Agricultural Research Information System
Report of Progress (AD-421)

Project Number: 5306-21000-001-01S      FY: 2004
Title: Develop Mathematical Models to Manage Irrigation, Fertilization, Run-Off in Greenhouses

Final Report?            No
Terminate in Two Months? No

1. What major problem or issue is being resolved and how are you resolving it?

Management of irrigation and fertilization are two of the most important aspects of greenhouse crop production. Despite the fact that significant regulatory pressures are now in place to reduce pollution from nurseries, growers still use luxuriant amounts of water and fertilizer so as to maximize productivity. Unfortunately, this also generates a large amount of nutrient-laden effluent which is typically discarded because it contains unknown amounts of the various fertilizer nutrients which may be polluting the environment. Many regional water quality districts and state governments are now restricting this discharge. The problem faced by the growers is that they do not have the needed information to minimize run-off without reducing crop productivity.

Our approach to the problem is to develop tools that can be used to simulate greenhouse production in relation to irrigation and fertilization strategy. In greenhouse production many crops can be produced hydroponically where recirculation is feasible. The problem is that the chemical constituents of the recirculating irrigation solution need to be adjusted dynamically so as to provide optimal nutrition for the plants at all times. Since there are no sensors and control systems that allow for dynamic control in existing fertilizer injection systems, we seek to develop models that allow calculation of the composition of the captured run-off, so that it can be augmented with the needed fertilizers to maintain optimal irrigation solution. This requires a number of submodels that will combine to form the desired simulation model.

The problem has become critical across the nation. Many states have mandated complete recirculation without realizing that this is impossible for growers. The growers are now in need of science-based information for adjusting their fertilizer injection systems.

2. List the milestones (indicators of progress) from your Project Plan.

The following list identifies the major elements (milestones) of the project:

A. Development of model(s) for nutrient uptake under greenhouse hydroponic flower production
   A.1 - Data collection
   A.2 - Model conceptualization and calibration
   A.3 - Model validation and analysis
B. Development of submodel(s) to describe the root zone oxygen effect on nutrient uptake and greenhouse rose crop production
   B.1 - data collection
   B.2 - model conceptualization
   B.3 - model calibration
   B.4 - model validation and analysis
C. Development of a simulation model/software
   C.1 - Simulation system for use in decision support
   C.2 - Implementation of greenhouse cut-flower rose model
   C.3 - Simulation analysis testing system for nutrient/water use/uptake parameters
   C.4 - Application of simulation system to test suitability for use in decision support
D. Development of specific recommendations regarding fertilizer and irrigation management

3. Milestones:

3A. List the milestones (from the list in Q#2) that were scheduled to be addressed in FY04. How many milestones did you fully or substantially meet in FY04 and indicate which ones were not fully or substantially met, briefly explain why not, and your plans to do so.

Significant progress has been made over the extent years of this project in areas A and B. However, none of the areas are fully completed as yet.

With regard to area A, significant progress has been made with A.1, but at least one more year of data collection is needed. Last year, in collaboration with Dr Silberbush (Israel) we made significant progress towards modeling N and K uptake in hydroponically grown roses. As we started to work in area A.3 we found that the model was not able to represent many conditions typically found in commercial production and it was decided to collect more data for N and K as well as for other primary and secondary nutrients. We also found that we need to explicitly include dynamic storage pools for each nutrient in the model so as to be able to handle luxuriant nutrient uptake (which appears to be happening in rose for some nutrients). In collaboration with a research assistant (Neil Mattson), we recently obtained enough data to restart the model development process (A.2). The data collected are of high quality and will result in a publication. However, the development of the model is significantly behind schedule because I have been unable to hire a researcher to do the modeling work. Mr Mattson has some model- and software-development experience, so that I am confident that we will be able to make significant progress this coming year.

In area B, we have made significant progress in area B.1, but this also has not yet resulted in a mathematical model. While we have enough information to identify the order of magnitude of some of the needed rate constants, we have not progressed to the stage where explicit equations have been formulated. A graduate student with some modeling experience (Mr Robert Flannery) is expected to work on this part of the project next year. Although we have not made as much progress as desired, we have been successful at alerting the greenhouse hydroponics industry as to the fact that oxygen concentration appears to be one of the most significant and rapidly-changing variables in hydroponic production systems.
In areas A, B and C, we are also working with an Israeli scientist (Dr. Micheal Raviv) and Prof David Burger (UCDavis) to develop a model for root respiration in relation to temperature, moisture tension, and oxygen concentration. Data collection has progressed, and some initial data yielded unexpected results that suggest that our conceptual model needs to be revised. In particular we had focused on modeling the potential growth of plants by measuring the calorimetric response of roots as a driving variable. However, our research suggests that the roots are not drivers for this; rather they respond to a “growth potential” that is dictated by the above-ground part of the plant. This was the result of work carried out this year on rose in collaboration with a Korean scientist (Dr. Byoung R. Jeoung) and seems to be corroborated by the data from our Israeli collaboration. This is an extremely important concept and may well affect the entire conceptual model for uptake of a wide range of nutrients. Thus we must repeat this part of the research and possibly re-conceptualize our model for nutrient uptake under greenhouse hydroponic conditions. A research scientist will be hired to carry out this experiment.

