H o r t i c u l t u r a l E n g i n e e r i n g

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Website: http://aesop.rutgers.edu/~horteng

Dr. David Fleisher joins Bioresource Engineering

Dr. David Fleisher will officially join the faculty of Bioresource Engineering on September 1, 2001. Dr. Fleisher completed his Ph. D. dissertation in early July under the direction of Dr. K.C. Ting, who is now chair of the Department of Food, Agricultural and Biological Engineering at Ohio State University. David's dissertation is titled "Modeling for multiple crop production and control in advanced life support systems". His work was part of the NJ-NSCORT project, which was funded by a five-year grant from NASA. David also received a prestigious NASA Graduate Student Researchers Program Fellowship. Dr. Fleisher discusses some of his dissertation research on pages 2 and 3 of this newsletter. David's appointment has a major teaching component, while his research will focus on instrumentation and sensor technology for greenhouse production. Welcome aboard David!

Dr. K.C. Ting inducted as ASAE Fellow

Dr. K.C. Ting (former chair and faculty member of Bioresource Engineering at Rutgers University) was inducted as an ASAE fellow at the annual international ASAE (society for engineering in agricultural, food, and biological systems) meeting in Sacramento, CA. Among Dr. Ting's many contributions to our profession are his dedication to teaching and mentoring, technical writing, and international collaborations. Congratulations to Dr. K.C. Ting!

Blue Ribbon Award

The Horticultural Engineering Web site (for the correct address see the top of this page) received a Blue Ribbon Award in this year's ASAE Educational Aids Competition in the category Web Pages. The award was announced at the annual international ASAE meeting in Sacramento, CA.

Department Name Change

As you recall, Bioresource Engineering was merged with the Plant Science Department on July 1, 2000. This Spring, the Plant Science Department was merged with the Plant Pathology Department and a new name was selected for this newly formed department: **Department of Plant Biology and Pathology**. Professor William Meyer (research interests: turfgrass breeding and disease resistant germplasm) was elected to serve as interim chair for the period of one year (starting July 1, 2001). A search committee will be formed soon to start identifying candidates to chair our new department.

Optimizing Your Production Environment

A.J. Both

When you are busy growing crops, hiring labor, filling orders, and paying the bills, there is little time left to take a step back and evaluate your production system. Perhaps, you are so accustomed to doing things a certain way, you may not realize there are different, and maybe better, approaches. Talking to and visiting with other growers as well as attending meetings and trade shows is usually well worth your investment of time. It makes little sense for any of us to reinvent the wheel, but why not try to keep it spinning as efficiently as possible? Here is a look at some production components that you may be able to improve to further optimize your production system.

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Control of Plant Growth in Controlled Environments for Advanced Life Support

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Basic requirements for supporting human life for manned space missions include the availability of air, food, and the treatment of waste products. Traditional life support systems, such as those used for the space shuttle and international space station, combine physical / chemical technologies with storage of resources to satisfy these needs. To establish a permanent human presence in space, however, it is thought that earth-independent life support systems capable of regenerating resources are required. NASA (National Aeronautics and Space Administration) researchers are addressing this regenerative type of life support through the Advanced Life Support

Incorporation of biological systems with chemical and physical ones is a key requirement of the ALSS program. The production of crops, such as wheat, soybean, and white potato, is expected to provide crew nutrition, atmospheric purification, potable water production, and nutrient recycling through the use of hydroponic production systems. ALSS crop production will take place in growth chambers with control over many environmental inputs such as light intensity, air temperature, and atmospheric carbon dioxide concentration. Nominal environmental set points will most likely be selected to promote yield production while minimizing resource requirements.

Environmental disturbances will be of concern in an ALSS, particularly if they are severe enough to alter planned crop production scheduling. Thus, a method for control of plant growth in ALSS needs to be developed. Historically, process control for controlled environments has focused on the climate by maintaining blue-print or predetermined environmental set points for crop production. These set points are typically derived from heuristic and empirical studies for the particular crop that is to be grown. More recent approaches are based on optimization, where appropriate environmental values are determined based on location, time of year, and the desired objective such as maximization of yield or quality and minimization of resource usage. Academic research is now focusing on devising set point trajectories in real-time. These methods employ mathematical models of the greenhouse environment, crops, and / or market and weather forecasts.

