Adjustable-Rate Fertigation for Site-Specific Management to Improve Fertilizer Use Efficiency

Project Leader
Michael Delwiche, Professor and Chair
Dept. of Biological & Agricultural Engineering
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-7023 phone, (530) 752-2640 FAX, mjdelwiche@ucdavis.edu

Cooperators
Robert Coates, Development Engineer
Dept. of Biological & Agricultural Engineering
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-6731 phone, (530) 752-2640 FAX, rwcoates@ucdavis.edu

Richard Evans, Cooperative Extension Specialist
Dept. of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-6617 phone, (530) 752-1819 FAX, ryevans@ucdavis.edu

Loren Oki, Cooperative Extension Specialist
Dept. of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-4135 phone, (530) 754-4883 FAX, lroki@ucdavis.edu

Lawrence Schwankl, Cooperative Extension Specialist
Dept. of Land, Air, and Water Resources
UC Kearney Agricultural Center
9240 S. Riverbend Avenue
Parlier, CA 93648
(559) 646-6569 phone, (559) 646-6593 FAX, schwankl@uckac.edu

Location
UC Davis and surrounding area

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Year 2: $38,161

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Year 1: $25,675
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Principal Investigator	**Date**	**Department Chair**	**Date**

B. Executive Summary

Problem Uniform application of fertilizer within large irrigation zones of commercial nurseries will over-fertilize some plants since the fertilizer requirement is based on plants with the greatest need. Similar problems exist with many other specialty crops. By decreasing the size of the irrigation zones and separating plants based on water and nutrient needs, site-specific fertigation can limit fertilizer waste and loss to the environment. However, there generally is not enough time to fertigate a large number of zones independently. The result is that the operation of several fertigation zones would have to overlap. The task of delivering different fertilizer rates to simultaneously operating zones is quite complex.

In a current project supported through the Specialty Crops Block Grant (SCBG) program of the CDFA, we are testing fertigation at different rates by adjusting the duration of **fixed-rate** fertilizer injection for each zone using a wireless sensor network. We think that more effective control of fertilizer application could be achieved by automatic adjustment of the injection rate for each zone, thus eliminating the need for manual adjustment by the grower. In this FREP project, we propose to develop simple technology for **adjustable-rate** fertilizer injection, which will then be integrated with the wireless control network of the SCBG project. Leveraging these projects will help us accomplish the overall goal of improving fertilizer use efficiency in container nurseries and have immediate application to other specialty crops as well.

Objectives and Approach

Objective 1. Develop a simple fertilizer injection system to give adjustable-rate fertigation. We will first review commercial fertigation technologies to determine how they can be modified to provide inexpensive, variable-rate injection for nurseries or other crops. We will select a simple injection technology that can be used off-the-shelf or with minor modification to develop a variable-rate injector that allows site-specific fertigation in nurseries while maintaining good application uniformity within each zone. Depending on the type of injector selected, a variety of control mechanisms may be used, including flow-control valves, motor speed controllers, water flow meters, and electrical conductivity meters.

Objective 2. Integrate the injector with a wireless irrigation control system to give automated, adjustable-rate fertigation for nurseries. We will design hardware and software to integrate the injector from objective 1 with the wireless system from our SCBG project. We are working with a commercial vendor of wireless sensor networks for agriculture and hope that the work completed in this project will be commercialized and become available to growers. The variable-rate injector with wireless network control will be tested in two commercial nurseries and experiments will be conducted to apply different rates of fertilizer to different fertigation zones. We will measure the water and fertilizer delivered to each zone, as well as fertilizer runoff.

Target Audience The ability to dynamically control water and fertilizer delivery to individual zones in a nursery will help growers improve the efficiency of fertilizer use and reduce the risk of runoff. In addition to nurseries, the results of this work will have application in agricultural crops such as orchards, vineyards, and landscapes. We are currently collaborating with a manufacturer of wireless sensor equipment to implement irrigation control in their product and will be testing the system in two commercial nurseries near UC Davis.