In area C, we continue to make slow progress with the existing model elements and their development into production management tools for areas that were previously developed. The bottleneck for development of models is that I have not been able to hire a scientist to work in this area. With regard to area C.1, we recently completed version 1.0 of a cut-flower Rose Timing Tool that assists growers with timing crops for holiday sales and in managing crop production. This is a simulation system that simulates the timing of various stages of development of rose crops. We have not yet determined whether we will use the same tool as a framework for the proposed software for fertilizer and irrigation decisions or whether a similar, but separate tool should be constructed. In this area I am also working in collaboration with a Korean scientist (Dr Wan Soon Kim). As part of this collaboration I am working with Dr Mi Young Roh (also from Korea) on developing a model and prototype of a software tool for hydroponically-grown bell-pepper.

The last area (D) is very much dependent on completion of the various submodels and their integration. The format of the recommendations will be a software tool that hopefully can respond to a wide array of conditions that may arise in commercial greenhouse crop production systems. At the same time we have been able to already make some recommendations for irrigation frequency in commercial production systems so as to assure adequate oxygen concentrations in root zones at all times.

While significant progress has been made in all areas, the project has not kept pace with the ambitions goals set out initially. I have not been able to hire a scientist with mathematical modeling experience to work on the modeling portion of the project (and the funds for this have not been expended). I intend to continue to search for a scientists that can integrate the mathematical models and work with me on software development.

3B. List the milestones (from the list in Q#2) that you expect to address over the next 3 years (FY05, 06&07). What do you expect to accomplish, year by year, over the next 3 years under each milestone?
There is significant additional progress expected with regard to all milestones over the next three years. The listed milestones (above) still represent our goals and we anticipate reaching many of these milestones over the next three years.

4A. What were the most significant accomplishments during FY2004 (one per Research 00D project)? (MUST BE ANSWERED IN 4-SENTENCE FORMAT BELOW)

(This question must be answered in the four sentence format below, one sentence per question!!!)

Sentence 1. Why did you do the research?
Sentence 2. What was done and where? (Include the name of your lab and collaborators/cooperators, if any)
Sentence 3. What were your specific accomplishments in the reporting period (FY2004)?
Sentence 4. What was (or could be) its impact, outcome, etc.?

This project is being carried out to develop mathematical models about nutrient uptake, as well as software tools based these that grower can use in making fertilizer and irrigation decisions. In collaboration with Dr Micheal Raviv, Mr Neil Mattson, Mr Robby Flannery, Dr Wan Soon Kim, and Dr Mi Young Roh we have collected extensive data on nutrient uptake of rose and pepper plants in hydroponic production here Ornamental Crop Simulation Lab in the Environmental Horticulture Department at the University of California, Davis. This resulted in important findings regarding the dynamics of oxygen concentration in the root zone, the pattern of nutrient uptake, and its relationship with plant growth and productivity. The most significant impact this past year has been in changing growers’ attitude towards oxygen management in hydroponics production.

4B. Other significant accomplishments?

4C. Significant activities that support special target populations?

This work supports US greenhouse cut-flower growers who are being target by USDA for benefits through the Floriculture Research Initiative.

5. Describe you major accomplishments over the life of the project, including their predicted or actual impact?

Over the life of the project we have made significant progress in developing information on the quantitative relationships between driving variables (Root zone temperature, oxygen concentration, nutrient concentrations) and various physiological rates (nutrient uptake, water-use, plant growth) and crop productivity.

6. What technologies have been transferred and to whom? When is technology likely to become available to the end user (industry, farmer, other scientists)? What are the constraints, if known, to the adoption durability of the technology?
The technology transfer process for the research results from the fertilization and irrigation research is currently limited to grower presentations. These are currently being made a rate of 2-3 per year. Ultimately we envision developing a software tool that will represent the primary extension vehicle and will allow growers to make dynamic fertilizer and irrigation decisions for hydroponically-grown crops. This tool is likely to become available for testing by growers in 2006. Collaborative projects with others will be developed in the future to address other hydroponic crops, once we have a first version in place that can demonstrate to other scientists the potential of such tools.

7. List your most important publications and presentations, and articles written about your work.
   (NOTE: this does not replace your review publications which are listed below.)
   (none since last year)

8. Enter peer-reviewed publications and major presentations (abstracts) in this section-ONLY THOSE WITH APPROVED ARS-115 APPROVAL IN ARIS and ONLY those not reported in a previous annual report.
   (none since last year)