A different strategy, model-based predictive control (MBPC) of crop growth, is introduced in this research project. The control algorithm applies mathematical models of the plant to estimate the effect of environmental disturbances on desired plant growth and development. These models are then used to compute new environmental set points that will compensate for the disturbance effects. The control is based on the crop itself rather than the climate. The control algorithm was developed for wheat, soybean, and white potato, and evaluated with simulated disturbances in light intensity, average daily air temperature, and atmospheric carbon dioxide concentration.

The success of the MBPC algorithm is largely dependent on the accuracy of the crop models. These models are used to estimate crop sensitivity to environmental changes. The first phase of the research was devoted to conducting growth chamber experiments at the New Jersey Agricultural Experiment Station greenhouses at Rutgers University. Data from these experiments were used to modify a state of the art model for white potato field production for controlled environment production.

The second phase of the research was to combine the potato model with previously developed models for wheat and soybean. This was done to simplify the controller design. In the control algorithm, current

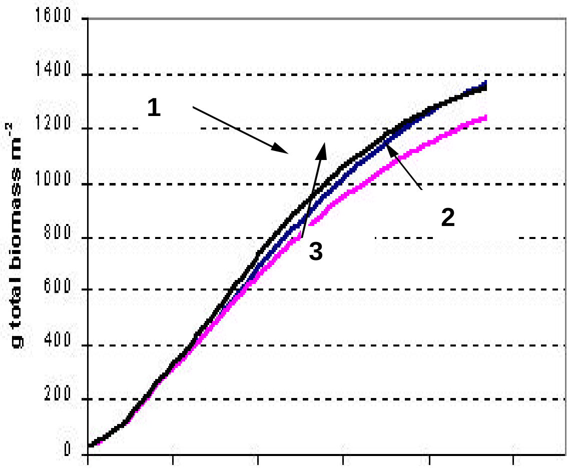

Figure 1: Three possible growth curves for wheat.

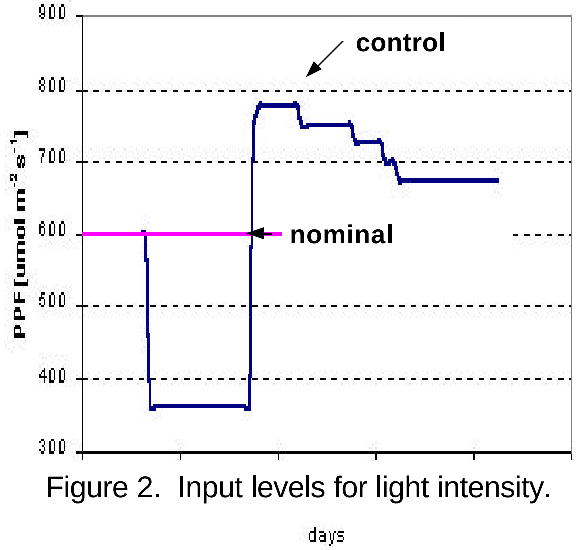

Figure 2. Input levels for light intensity.

crop mass is estimated by entering current and past environmental conditions to the crop models. The control then minimizes the differences between desired (i.e., produced under nominal conditions) and the current crop total and yield biomass (which is simulated by using the crop models). A new set of environmental inputs, to be applied for the following day, is obtained through this minimization.

The control algorithm was evaluated with simulated environmental disturbances for the three crops. One case is illustrated with wheat in Figures 1 and 2 where a large disturbances in light intensity was simulated from day 15 to 35. Figure 1 shows total biomass versus time for three cases. Case 1 is the nominal or desired values. Case 2 shows the results where no effort is made to compensate for the disturbance. Case 3 shows the results when the MBPC suggestions are applied. The difference between desired and current total biomass is almost eliminated. Figure 2 shows the values for light intensity versus time. The 'nominal' curve shows the nominal set point value. The 'control' curve shows the new values specified by the MBPC required to compensate for the disturbance (these are the values used to produce Case 3).

The results from this and other analysis suggest that this control approach is viable for crop production in controlled environments. Additional work should be conducted in validating the mathematical crop models and extending the controller to accommodate additional environmental and cultural inputs, such as the effects of microgravity on crop growth and development. Another main goal will be to incorporate real-time feedback from the crop into the control algorithm.

<u>Recent Publications:</u>

Fleisher, D.H., S. Kang, and K.C. Ting, 2001. Software for Multiple Crop Production in Advanced Life Support Systems. ASAE paper No. 014084, St. Joseph, MI ASAE.

Fleisher, D.H. and H. Baruh, 2001 (in press.) An Optimal Control Strategy for Crop Growth in Advanced Life Support Systems. Life Support and Biosphere Science.

