuccio, M. de Carbonnel, Y. Suna, A. Zhoua, G. Crabb, J. Nichols, H. Zhou, and N. Bate. 2014. An automated whole plant phenotyping system for high resolution characterization of plant x environment interactions. Maize genetics conference, Bejing, China.

Fernandez, R.T., X. Wang, A. Ingrao, G. Bi, A. Fulcher, R. Geneve, G. Niu, Y. Sun, S. Verlinden, B. Cregg, M. Ngouajio, R. Auras, S. Nambuthiri, and R. Conneway. 2014. Water use and performance of plants grown in alternative nursery containers. ISHS IHC 2014, Brisbane, Australia.

Fernandez, R.T., H.M. Stoven, and S. Doane. 2014. Using RFID for inventory tracking in container and field nursery operations. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press.

Fernandez, R.T., X. Wang, G. Bi, G. Niu, R.L. Geneve, A.F. Fulcher, and D. Cochran. 2014. Water use of nursery plants grown in alternative containers: Implications for sustainability. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press. Invited Workshop Presentation.

Fernandez, R.T. 2014. Not just another pretty plant: Using plants for improving water resources. Meadow Brook Garden Club. April 25, 2014.

Fernandez, R.T. 2014. Phytoremediation: Putting plants to work. Kalamazoo Area interested citizens. Portage, MI April 15, 2014.

Fernandez, R.T. 2014. Do your plants have a drinking problem? Managing irrigation to improve plant growth and quality. Idaho Horticulture Expo, Boise, ID. January 23, 2014.

Fernandez, R.T. 2014. Stemming the off-site tide: Managing nursery irrigation and runoff. Ohio Nursery Short Course, Columbus OH. January 13, 2014.

Fernandez, R.T. 2014. How water quality, substrates and irrigation management affects container plant production and movement of nutrients and pesticides. MNLA GLTE, Grand Rapids, MI January 6, 2014.

Fernandez, R.T. 2013. Irrigating substrates to improve nutrient retention and plant growth. 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S100 Invited Workshop Presentation.

Fernandez, R.T. 2013. Pesticides in recycled water: What are the issues? 2013 American Society for Horticultural Science Annual Conference, Palm Desert, CA. HortScience 48:S101 Invited Workshop Presentation.

Fulcher, A. and D. Cochran. Exploring Oxygenation of Irrigation Water. Annual SCRI meeting of Integrated Management of Zoosporic Pathogens and Irrigation Water Quality for A Sustainable Green Industry, November 14, 2013, Virginia Beach, VA.

Kim, H.J., P. Singleton, J. Lichty, and A. Kawabata. 2013. Water requirements of tropical ornamental crops. Greensys2013, International Society for Horticultural Science, Jeju, Korea.

Li, T., G. Bi, G. Niu, S. Nambuthiri, R.L. Geneve, X. Wang, R.T. Fernandez, A.F. Fulcher, Y. Sun, and X. Zhao. 2014. Use of fiber containers in pot-in-pot system for a two-year nursery production of birch. 2014 American Society for Horticultural Science Annual Conference, Orlando, FL. HortScience 49:in-press.

Li, T, G. Bi, G. Niu, S. Nambuthiri, R. Geneve, X. Wang, R.T. Fernandez, A. Fulcher, and Y. Sun. Use of Biocontainers in Pot-in-Pot Nursery Production System. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

Mangiafico, S.S. 2013. State of Our Watersheds: Salem River and Oldmans Creek. South Jersey Land and Water Trust Landowner Workshops. Harrisonville, NJ.

Mangiafico, S.S. 2014. Reducing Pesticides in Agricultural Runoff: Update on Local Conservation Practices to Prevent Pesticide Runoff. 2014 Salem County Pesticide Safety Meeting. Woodstown, NJ.

Mangiafico, S.S. 2014. Optimizing Productivity and Protecting the Environment with Cumberland County Soils. 2014 South Jersey Nursery Meeting. Millville, NJ.

Meder, A. and A. Wright. 2014. Phosphorus uptake and flooding tolerance of three native landscape plant species. Oral presentation Southern Region American Society for Horticultural Science Annual Meeting.