C. Justification

Uniform application of fertilizer within large irrigation zones of commercial nurseries will over-fertilize some plants since the fertilizer requirement is based on those with the greatest need. Similar problems exist with many other specialty crops. By decreasing the size of the irrigation/fertigation zones and separating plants based on water and nutrient needs, site-specific fertigation can limit fertilizer waste and loss to the environment. Installation and management of small, site-specific zones is greatly simplified by using wireless sensing and control technology.

We recently started a research project supported through the Specialty Crops Block Grant (SCBG) program of the CDFA to test wireless control technology for site-specific water and fertilizer application in container nurseries. In the SCBG project we will use fixed-rate injection and adjust the time of fertigation for each zone. More effective control of fertilizer application could be achieved by automatic adjustment of the injection rate for each zone, thus eliminating the need for manual adjustment by the grower.

In the work proposed here to FREP, we will leverage the SCBG project by developing simple technology to allow adjustable-rate fertilizer injection, which will then be integrated with the wireless control network. **Our overall goal is to improve fertilizer use efficiency in container nurseries through site-specific fertigation.** This goal is consistent with several of the current CDFA/FREP program goals:

- *Fertilization practices — develop fertilization practices to improve crop production, fertilizer use efficiency or environmental impact.*
- *Site-specific fertilizer technologies — demonstrate and quantify applications for site-specific crop management technologies and best management practices related to precision agriculture.*
- *On-farm demonstrations of proven practices and technologies within FREP goals to encourage their adoption in California…*

To maximize the benefit of a site-specific system, it is desirable to increase the number of fertigation zones such that each zone delivers the correct amount of fertilizer to match crop demand. However, there might not be enough time available to irrigate or fertigate a large number of zones independently. Precision fertigation is a complex control problem for installations with long drip lines, many hydrozones, and a wide variety of crop needs. There may also be resource limitations such as limited hours of water/pump availability and energy costs associated with running pumps longer, technical limitations such as minimum flow rate or peak efficiency for pumps, or biological criteria such as the best time of day to apply water and fertilizer. The result is that the operation of several fertigation zones would have to overlap. The task of delivering different fertilizer rates to simultaneously-operating zones is not trivial. Zones could be fertigated at different rates by using different durations of fixed-rate fertilizer injection for each zone and this will be tested in our SCBGP project. The ability to automatically vary the rate of injection will provide greater flexibility to deliver fertilizer at different rates to each zone.

In the review by FREP of our project suggestion, we were asked "why such technology should not more properly be developed by a private company." The technology to deliver different fertigation rates is not new, but requires costly and dedicated injection stations. Growers have become more interested in wireless networks to monitor and control their irrigation systems and

integration of fertigation control with these systems will not likely be accomplished by existing fertigation vendors. We are currently working with a key manufacturer of wireless hardware (Crossbow/MEMSIC) for agricultural markets. Unlike private companies that manufacture just fertigation systems, we have the unique opportunity to bridge the gap between the wireless manufacturer and the agricultural application. The sensor network could also provide remote sensor feedback during fertigation to ensure fertilizer is reaching each zone with the proper concentration and duration.

Previous Research

In our previous FREP project we developed and deployed a wireless valve controller network for site-specific irrigation and fertigation (Coates and Delwiche, 2009). Wireless nodes eliminate the need for wired valves and sensors. This allows simpler installation and management of small hydrozones. The network used mesh networking to extend the effective communication range without using high power radios (Figure 1). Solar energy was collected with a miniature panel to operate each controller node without yearly battery replacement. Nodes opened or closed a latching valve to control water and fertilizer flow and send sensor data back to a central field controller. Electrical conductivity (EC) probes were used to monitor fertilizer concentration and location within fertigation lines (Figure 2). We tested an EC probe in UAN-32 and 20-20-20 (NPK) fertilizer solutions with 0 to 2000 μS/cm conductivities. Different quantities of 20-20-20 fertilizer were applied to two fertigation zones operating simultaneously (Figure 3). We also developed strategies that can be implemented for site-specific fertigation in a variety of applications (Delwiche et al., 2009). The amount of fertilizer delivered to each zone can be controlled by varying the durations of irrigation and fertilizer injection, but consideration must be given to the number of fertigation zones and application uniformity within each zone. EC sensors were useful for detection of the fertilizer head and tail in long fertigation lines and for quantifying the amount of fertilizer being applied in each zone. **Addition of a variable-rate injector and sensors to the wireless network (as presented in this proposal) would allow more precise control of fertigation with this system.**

