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CCEA Newsletter

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The Center for Controlled Environment Agriculture is a research organization dedicated to the improvement and vitality of the Controlled Environment Agri-culture Industry. CCEA is funded by industrial and grower partners who volun-tarily contribute a yearly partnership fee. For more information contact:

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Vision Statement
CCEA, The Center for Con-trolled Environment Agri-culture of NJAES at Rutgers University, a partnership among growers, industry, and researchers, will devote itself to research and trans-ferring information required for an economically viable and environ-mentally aware controlled environment agriculture industry. We will particu-larly strive to identify future trends, critical issues, appropriate emerging techno-logies and provide leadership for opportunities which challenge world-wide control-led environment agriculture in the 21st century.

In this issue:

In September 2003, a new tomato crop was planted in our high tunnels. The goal of the experiment is to evaluate fall and early win-ter production using some supplemental heat.

High Tunnel Update: Construction and Tomato Production

A.J. Both

Summary

Six high tunnels were constructed at two different locations: two of the tunnels were erected on the horticultural research farm at the Cook College Campus in New Brunswick. The remaining four tunnels were installed at the Rutgers Agricultural Research and Extension Center in Centerton. The tunnels were con-structed according to the Penn Sate high tunnel design with some small modifications. The tunnels will initially be used for research on the feasibility of tomato production.

Tunnel Design

The tunnels were constructed according to the Penn Sate high tunnel design. The hardware for the 17 by 36 feet tunnels was purchased from Ledgewoods Farms (Moultonboro, NH, 1-603-476-8829). These high tunnels are classified as temporary agri-cultural structures because no concrete footings were used to anchor the foundation posts. In fact, the foundation posts were hammered into the ground allowing for relatively easy removal. The hoops were bolted to the anchor posts making for easy in-stallation with two people. These tunnels are called high tunnels because it is possible to stand up straight almost throughout the tunnels without touching the cover material or the structural elements. This design allows for large hinged doors in the end walls that, when opened, enable a small tractor to drive straight through during soil and growing bed preparation. The relatively tall (5-6 feet) vertical sidewalls were installed as roll-up sidewalls allowing for sufficient cross ventilation during crop production. Often such roll-up sidewalls are operated manually because there is no electricity on site to operate an electric motor, or because of the costs involved with installing motorized sidewalls. The roof of the high tunnels has a sufficiently steep angle (approximately 26.5 degree) for most snow accumulation to slide off. Unless motorized sidewalls are used, only a reliable water source is needed at the site to grow a crop. A standby heater may be needed to prevent frost damage very early or late in the growing season. A single layer (6 mils) of 4-year polyethylene greenhouse film was used to cover the tunnels. It is recommended to install a film with anti-condensate and infrared blocking features, to prevent condensation drips and reduce the heat load on the crop.

End Walls

The end walls were made of three different sections: 1) a permanently installed triangular shaped section covering the top part of the end walls, 2) a large rectangular shaped section that is hinged from the top section, and 3) two curved sections filling the space between the large hinged door and the sidewalls. A regular access door was framed as part of one of the large hinged doors. All of the different end wall sections were covered with a single layer of the same polyethylene film used to cover the rest of the tunnel. In order to easily attach the polyethylene covering film, the entire sidewall was framed in wood using 2 by 4 framing studs. Where the wood came in contact with the soil, pressure treated wood was used. In order to increase the strength of the wooden end wall frame, all wood on wood connections were lapped, glued and screwed. Curved sections of the end wall frames were made out of ¾ inch pressure treated plywood, that when doubled up were the same thickness as the other framing elements. Where needed, the wooden end wall frame was bolted to the outside metal framing bow. The polyethylene covering film can be attached to the frame of the end walls with wooden lathe, or with extruded aluminum profiles that secure the film with a stainless steel wire profile.

During soil and growing bed preparation, the large hinged doors were placed in a vertical position by placing a temporary support underneath the bottom of the doors. In addition, the curved sections to the left and right of the hinged door were removed to allow easy access for the tractor and soil tillage equipment.

Sidewalls

The sidewalls of the high tunnels can be rolled up to allow for cross ventilation when the inside temperature rises above a target set point temperature. Typically, such sidewalls are operated manually: opened in the morning and closed in the evening. The polyethylene film covering the sidewalls was rolled around a metal pipe extending the entire length of the tunnel. Once the desired opening was reached, the pipe was secured in place by sticking another pipe through a T-section attached at the end of the roll-up pipe.

In order to reduce the labor involved in operating the sidewalls and in an attempt to improve the temperature control inside the tunnels, two of the six tunnels constructed for this project were outfitted with motorized roll-up mechanisms. These automatic systems contained the following components: 1) a motor controller that uses temperature measurements to engage an electric switch that operates the tube motors, 2) a tube motor for each roll-up side and attached to the end of the roll-up pipe, 3) extruded pipe segments that form the roll-up pipe and were secured on either side at the bottom of the polyethylene film, 4) a special aluminum extrusion attached to the baseboard at the bottom of the side opening (this extrusion holds the roll-up pipe firmly in place when the sides are closed), and 5) some additional hardware needed to guide the tube motor during operation. The hardware for the automatic sidewalls was purchased from Advancing Alternatives, Inc (Schuylkill Haven, PA, 1-877-546-2257). Finally, a rope webbing was installed outside the side vents to prevent the vents from flopping around during high wind conditions.