Moorman, G.W. What plant pathogens could be in irrigation water? 12/3/2013. 85 logged in. Recorded presentation: https://connect.extension.iastate.edu/p3u8rvp77kf/

Moorman, G.W. How do plant pathogens get into and move in irrigation water? 1/7/2014. 70 logged in. Recorded presentation: https://connect.extension.iastate.edu/p5k9xrwl0vb/

Moorman, G.W. How do we determine irrigation water is clean or contaminated? 2/4/2014. 79 logged in. Recorded presentation: https://connect.extension.iastate.edu/p6g6f7h6dj2/

Nambuthiri, S., R. Geneve, and A. Fulcher. Comparison of Irrigation Scheduling Based on Daily Water Use or Plant Water Demand of Container Grown Woody Plants. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

Niu, G., Y. Sun, and C. Perez. 2014. Growth and physiological responses of selected ornamental plants to salinity stress. Proc. International Salinity Forum. Riverside, CA.

Owen, J.S., Jr. 2014. Water and Nutrient-use Efficiency for Commercial Nursery Crops. "Kicking off the Season" Specialist Day!, Eastern Shore AREC, Painter, VA. March 7. Audience Size: 12. Hours of Instruction: 1.0.

Owen, J.S., Jr. 2014. Utilizing best management practices today to help prepare for water quality regulations of tomorrow. Shenandoah Nursery and Greenhouse Association, Blueridge Community College, Weyers Cave, VA. February 12. Audience Size: 42. Hours of Instruction: 1.0.

Owen, J.S., Jr. 2014. Opportunities utilizing unmanned aerial vehicles in agriculture, Farm Bureau, Suffolk, VA. February 10. Audience Size: 138. Hours of Instruction: 0.5.

Owen, J.S., Jr., J. Latimer, L. Fox. C. Hong 2013. Water management for ornamental crops workshop and in-service training, Virginia Beach, VA. October 29-30. Audience Size: 28. Hours of Instruction: 14.0.

Owen, J.S., Jr. 2013. Properly scheduling irrigation for smarter water use. Water Management for Ornamental Crops Workshop, Virginia Beach, VA. October 29. Audience Size: 28. Hours of Instruction: 1.0.

Owen, J.S., Jr. 2013. Nursery automation: Tree counter demonstration. Nursery Works, Kansas State University, Manhattan, KS. July 18. Audience Size: 65. Hours of Instruction: 1.0. *Invited*

Owen, J.S., Jr. 2013. Increasing nursery efficiency and profits with automation. Nursery Works, Kansas State University, Manhattan, KS. July 17. Audience Size: 65. Hours of Instruction: 1.0. *Invited*

Owen, J.S., Jr. 2013. Understanding nursery production: From propagule to tree. Trees: The Dirty Truth, Virginia Western Community College, Roanoke, VA. May 22. Audience Size: 65. Hours of Instruction: 1.0.

Owen, J.S. Methods for Analysis of Soilless substrate physical and hydraulic properties. HortScience 48:S104. (invited oral presentation In: Horticultural Substrates: Current Research, Development, and Characterization for Improved Crop Production Workshop)

Sluznis, R., A. Wright, and C. LeBleu. 2014. Greywater irrigation of two herbaceous landscape plant species. Oral presentation Southern Region American Society for Horticultural Science Annual Meeting.

Sun, Y. G. Niu, and C. Perez. 2014. 95th Annual Meeting of the Southern Region-ASHS. Dallas, TX. Jan. 31 - Feb. 2, 2014.

Van Iersel, M.W., M. Chappell, and P.A. Thomas. 2014. Precision irrigation in greenhouses and nurseries: improving production and increasing profits. Horticulture Growers Short Course. Lower Mainland Horticulture Improvement Association, Pacific Agriculture Show, Abbotsford, BC.

Van Kampen, K., S.A. White, and S.N. Jeffers. 2014. Exposure of *Canna flaccida* and two *Canna* hybrids to five species of *Phytophthora*. Southern Region-American Society for Horticultural Science, Dallas, TX.

Wang, X., T. Fernandez, G. Bi, A. Fulcher, R. Geneve, G. Niu, S. Verlinden, B. Cregg, M. Ngouajio, T. Kijchavengku, R. Auras, S. Nambuthiri, R. Conneway and Y. Sun. Plant Growth and Water Use in Plastic, Fiber, Keratin and Root Pouch Containers. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

White, S., J.S. Owen, Jr., J. Majsztrik, T. Fernandez, P. Fisher, C. Hall, T. Irani, J. Lea-Cox, J. Newman and L. Oki. 2013. Containment, remediation, and recycling of irrigation water for sustainable ornamental crop production: results of a SCRI planning grant. HortScience 48:S427-S428 (poster).

White, S.A, J.S. Owen, Jr., J.C. Majsztrik, R.T. Fernandez, P. Fisher, C.R. Hall, T. Irani, J.D. Lea-Cox, J.P. Newman, and L.R. Oki. 2014. Grower Priorities for Water Research: Results of a SCRI Planning Grant. Southern Region-American Society for Horticultural Science, Dallas, TX .