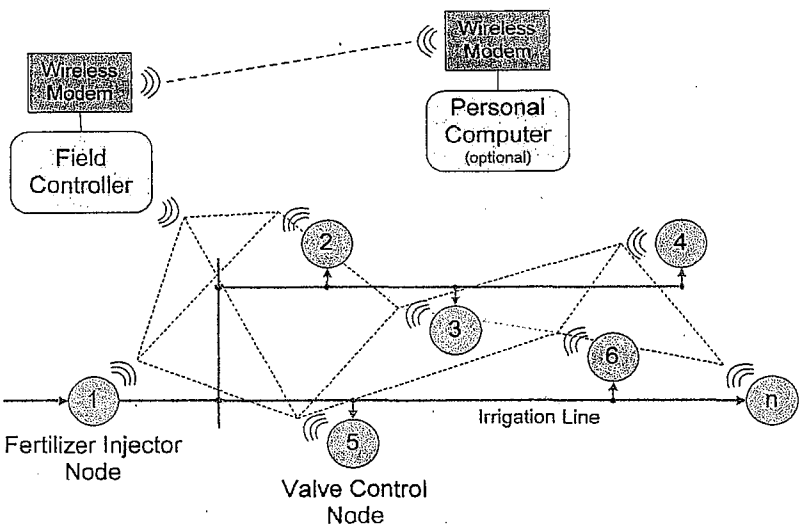

Figure 1. Layout of wireless network for valve control.

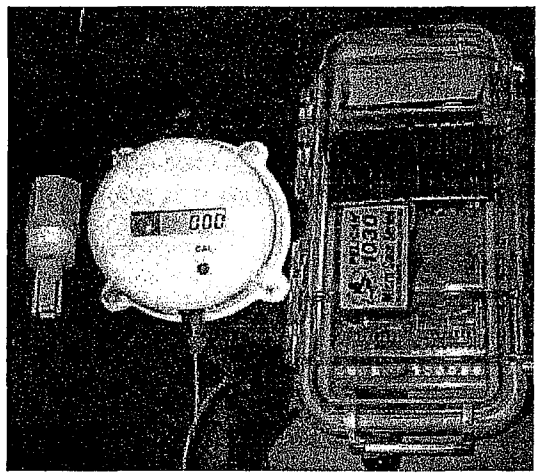

Figure 2. Electrical conductivity sensor connected to wireless valve.