Construction Costs

Table 1 shows the price estimates based on the prices paid and the amount of labor required to build the high tunnels for this project (2002-2003). Note that the motorized roll-up mechanism almost doubled the price. However, significant labor savings can be realized by using an automated ventilation system. The research project aims to investigate whether the improved temperature control as a result from the automatic operation of the side vents will have a positive impact on tomato fruit quantity and quality.

Preliminary Production Data

The data shown in Figures 1-4 were collected at the research site in New Brunswick.

Prior to transplant, the soil in the high tunnels was tilled and a herbicide was applied to reduce weed growth during the early stages of crop growth. Immediately thereafter, the beds were formed and the plastic mulch and irrigation drip tape (underneath the mulch) were installed. The tomato seedlings were transplanted into the tunnels on May 5, 2003. The first harvest occurred on July 2, 2003. Two tomato varieties were planted: SunBright and SunShine. In each tunnel, four beds

Component	*Price (manual roll-up)*	*Price (motorized roll-up)*
High tunnel frame	$ 770	$ 650
Lumber	$ 260	$ 260
Hardware	$ 400	$ 400
Polyethylene covering film	$ 145	$ 145
Roll-up sides	included	$ 2,545
Construction labor ($15/hr)	$ 1,200	$ 1,440
Total	**$ 2,775**	**$ 5,440**

Table 1. Price estimates for the various components of the two types of high tunnel used for this project (17 by 36 feet). Note that this table does not include price estimates for freight, bringing water and electricity to the site, nor price estimates for growing a crop (e.g., irrigation, fertigation, mulch film, soil and growing bed preparation, seedlings, crop scouting and pest management, labor for crop maintenance and harvesting).

were prepared. The distance between the beds was approximately 4 feet, while each bed was approximately 21 inches wide. In each bed, the distance between the plants was 18 inches. Each of the four beds received a different mulch treatment: one of the beds was left uncovered, while the remaining three beds were covered with a red, green, or black colored plastic mulch, respectively. Each bed was divided in two sections of equal length, and each section was planted with one of the two cultivars. A guard plant was planted at the end of each bed and in between the two sections planted with the two different cultivars. The plants were irrigated with tap water based on tensiometer readings. When necessary, a liquid fertilizer solution was injected into the irrigation water. As the plants grew, stakes and strings were used to keep the plants growing in an upright direction and to support the weight of the tomatoes. The tomatoes were scouted weekly to check for insect infestations and sprayed with a pesticide when necessary. Figures 5 and 6 show some of the measured average daily air and soil temperatures outside and inside the tunnels.

Production Summary

Through the end of the experiment (August 29), we have harvested a total of 1697 pounds from 144 plants in two 17 by 36 high tunnels (approximately 11.8 pounds per plant). There appeared to be little difference between 1) the manual and automatic roll-up sides, 2) the two different varieties, and 3) the different colored mulches.

For Additional Information:

2003 High Tunnel Production Manual, published by the Pennsylvania State University Center for Plasticulture: http://plasticulture.cas.psu.edu/