White, S.A. 2014. Plant-based remediation systems to manage agricultural contaminants. University of Georgia. Department of Environmental Health Science. Athens, GA.

White, S.A. 2013. Evaluation of Floating Treatment Wetland Plant Nutrient Uptake with Varied Nutrient Loading Rates. Floating Treatment Wetland Expert Panel. Chesapeake Bay Program. Annapolis, MD.

White, S.A. 2013. Nursery BMPs. Horticultural Inspection Society - Southern Chapter, Greenville, SC.

Wilson, S.E., D. Cochran, and A. Fulcher. Container-grown Lavender Affected by Oxygenated Irrigation Water. American Society for Horticultural Science Annual Conference, July 22-26, 2013, Palm Desert, CA.

Yeager, T. 2014. Container plant irrigation considerations. Georgia Green Industry Research Update, Duluth, Georgia.

Yeager, T. 2014. Container plant irrigation management. Central Florida Extension Workshop Optimizing Profits by Controlling Resources, Eustis, Florida.

Yeager, T. 2014. Container plant irrigation considerations. Treasurer Coast Educational Program, Ft. Pierce, Florida.

8. Fund leveraging, specifically, collaborative grants between stations and members.

Behe, B.K., P. Huddleston, R.T. Fernandez, T. Dudek, K. Getter, H. Wollager. 2014. Does the role of branding on plant quality perceptions vary by age cohort? Project GREEEN $35,000.

Bessin, Ric – PD: Co-PI: Winston C. Dunwell, C. Lee, Patricia Lucas, G. Schwab, and L. Murdock. 2013-2016. IPM in Kentucky-Integrated development and delivery. NIFA-Extension Integrated Pest Management Coordination and Support. $86,500 for 3 years starting October 2013.

Collaborative agreement between USDA-ARS Southern Horticultural Laboratory and LSU AgCenter Hammond Research Station. $20,000. 2012 – 2017 (Chen).

Cregg, B.M. 2013. Utility of Plant Growth Regulators in Christmas Tree and Conifer Nursery Production. USDA SCRI Block Grant $69,241.

Cregg, B.M. 2013. Urban tree selection in changing climate. Project GREEEN $70,000.

Cregg, B.M. 2013. Urban tree selection in a changing climate. Michigan Department of Agriculture and Rural Development. $9,518.

Cregg, B.M. 2013. Urban tree selection in a changing climate. Michigan Nursery and landscape Association. $5,000.

Cregg, B.M., B. Crain, P. Nzokou, J. O'Donnell, and B. Bishop. 2013. Environmental control of coning in Fraser fir. Michigan Department of Agriculture and Rural Development. $9,235.

Cregg, B.M. 2013. Environmental control of cone production in Fraser fir Christmas tree plantations. Michigan Christmas Tree Association $4,652.

Fernandez, R.T., B.K. Behe, and T.A. Dudek. 2014. RFID for decision support and logistics management for the container plant value chain. Project GREEEN $39,150.

HRI 2013 project: A new technology for reducing irrigation application and controlling leaching in greenhouse and nursery production. $17,350 (Beasley).

LeBude, A.V., S.A. White, A. Fulcher, J.-H. Chong, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, F. Hale, W. Klingeman, G. Knox, J. Neal, N. Ward, A. Windham, and J. Williams-Woodward. Experiential Nursery IPM Workshop Series to Enhance Grower Adoption and Extension Agent Facilitation. Southern Region IPM Center (Prime--US Dept. of Agriculture (USDA) - National Institute of Food and Agriculture) $39,982.

Mississippi Agricultural and Forestry Experiment Station. Nutrient release and plant nutrient use efficiency using controlled-release and water-soluble fertilizers in container nursery production systems. 2014. E.K. Blythe. $10,000.00. (In support of collaborative projects with University of California, Riverside and with USDA-ARS.

Owen, J.S. and J.S. Fields. 2014. Modeling soilless substrate to maximize plant available water for containerized nursery crop production. Center for Applied Nursery Research. $2,500.

Owen, J.S. and J. Brindley. 2014. Evaluating compost filter socks for agrichemical remediation of runoff in ornamental nurseries as a cost-effective means to effectively treat water. Oregon Department of Agriculture / Oregon Association of Nurseries. $14,991.

Owen, J.S., S. White, B. Krug and B. Whipker. 2014. Managing water and fertilizer: A comprehensive crop production tool for the mobile grower. Horticultural Research Institute. $14,498.

Owen, J.S. and J. Brindley. 2013. Economical and efficient water treatment: Evaluating compost filter socks for agrichemical remediation of runoff in ornamental nurseries. J. Frank Schmidt Family Charitable Foundation. $8,794.