Fleisher, D.H. 2001. Modeling for Multiple Crop Production and Control in Advanced Life Support Systems. Ph.D. Dissertation Rutgers University Libraries, New Brunswick, NJ.

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Irrigation and Watering

It all started with hand watering and, in some cases, that's what people are still using. Why? Because sometimes it takes a little human "touch" to observe the condition of the plants and apply the correct amount of water. The growing media doesn't always dry out uniformly whether within a container or from container to container. But it is clear that hand watering can be very labor intensive. Several different automated watering systems have been developed either for top or bottom irrigation. Fertilizer can be added to the media (e.g., slow release) or it can be dissolved in the irrigation water. The key is of course to provide every plant with the correct amount of water and fertilizer at the correct time. To make this possible, the production process is usually standardized and all plants are treated the same. These systems are particularly efficient for larger growing areas. Some irrigation systems can be easily moved from one greenhouse bay to the next, further reducing the per plant investment. Whatever system you use, it should result in excellent plant quality at minimum system and labor cost. Frequent checking of the media and nutrient solution composition as well as the equipment dosage rates can prevent costly mistakes.

Transportation

Whether it is bulk media, freshly seeded containers, or finished product, it is always coming from somewhere and it needs to go some place else. At the same time, we need room to allow us to move things around. In addition, we want to keep the greenhouse completely filled with plant material as much as possible. The higher the "occupancy rate", the lower the production cost per plant, and the more money stays in your pocket. Efficient and timely transportation of your plant material through the entire facility requires careful planning. In many cases, a simple conveyor belt can make life a lot easier. Conveyors come in many different shapes and sizes and can be adapted for almost any transportation job. Carts and monorails are also very popular because they helped solve many transportation problems, while reducing a significant amount of physical labor. The Dutch moving tray system combines a growing bench (ebb and flood table), cart, and conveyor all in one. So why not plan an efficient transportation system for your operation?

Growing Media Handling

Different crops perform better using different growing media mixes. In addition, many growers have their own preferences based on the particular growing system they use. Shredders, mixers, fillers, and conveyors are used to prepare the desired growing mix. Larger equipment can handle larger quantities usually resulting in improved batch-to-batch uniformity. However, handling larger volumes requires even more equipment and more storage space. The trick is to design a system that satisfies your needs without creating any handling problems (such as lack of storage space, inefficient material flow, strenuous body posture of the operators, excessive dust production). When possible it would be desirable to locate the media handling operation in a separate area in your operation with easy access to the loading area as well as to the greenhouse. The main advantage of creating your own mix is that you can precisely determine its composition. Continued experimentation will allow you to select the optimum mix for your production system. Soilless mixes are generally very uniform as well, but they can be more expensive. Whether a mix can be recycled after use can be a serious consideration when you have limited or expensive disposal facilities.

Seeding

A lot of crops we grow start from seed. Quality, quantity, availability, and price play an important part in our purchase decision. But once delivered, we need to make sure the seed is stored under optimum conditions so it does not lose any of its vigor. Temperature- and humidity-controlled storage is highly recommended. Older seed should be tested for germination percentage, especially when large batches are to be sown. Accurate record keeping is necessary to assist you when you are ready to reorder (preferably from the same seed lot). Different types of seeders are available depending on the amount of seeding required (from flat- to reciprocating-, to drum-seeders). Most seeders use reduced air pressure (suction) to hold the seed in place prior to planting. Operating the seeding equipment requires attention to detail and is usually left to skilled labor. Seeding mistakes can be costly and will have an impact through the final shipping date. Good contact between the seed and the growing media is important for uniform and timely germination.

Transplanting

Once the seed has germinated and grown to mature seedlings (usually in a nursery area), it is time to transplant these seedlings into the greenhouse environment. Traditionally, this was a labor-intensive operation that, although monotonous, provided an opportunity to carefully select the most vigorous seedlings. Seedling selection at the transplant stage results in uniform crop material that, when grown under carefully controlled conditions, will be simultaneously ready for harvest. These days, a variety of sophisticated equipment is available to transplant seedlings at great speed. Skilled labor is needed to maintain this equipment and ensure quality control. Usually, some additional labor is still required to correct any "misses". Finally, some plug producers decided to market their plug flats as 100% filled, requiring special transplanting equipment or so-called flat fixers. All this equipment can significantly increase your transplanting speed, but for maximum return on your investment, the equipment needs to be carefully integrated into the entire production system (e.g., can your crop be paced in the greenhouse as fast as the equipment can produce transplants?).