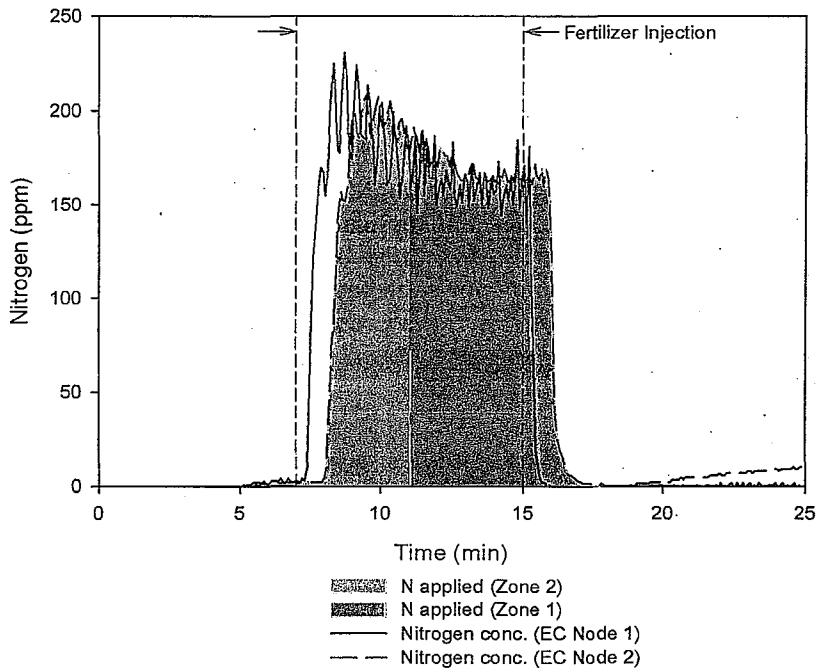

Figure 3. Nitrogen concentration over time for two simultaneously fertigated zones where zone 2 applied twice as much fertilizer as zone 1.

D. Objectives

1. Develop a simple fertilizer injection system to give adjustable-rate fertigation.
2. Integrate the injector with the wireless irrigation control system to give automated, adjustable-rate fertigation for nurseries.

E. Work Plan and Methods

Objective 1. Develop a simple fertilizer injection system to give adjustable-rate fertigation.

Task 1.1. Review existing injection technologies. (year 1)

There are many commercial fertilizer injection systems available to growers today and we will first do a comprehensive review of fertigation technologies to determine how they can be modified to provide inexpensive, variable-rate injection for nurseries or other crops. Injectors range from simple passive injectors to complex active injection stations with multiple fertilizer mixtures and wired control valves. We will select a simple injection technology that can be used off-the-shelf or with minor modification to provide injection-rate adjustment by electronic control.

Task 1.2. Develop simple variable-rate injector. (years 1-2)

We will then develop a variable-rate injector that can be used in nurseries to maintain good application uniformity within each zone during site-specific fertigation. Two examples of injector types we will consider are Venturi injectors and positive displacement pumps. Venturi injectors are simple, inexpensive, and require no electricity, but yield poor injection-rate uniformity and have a relatively fixed injection ratio. We propose to insert valves in the injector suction tubes and use feedback from flow meters or electrical conductivity (EC) probes to control and monitor the injection rate for each zone (Figure 4). Positive displacement pumps are water-driven or powered by electric motors and provide a more constant injection rate than Venturi systems, but are more complicated and expensive. Pump injection rate would be controlled using flow-control valves or motor speed controllers and would also use sensor feedback from flow meters or EC probes.

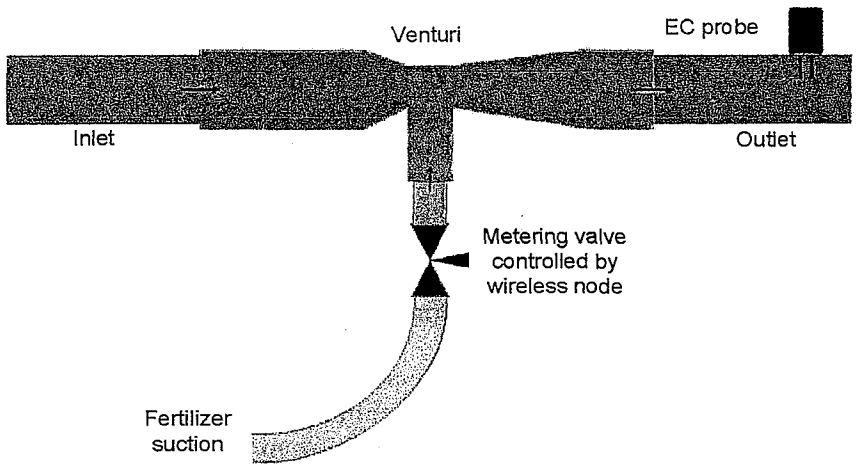

Figure 4. Diagram of proposed variable-rate injector using Venturi, valve, and electrical conductivity probe.