Stewart, R., G. Bi, R. Brumfield, M. Evans, T. Fernandez, A. Fulcher. R. Geneve, D. Kovacic, D. Lindsey, G. Niu, R. Schnelle, and S. Verlinden. 2010-2014. Impact and Social Acceptance of Selected Sustainable Practices in Ornamental Crop Production Systems. USDA Specialty Crops Research Initiative. $1,548,793. http://www.reeis.usda.gov/web/crisprojectpages/222423.html

White, S.A., A. Fulcher, J.-H. Chong, A. LeBude, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, F. Hale, W. Klingeman, G. Knox, J. Neal, N. Ward, A. Windham, and J. Williams-Woodward. 2013. IPM for Shrubs in Southeastern U.S. Nursery Production (Vol. I), a SNIPM Working Group Effort. Southern Region IPM Center – IPM Enhancement Program. $29,983 awarded.

Wright, A., E. Brantley, and J. Howe. Evaluating Pollutant Removal Capabilities of Rain Gardens in Alabama**.** Alabama Agricultural Experiment Station.

Pending:

Bauerle, W.L., J.D. Lea-Cox, R.T. Fernandez, A.G. Ristvey, G.A. Kantor, T.L. Bauerle, M. van Iersel, P. Thomas, M. Chappell, C. Campbell, L. Crawford, C. Lund, E. Lichtenberg, and S. Kim. 2014. Maximizing the value of wireless sensor networks through sensor-based fertilization and scaled up irrigation control. USDA-NIFA-SCRI. $5,999,802 over 4 years (PENDING).

Fernandez, R.T. 2014. Maximizing the value of wireless sensor networks through sensor-based fertilization and scaled up irrigation control. MSU Project GREEEN $160,000 (PENDING and tied to Bauerle et al., SCRI).

Fernandez, R.T., B.K. Behe, J.D. Lea-Cox, and E. Lichtenberg. 2014. RFID for nursery and greenhouse cost of production, logistics, and decision support. Horticulture Research Institute $90,000 over 2 years (PENDING).

Fernandez, R.T., B.M. Cregg, and B.K. Behe. 2014. Clean WateR^3 - Reduce, Remediate, Recycle: Informed Decision-Making to Facilitate Use of Alternative Water Resources and Promote Sustainable Specialty Crop Production. $200,000 (PENDING and tied to White et al., SCRI).

White, S.A., J.S. Owen, B. Behe, B. Cregg, R.T. Fernandez, P. Fisher, C.R. Hall, D. Haver, D. Hitchcock, D.L. Ingram, S. Kumar, A. Lamm, J. Lea-Cox, L.R. Oki, J.L. Parke, A. Ristvey, D. Sample, and L.S. Warner. 2014. Clean WateR^3 - Reduce, Remediate, Recycle: Informed Decision-Making to Facilitate Use of Alternative Water Resources and Promote Sustainable Specialty Crop Production. USDA-NIFA-SCRI. $8,734,103 over 5 years (PENDING).

9. Other relevant accomplishments and activities.

At Auburn University, initiated research to screen additional plant species for tolerance of repeated short-interval flooding like what would be expected in rain gardens. Plants being evaluated include *Illicium floridanum*, *Morella cerifera* (dwarf), *Lobelia cardinalis*, and *Chasmanthium latifolium*. New field research has been initiated to determine the effect of rain garden surface on rain garden uptake and leaching of phosphorus. Rain gardens are planted with turf only, landscape plants with mulch, or mulch only. Landscape plants include a polyculture of *Ilex verticillata*, *Ilex glabra*, *Chasmanthium latifolium,* and *Coreopsis verticillata*. Rain gardens were constructed in two locations to determine the effect of soil type on rain garden efficacy.

Data analysis and manuscript preparation is underway for a study examining the effect of controlled-release fertilizer type on nutrient leaching and nutrient uptake in outdoor-grown Texas privet and greenhouse-grown azalea by Donald J. Merhaut (University of California, Riverside), Eugene K. Blythe (Mississippi State University), and Joseph P. Albano (formerly USDA-ARS). In these studies, we are quantifying nutrients lost through leaching and nutrients taken up by plants during an 11-month growing period using four different types of controlled-release fertilizers and standard nursery production procedures.

Texas A&M University Ph.D. student, Xiaoya Cai will graduate in August 2014, co-advised by Dr. Terri Starman and Dr. Genhua Niu. Xiaoya Cai's dissertation is "The responses of selected garden roses (*Rosa* × *hybrida*) to drought and salt stresses."