Respacing
Not all crops require a respacing once they are placed in the greenhouse. However, a respacing usually improves the space efficiency by allowing plants just enough room to develop. On the other hand, respacing requires another handling of the crop resulting in increased labor and potential crop damage. And not all irrigation systems can easily accommodate different crop spacings. Thus, the main issue becomes a choice between using extra labor to perform the respacing and creating more space to grow additional crops. Automated respacing systems have been developed for certain crops (e.g., plants grown in pots on ebb and flood floors). It would be a worthwhile exercise to calculate the space savings that can be obtained from implementing a respacing sometime between transplanting and harvesting. Just think of all the time supermarkets use making sure all their shelves are fully stacked. Greenhouse space is costing you money (heating, cooling, lighting, etc.) whether it is filled or not, so you might as well fill it with as many plants as possible.

Harvesting
Harvesting can be a very labor-intensive procedure. Some equipment has become available over the years, but by and large harvesting requires a significant amount of manual labor. Harvesting robots are being developed (tomato, cucumber), but this equipment is experimental and expensive. For your greenhouse operation you may evaluate the different components of the harvest to investigate whether any of them can be automated or mechanized. For example, a conveyor system to bring your product from the greenhouse to a packing area, grading-, sleeving-, packing-, tagging-, and stacking equipment, etc. Whatever type of equipment or form of automation you decide to use, during the final harvest you have one last opportunity to perform a final product quality check. After all you want your customers to stay your customers!

Environment Control
Most of us do a pretty good job maintaining proper temperatures in our greenhouses. As long as the sensors are located in an aspirated box and the aspirated box is placed in a representative location close to the top of the canopy, the control system will have an accurate "sense" of what the plants are experiencing. For example, we don't need to know the temperature at five feet above the floor, when a short crop is grown on the floor. In fact, the control system is used to provide an optimum plant growing environment, but not to control the environment some distance away from the crop. Other important environment conditions we need to pay attention to are light, (relative) humidity, and carbon dioxide. Light quantity is generally controlled by shading (white wash or shade screening) in the summertime and supplemental lighting in the wintertime. Similarly, the photoperiod response can be controlled by blackout cloth (daylength reduction) and/or low intensity lighting (daylength extension). Humidity control is necessary to prevent condensation on crop surfaces or greenhouse structures. Wet plant surfaces should be avoided to reduce the risk of disease. The combination of heating followed by venting results in moisture removal, provided the incoming air is not already saturated and the greenhouse temperature is not too high. Humidity control during warm and humid summer days can be a challenge. The carbon dioxide concentration inside the greenhouse can drop significantly during periods with low ventilation rates (wintertime). Therefore, some ventilation is needed to keep the carbon dioxide concentration from becoming the limiting factor for photosynthesis. Optimum greenhouse environment conditions can be more easily maintained throughout the entire greenhouse with the help of horizontal airflow fans. Finally, greenhouse environment control can be significantly improved with the help of computer systems. These computer algorithms can evaluate many different parameters before any adjustment are implemented. In addition, inside and outside environment parameters can be recorded for future analysis. These algorithms are constantly updated when new research developments become available. Are you ready to install such a system? You will be surprised by all the different features and your plants may thank you for it!

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HORTICULTURAL ENGINEERING

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Horticultural Engineering on the Web

This issue of Horticultural Engineering, like previous ones, will soon be available on the internet at:

http://aesop.rutgers.edu/~horteng

We will send an e-mail announcing each Horticultural Engineering Newsletter as it is posted on our web site.

Thanks to those of you who have elected to receive this newsletter via the Web. We appreciate your help in saving the duplicating, postage, and handling costs.

Several useful Websites:

http://www.ag.ohio-state.edu/~vegnet
http://www.ces.ncsu.edu/depts/hort/greenhouse_veg
http://ag.arizona.edu/hydroponictomatoes
http://res2.agr.ca/harrow
http://www.rce.rutgers.edu

Important Dates
January 14– 15, 2002
Greenhouse Engineering Short Course at Rutgers University

This 2-day course, coordinated by your editor, features timely topics for greenhouse operators and those interested in learning more about greenhouse engineering or perhaps thinking about getting started in the greenhouse business. Registration information is available for the Office of Continuing Professional Education at Cook College,
Phone: (732) 932-9271, or on the web: http://cook.rutgers.edu/~ocpe
It is not too early to plan to attend this program. Speakers include: Professor emeritus Bill Roberts, Professors George Wulster, David Mears, David Fleisher, your editor, and more!