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Microirrigation for Sustainable Water Use: Research and Outreach through a Multi-State Collaboration

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ABSTRACT. *This paper summarizes recent developments, ongoing efforts and planned activities of a long-term research and outreach collaboration to advance microirrigation. Participation of research and extension programs from 15 universities and 2 federal agencies from across the United States, including Puerto Rico and the Virgin Islands, makes this a truly regional endeavor. Since its inception in 1972, this USDA-RRF Regional Microirrigation Project group has been very active, with members participating in organizing conferences, writing microirrigation books and contributing many papers at conferences. Integrated applied research and outreach education objectives emphasize practical applications and delivery of information for end-users. Building upon past efforts, including recent work to improve understanding and remove barriers to adoption of microirrigation technologies, the group is developing recommendations and best management practices for successful implementation and sustainable application of microirrigation.*

Keywords. Microirrigation, subsurface drip irrigation, evapotranspiration, irrigation scheduling, irrigation research

INTRODUCTION

Through multi-state, multi-agency and interdisciplinary collaborations under the guidance of the United States Department of Agriculture National Institute of Food and Agriculture (NIFA, formerly the Cooperative State Research, Education, and Extension Service, or “CSREES”), regional project research teams work to solve problems identified as critical public concerns. Regional projects must have clear and focused objectives; direct involvement of multi-state and multi-disciplinary participants; approval through a peer-review process; direction toward achieving specific outcomes and impacts based upon stakeholder identified priorities; and they must be responsive to NIFA goals (USDA-NIFA, 2009).

The USDA-RRF Regional Microirrigation Project group has been working since its initiation in 1972 to address practical issues related to applications of microirrigation technology. Originally formulated as a western U.S. regional project concerning drip and trickle irrigation, W-128, the group has always included a multiple of disciplines such as irrigation engineers, crop and soil scientists, chemists and agricultural economists. The project was known as W-128 until 2004, when administrative requirements necessitated a name change to W-1128, which ran from October 2004 through September 2009. The goal from the original project inception has been to advance microirrigation as a potentially highly efficient irrigation technology by addressing technical concerns (system design and maintenance), application and management concerns (irrigation scheduling, chemigation, and crop-specific issues); and education and technical support concerns (information accessibility and outreach education). Applied research and targeted extension efforts conducted by participating Land Grant University and USDA-ARS programs are addressing specific identified needs.

A major project accomplishment during the early years was publication of the original reference book, *Trickle Irrigation for Crop Production: Design, Operation, and Management* (Nakayama and Bucks, 1986). Several current project members were involved in the completion of this book’s revision, *Microirrigation for Crop Production* (Lamm, et al., 2007). *Microirrigation for Crop Production* summarizes the advancements made in design, operation, and management of microirrigation systems since *Trickle Irrigation for Crop Production* was published in 1986. Suitable as a comprehensive reference for researchers and practitioners or as a textbook for irrigation courses, *Microirrigation for Crop Production*, addresses microirrigation theory and design principles (including soil water concepts, irrigation scheduling, salinity management, general design principles applicable to all microirrigation systems, and economics of microirrigation); operation and maintenance principles (including system automation, application of chemicals, application of biological materials, field performance and evaluation, and system maintenance); and system type and management principles (including design, installation and management of surface drip, subsurface drip, bubbler and microsprinkler systems). The project participants have also been heavily involved in the International Microirrigation Congresses, particularly those held in the United States in 1985 and 1995. Numerous other technical manuals, Extension fact sheets, short courses, demonstrations, journal articles, field days, web sites and other products and programs have been developed to ensure that results from the research efforts are readily available for use by the public.

Building upon these accomplishments, the microirrigation research group has initiated the project for the next 5-year cycle, W-2128, "Microirrigation for Sustainable Water Use," to address newly identified and lingering technical and practice issues related to applications of microirrigation technology. Objectives of this work will include: 1) comparing irrigation scheduling technologies and developing grower-appropriate scheduling products; 2) developing design, management and maintenance recommendations; 3) developing best management practices for application of agricultural chemicals; and 4) evaluating use of non-potable water through microirrigation.

Comparing irrigation scheduling technologies and developing grower-appropriate scheduling products

Although microirrigation is widely considered to be the most efficient irrigation method, additional water savings are achievable through refinements in microirrigation management. Improvements in irrigation scheduling (timing and amounts) can result in significant water savings, but water savings must be balanced against the economic necessity to maintain or improve crop yield and quality.

