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GREENHOUSE ENGINEERING RESEARCH AT NCSU

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The Greenhouse Engineering Research Program at NCSU is entering its 17th year, yet it is not as well known in N.C. floricultural circles as it might be. Part of this stems from the lack of an extension position in Greenhouse Engineering in our department and part because our program has been, and still is, more closely tied to greenhouse vegetable production than to floriculture (for reasons of funding and personnel assignments). Nevertheless, a great deal of the activity in the program is relevant to floriculture and is worth bringing to your attention.

In an effort to foster a greater awareness of our program I have, at the suggestion of Dr. Doug Bailey, committed to a series of articles outlining it and emphasizing some of the more important results and directions. The first of these is a historical perspective which will, hopefully, serve as a basis for the follow-on articles.

1974–1981

I arrived at N.C. State in 1974 to fill a teaching and research position vacated by Dr. Bob Holmes, who had just left to join the faculty at Ohio State after 10 years here. Bob had just switched his research area from strawberry mechanization to nursery mechanization during the previous year because of diminishing interest in strawberry harvesting and because of a departmental needs assessment prompted by requests from N. C. nursery/greenhouse leaders for engineering assistance.

After I had been here a year it became apparent that the energy crisis was a major problem facing the industry and that an intensive effort would be required to address the problems. Since the facilities and expertise required for energy and environment research were not entirely compatible with those of mechanization, a choice had to be made to best utilize the resources available. It was at that point that the Greenhouse Engineering Program was born; unfortunately, no facilities existed, funding was minimal and no technician was available.

Negotiations with the director's office produced an offer of funds for the construction of an inter-departmental greenhouse vegetable facility at Unit 4. Of the 13 greenhouses constructed, the Greenhouse Engineering

Research Program was assigned four, with the others going to Horticultural Science, Plant Pathology and Entomology. Salary money was made available for a technician in mid-1976 and one was hired in January of 1977.

The next 5 years were occupied with various greenhouse energy projects, some of which were fruitful, some of which showed potential and some of which were dismal failures. The successes included suggestions for improvements to the standard gas unit heaters (*reported in the Dec. 1982 issue of the NCCFGA Bulletin*) and investigations into north wall insulation (*reported to various NCGVG and NCCFGA meetings*). The project offering the most potential was the use of rockbeds as energy source/sinks for greenhouses (a DOE grant was obtained to investigate them). The biggest failure was a partitioned thermal curtain (it looked like a good idea at the time) which was too costly for the return in energy savings (however, it did provide a spin-off in the form of the heater modification work).

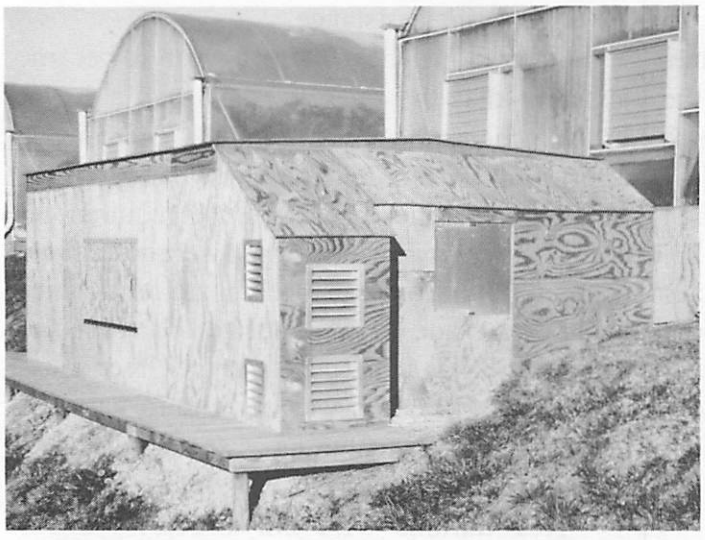
'Research results to-date suggest that conventional shade cloths placed on greenhouses may actually cause more harm than good. More on that in future articles.'

1982–1988

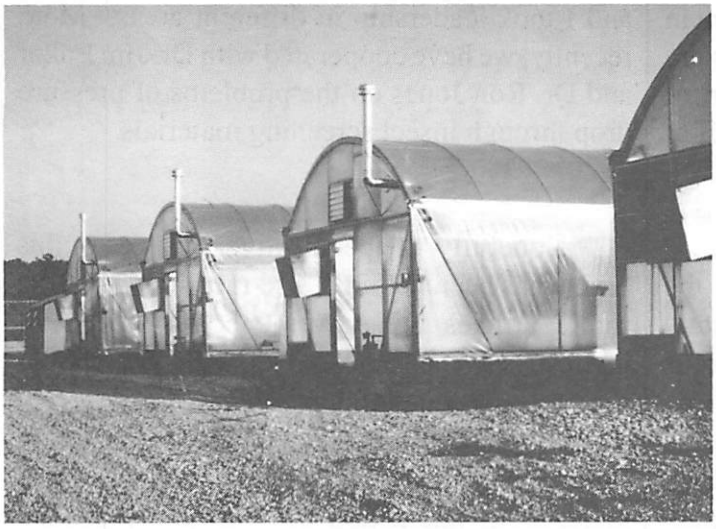
At the close of the rockbed energy studies, it became apparent that the real promise of rockbeds was not energy savings, but rather their ability to extend the periods of time greenhouses could remain closed; decreasing the time venting would be necessary. This ability stems from the fact that, when charging, warm air is removed from the greenhouse and replaced with cool air from the rockbed, thus providing greenhouse cooling without the use of outside air; thus allowing injection of carbon dioxide into the greenhouse (CO_2 enrichment) when it would not ordinarily be possible. The potential return on investment from increased yield due to CO_2 enrichment was found to far outweigh any return from energy recovery, even though as much as 20% of nighttime heating costs could be provided by the rockbeds.