Objective 2. ***Integrate the injector with the wireless irrigation control system to give automated, adjustable-rate fertigation for nurseries.***

Task 2.1. Integrate variable-rate injector with wireless control system. (years 1-2)

In our previous work with FREP we began development of a wireless network for irrigation and fertigation control and explored site-specific delivery of water and fertilizer for simultaneously-operating fertigation zones. In this new project we will design hardware and software to integrate the injector from objective 1 with the wireless system from our SCBG project. We are working with a commercial vendor of wireless sensor networks for agriculture. They have an interest in expanding the capabilities of their product and it is possible that the work completed in this product will be commercialized. We feel that this is an important aspect of our outreach since it allows the ideas to move beyond academia to company-supported products that can be used by growers. The wireless vendor will likely provide some technical support to us in developing the hardware interface between the injector system and wireless nodes as well as software to allow automated fertigation control through the network.

Task 2.2. Test site-specific fertigation with variable-rate injector. (year 2)
The variable-rate injector with wireless network control will be tested in the two commercial nurseries we are cooperating with on the SCBG project (Village Nurseries in Sacramento and Four Winds Growers in Winters). We will include both drip emitters and overhead sprinklers in our design, and consider issues of pressure drop across injectors and the fertilizer application uniformity within each zone. Experiments will be conducted to apply different rates of fertilizer to different fertigation zones and measure the water and fertilizer delivered to each zone, as well as fertilizer runoff. Applied fertilizer through emitters in each zone will be measured using EC sensors and water/soil analysis. Fertilizer runoff will be measured with discharge flumes and EC sensors.

F. Project Management, Evaluation, and Outreach

This project will be directed by Dr. Delwiche, whose area of research is electronic instrumentation and sensor development for agricultural systems. The work will be done by a graduate student researcher under the direction of Dr. Delwiche and the day-to-day guidance of Mr. Robert Coates. Mr. Coates is an associate development engineer and has been responsible for prior development of wireless irrigation and fertigation control systems. Dr. Oki is an extension specialist with experience in landscape horticulture. Dr. Evans is an extension specialist with experience in greenhouse and nursery horticulture. Dr. Schwankl is an extension specialist with extensive irrigation design and testing experience. Dr. Delwiche, Mr. Coates, and the graduate researcher will meet weekly to discuss the system design and testing, and confer frequently with the appropriate project cooperators for each task.

Progress will be evaluated by successful completion of the tasks listed in section E. After the first year, we expect to have completed a review of commercial injectors and have mostly finished development of a simple variable-rate injector system. We will begin integration of the injector system and wireless system in the first year and complete it in the second year. Testing of the injector and wireless network will occur in two nurseries during the second and final year. Industry adoption of precision fertigation will require commercial development and distribution of the hardware and software components. To this end, we intend to work with wireless network vendors and the UC Office of Technology Transfer to facilitate development of a commercial system available to growers. Wireless valve control developments we completed in a previous FREP project are currently being integrated with a commercial product for wireless sensors in agriculture.

Specific outreach activities will include direct interaction with the nursery growers where these systems will be tested, and presentation of the results and demonstration of the hardware at grower meetings (e.g., Nickels Field Day, California Association of Nurseries and Garden Centers) and FREP conferences. Throughout the development process we will consult with experts in irrigation and wireless technology. Results from fertigation trials and wireless control will be published in technical journals to preserve the technical record.

Timeline

Objective	Year 1				Year 2			
	W	Sp	S	F	W	Sp	S	F
1. Develop adjustable-rate injector								
1.1. Review existing technologies								
1.2. Develop simple injector system								
2. Integrate with wireless and test								
2.1. Integrate with wireless control network								
2.2. Test site-specific fertigation								

References

Coates, R.W. and M.J. Delwiche. 2009. Wireless Mesh Network for Irrigation Control and Sensing. *Transactions of the ASABE* 52(3): 971-981.

Delwiche, M.J., R.W. Coates, P.H. Brown, B.R. Hanson, R.Y. Evans, and L.R. Oki. 2009. Precision Delivery of Fertilizer to Satisfy Crop Demand. Pages 39-45 in *Proceedings of the Seventeenth Annual Fertilizer Research and Education Program*, California Department of Food and Agriculture, Sacramento, California.