Several microirrigation scheduling approaches can be utilized for any particular crop and environment, and many practical factors, including irrigation system capabilities, should be considered. Methods used for on-farm irrigation scheduling are often based upon evapotranspiration (ET) estimates from locally available weather data; soil moisture management; and/or plant-based indicators. Evapotranspiration estimates apply understanding of overall plant water requirements and atmospheric water demand through a mass balance approach (Howell and Meron, 2007). In this approach, reference ET for a standard canopy is calculated from weather data and then multiplied by one or more crop coefficients (Kc) to estimate the water requirement for a particular crop. This approach is well established, yet continued research is needed to advance understanding of underlying factors and applicability of the method to additional crops and production conditions, particularly practices involving deficit irrigation, as well as to improve interpretation and application of ET information to microirrigation scheduling.

Soil moisture management based irrigation scheduling involves direct or indirect measurement of soil water, as well as an understanding of soil moisture storage capacity and irrigation system capacity. Research and informational materials are needed to support proficiency in selection and placement of soil moisture sensors and correct interpretation of soil sensor data. Plant indicator based irrigation scheduling may use direct or indirect measurements of plant water status to determine when water should be applied. Research and informational materials are needed to evaluate and promote appropriate plant water assessment technologies, and proficiency in applying them and in interpreting the information they provide.

In addition to improvements in assessing crop water demand for irrigation scheduling, information is needed from a range of crops and environments to determine the effects of different irrigation scheduling approaches on yield and product quality. Particularly in production systems where water resources are limiting, understanding of crop response to managed deficit irrigation strategies will be essential to optimizing limited irrigation water resources. While it is generally assumed that irrigation should fully meet ET-based crop water demand to maximize yield, economic and/or horticultural benefits of managed deficit irrigation (regulated deficit irrigation, RDI) have been demonstrated for some crops (Boland et al., 1993; Shackel et al., 2000). Research conducted under this project will investigate crop response to these regulated deficit irrigation and other strategies, intended to utilize more fully the flexibility and precision in water application afforded by well-planned microirrigation systems.

Soil moisture and plant indicator based irrigation scheduling methods using sensors and controls to initiate and terminate irrigation can also be readily applied with microirrigation, taking advantage of its high degree of automation and application uniformity. Major advances in sensor technology, including improved reliability and communication capabilities, have improved potential for utility of these tools in microirrigation. Sensor calibration and comparison, and evaluation of sensor-based controls and strategies will be conducted.

Developing design, management and maintenance recommendations

Another key to sustainable water use through microirrigation is the improvement of crop yields through improved microirrigation management and increased usage and reliability of microirrigation systems through better system design and maintenance. Interest in microirrigation technology is increasing in many areas, and adoption of microirrigation often involves comparison with other irrigation methods commonly used within a region. These system comparisons generally consider crop yield and economics, water use and conservation, and environmental issues (chemical leaching and drainage). Although the pertinent factors may differ with region, crop, soil, and climate constraints, proper management strategies for any irrigation method, particularly those methods with which producers are less familiar, such as microirrigation, must be developed or adapted for local conditions. This project aims to establish baseline information about alternative irrigation systems for various crop production systems and regions. Results will be shared among participants, and will be used to develop common guidelines for optimizing performance of the various irrigation systems, taking into account economic and environmental considerations.

Recent surveys conducted by the USDA-RRF Microirrigation Project group have indicated a need for continued and expanded research and extension efforts to help producers manage for optimal crop production, protect the environment, and maximize system life through proper maintenance. Emitter clogging remains the primary cause of microirrigation system failure, so improved emitter maintenance will be a key factor in having sustainable microirrigation systems. The project group will create a widely applicable web-based tool, compiling recommendations based upon diverse research efforts, to assist producers in assessing and addressing clogging hazards.

Developing best management practices for application of agricultural chemicals

Conjunctive use of agricultural chemicals with microirrigation can help achieve sustainable water use through greater crop yields and improved crop quality, and through protection of surface water and groundwater resources from agrochemical pollution in runoff and leachates. Agricultural chemicals, whether applied through the irrigation system or through other means, are used for a wide range of purposes. In maintenance of microirrigation systems, acids, chlorine, herbicides and other products are sometimes used to prevent emitter clogging due to chemical precipitates, biological growths, or root intrusion. Precise application of fertilizers and/or pesticides through the microirrigation system is often cited as an advantage of microirrigation (Ayars et al., 2007). Effective use of fertilizers or other agricultural chemicals applied through other means (ground rig or aerial application, for instance) may require extra considerations in microirrigated conditions. Potential obstacles to chemical applications with microirrigation include limitations to applicability of soil injected chemicals and limitations of agricultural chemical labeling for microirrigation application.