Given the potential use of rockbeds for CO_2 enrichment, funding was obtained (again from DOE) to construct four additional greenhouses, two with rockbeds attached. The following 6 years were devoted primarily to enrichment studies with cucumbers, tomatoes, lettuce and chrysanthemums (in cooperation with Drs. Mary Peet and Paul Nelson). Based upon those studies, an economic study has been initiated to determine the economic efficacy of rockbeds in commercial greenhouse operations. The results of that study will probably be available soon (the student is expected to graduate within a few months).

In the process of trying to improve the cooling ability of rockbeds the complexity of greenhouse cooling became apparent. For example, external



This building houses a rockbed used in NCSU greenhouse energy studies. The untapped potential of rockbeds may be their greenhouse cooling capability rather than their use in heating greenhouses.



Experimental air conditioned greenhouses at NCSU. Installation of units for cooling at night to prevent heat delay in plants such as chrysanthemums may have a payback period of only 2 years.

shade cloths were applied in an effort to aid rockbed cooling; however, the result was not that expected (some temperatures actually increased). As a result, intensive field and laboratory studies of shading were begun (and are still underway) to try to understand exactly what influences shade performance. Research results to-date suggest that conventional shade cloths placed on greenhouses may actually cause more harm than good. More on that in future articles.

1987–Present

In addition to shading, experiences with rockbeds have suggested some unusual approaches to cooling. Conventional wisdom long ago ruled out the use of air conditioners (heat pumps) for cooling greenhouses because of the high cost of handling the high mid-day solar loads; however, the same factors that make air conditioners impractical for daytime cooling also make nighttime cooling worth considering (that is, the relatively small thermal capacity of greenhouses, compared to commercial and residential buildings, means that very little of the high daytime cooling load is transferred over to the night), and numerous plant species respond favorably to reduced nighttime temperatures during the hot summer months.

Funding was obtained in 1987 to add three air conditioned greenhouses to the existing "range". These were used in a two year study which produced tomato yield increases of 28.0% and 52.8% in houses in which the nighttime temperatures were maintained 6.1°F and 7.4°F less, respectively, than the nighttime temperatures in the control houses. The additional cooling costs incurred could easily be offset by the increase in production, with an estimated payback of about 2–4 years. Discussions with Doug Bailey have resulted in the suggestion of several floricultural species that might benefit from night cooling and future studies are planned to investigate these.

Computer Control

In addition to the cooling/CO_2 enrichment work, we have been involved for some time in the area of computer control for greenhouses. We have been using computers to control our research greenhouses since 1976 but cost-effective commercially available control computers are only just now appearing on the scene (most are still not cost effective). Numerous factors account for this: 1) the demands on control computers are generally unique to each operation; 2) the cost of control software is considerably higher than business software, because of its limited marketability; and 3) plant needs are only just beginning to be understood well enough to exploit the capabilities of computers.

In anticipation of solutions to 1) and 2), we have been working on modeling plant responses to environmental stimuli, anticipating incorporation of those models into future computer control algorithms. Specifically, nutrient uptake rates in chrysanthemum have been modeled, as have cucumber and tomato responses to CO_2 enrichment and responses of chrysanthemum to sudden changes in light.

Presently, Barry Jacobson (a graduate student in our department) is attempting to model stem elongation in chrysanthemum as a function of DIF treatment (subjecting plants to night temperatures greater than day temperatures).

Cooperative Work

In addition to the work for which the Greenhouse Engineering Program is directly responsible, we have been active in numerous cooperative projects dealing with floriculture. For example, we were actively involved in the economic analysis work headed up by Dr. Paul Nelson in the late 1970's. The chrysanthemum nutrient uptake work was also a cooperative venture in which Dr. Paul Nelson, Dr. Mary Peet and I took leadership in different areas. More recently, we have cooperated with Dr. Jim Baker and Dr. Ron Jones on the problems of pressure drop through insect screening materials.

Summary

Hopefully, the perspective provided in this article has been helpful. As I mentioned earlier, future articles will cover specific studies of interest, such as our studies with greenhouse shading techniques, followed by a wrap-up giving my view of where the Greenhouse Engineering Program is going. I welcome the opportunity to increase my interaction with this group and am certainly looking forward to working with Doug. With your input, and Doug's help, I am certain we can make the Greenhouse Engineering Program a credit to North Carolina floriculture.