Microirrigation chemigation is based on the principles of precision farming where system inputs are qualitatively and quantitatively matched to the needs of the crop. Subsurface drip (SDI) and surface drip systems (DI) can be used for the injection of systemic pesticides and some biocontrol agents while surface microsprinklers may be used to apply biocontrol agents over larger areas and on plant canopies. Use of SDI systems for systemic insecticide or fungicide application has the advantage of compatibility with integrated pest management principles. However, the use of pesticides through microirrigation systems is much less advanced as compared to nutrient fertigation. Current research programs conducted by participants of this project are beginning to address fertigation and chemigation through microirrigation (particularly through subsurface drip irrigation), yet results are generally preliminary or otherwise not sufficiently interpreted for development of best management practices. Research and extension/outreach associated with this project will advance knowledge necessary to develop, evaluate and recommend best management practices.

Evaluating use of non-potable water through microirrigation

Sustainability of water use can be augmented through microirrigation of non-potable waters. Use of non-potable waters as an alternative water resource is becoming more common as limited high quality water sources are allocated to higher priority municipal and industrial users. Irrigators are increasingly turning to lower quality water sources, including saline surface water and groundwater and reclaimed water from wastewater treatment plants, animal agriculture operations, and other effluents and produced waters.

Extending the concept of sustainability to life of the system, microirrigation of non-potable waters requires careful selection of system components and appropriate management of the overall microirrigation system. Use of non-potable water can reduce treatment costs by reducing the level of treatment required for environmentally appropriate disposal. In fact, some non-potable waters contain nutrients that can be beneficially used to meet crop requirements. Yet there are often other concerns, including salts and potentially excessive levels of some constituents that require special management to avoid adverse impacts on soil quality and crop productivity. Nutrients and other constituents in these waters present additional challenges to operation and maintenance of microirrigation systems. Since non-potable waters can come from processing facilities, homes, municipal treatment plants, rural municipal lagoons, and livestock lagoons, the characteristics of these water sources can vary widely in terms of chemistry, biological activity, and physical condition. These characteristics influence filtration requirements, treatment practices, emitter performance, soil conditions, and crop and landscape performance. Through this project, research will be translated into better recommendations for system hardware selection, improved maintenance procedures and guidelines for non-potable water utilization for different geographic locations, environmental conditions, soil characteristics, and water sources.

SUMMARY

Sustainability and conservation of limited high quality water resources necessitate high irrigation application efficiency and overall water use efficiency. Preserving and protecting the quality of water resources includes safely using lower quality waters for irrigation and preserving high quality water for drinking and other uses. To justify investment in and adoption of microirrigation technology, economic sustainability must be addressed through maintaining crop yield and quality and by ensuring longevity of microirrigation systems.

Applied research programs at multiple locations will evaluate microirrigation scheduling strategies and products and develop recommendations for applicable tools according to crop, location and farm-level capabilities. Researchers will build upon previous research progress to address irrigation system design, management and maintenance concerns related to microirrigation system performance and longevity. Since microirrigation technology is well-suited to precise application of agricultural chemicals, team members will investigate products and protocols and develop best management practices for application of agricultural chemicals with microirrigation. Through studies using reclaimed and other non-potable water sources, researchers will assess the advantages, limitations and necessary precautions associated with beneficial use of lower quality waters. Resulting recommendations will be made easily accessible through user-friendly online trouble-shooting tools.

The aim of the project team is to promote adoption of microirrigation by developing practical solutions to concerns related to application of the technology. To maximize the impact of the research, educational materials and opportunities will be emphasized throughout the project. Research results, recommendations and best management practices information will be made available to the public through audience targeted meetings, workshops, field days, print and electronic media (including public web sites).

The project participants from various universities, USDA-ARS and USDA-NRCS locations have a long history of working together cooperatively on the topic of microirrigation. Progress has been steady over the years since 1973, and current project members are excited about the potential for further expansion of microirrigation.

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Organization-Location	Participating Scientists	Expertise
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University of Arizona	Muluneh Yitayew	Agricultural Engineering
University of California-Davis	Patrick Brown Jan W. Hopmans Larry Schwankl Kenneth A. Shackel	Pomology Vadose Zone Hydrology Irrigation Engineering Pomology
Colorado State University	Mike Bartolo	Plant Physiology – Vegetable Crops
University of Florida	Lawrence Parsons Bielinski M Santos Craig D Stanley	Horticulture Horticulture Soil and Water Management
University of Hawaii	Ali Fares	Watershed Hydrology and Tropical Soils
University of Idaho	Howard Neibling	Irrigation and Water Management Engineering
Iowa State University	Amy Kaleita	Agricultural Engineering
Kansas State University	Mahbub Alam Freddie Lamm Dan Rogers	Irrigation Engineering Irrigation Engineering Agricultural Engineering
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