Rutgers tomato web site: http://www.rutgerstomato.org

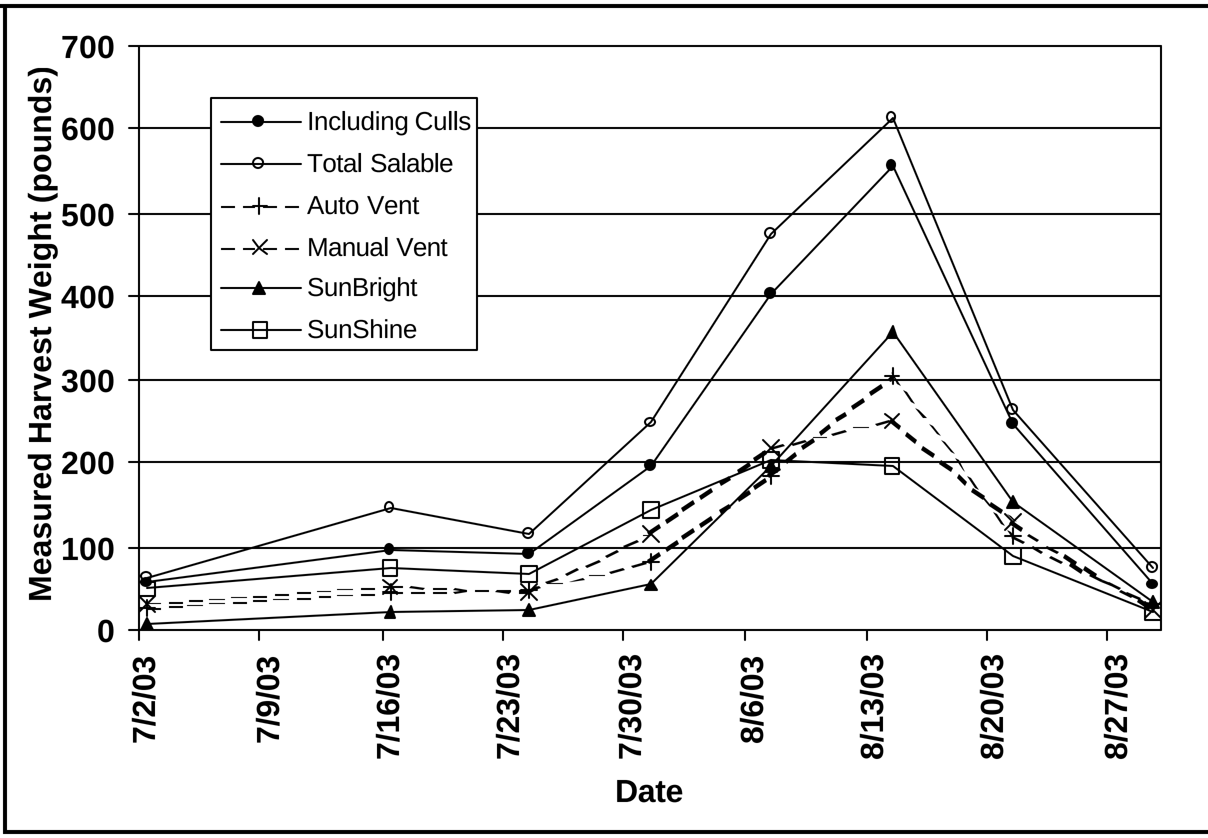

Figure 1. Measured harvest weights.

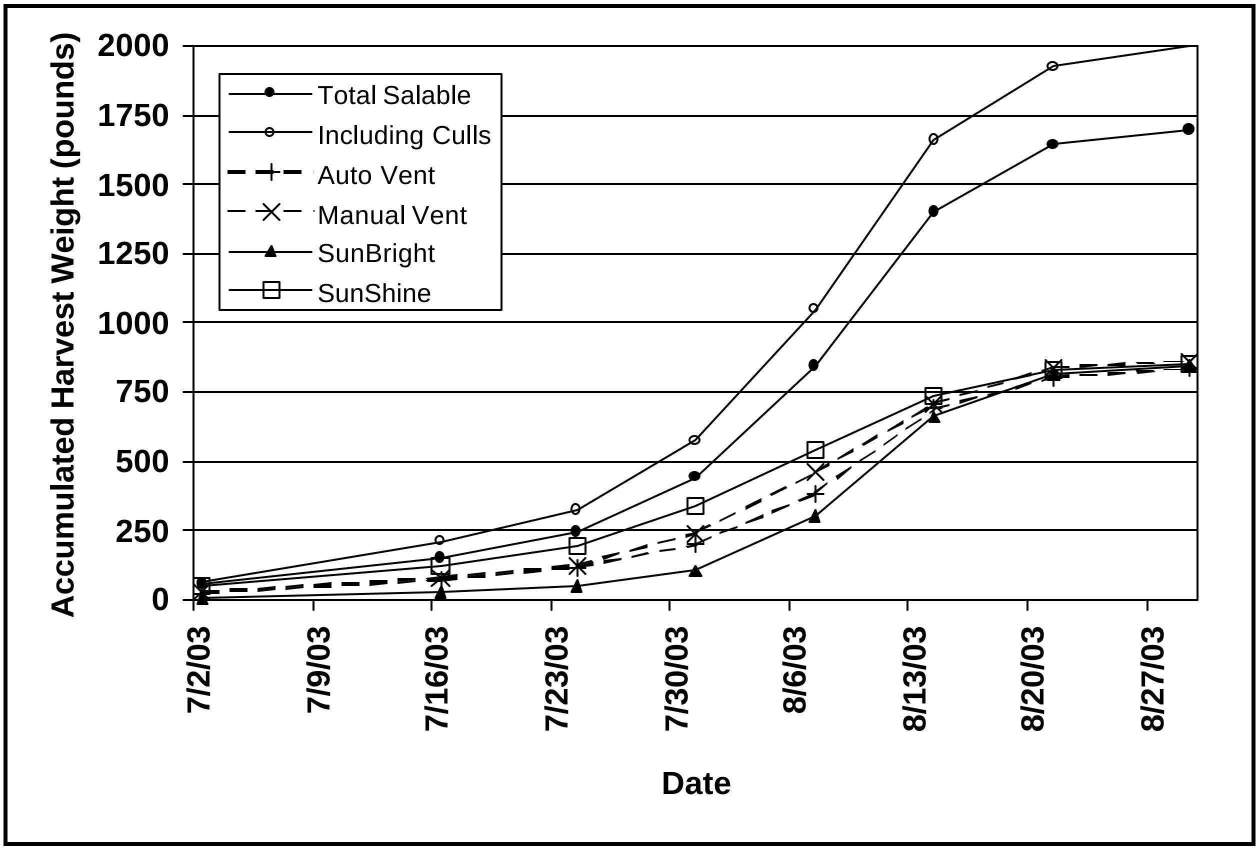

Figure 2. Accumulated harvest weights.

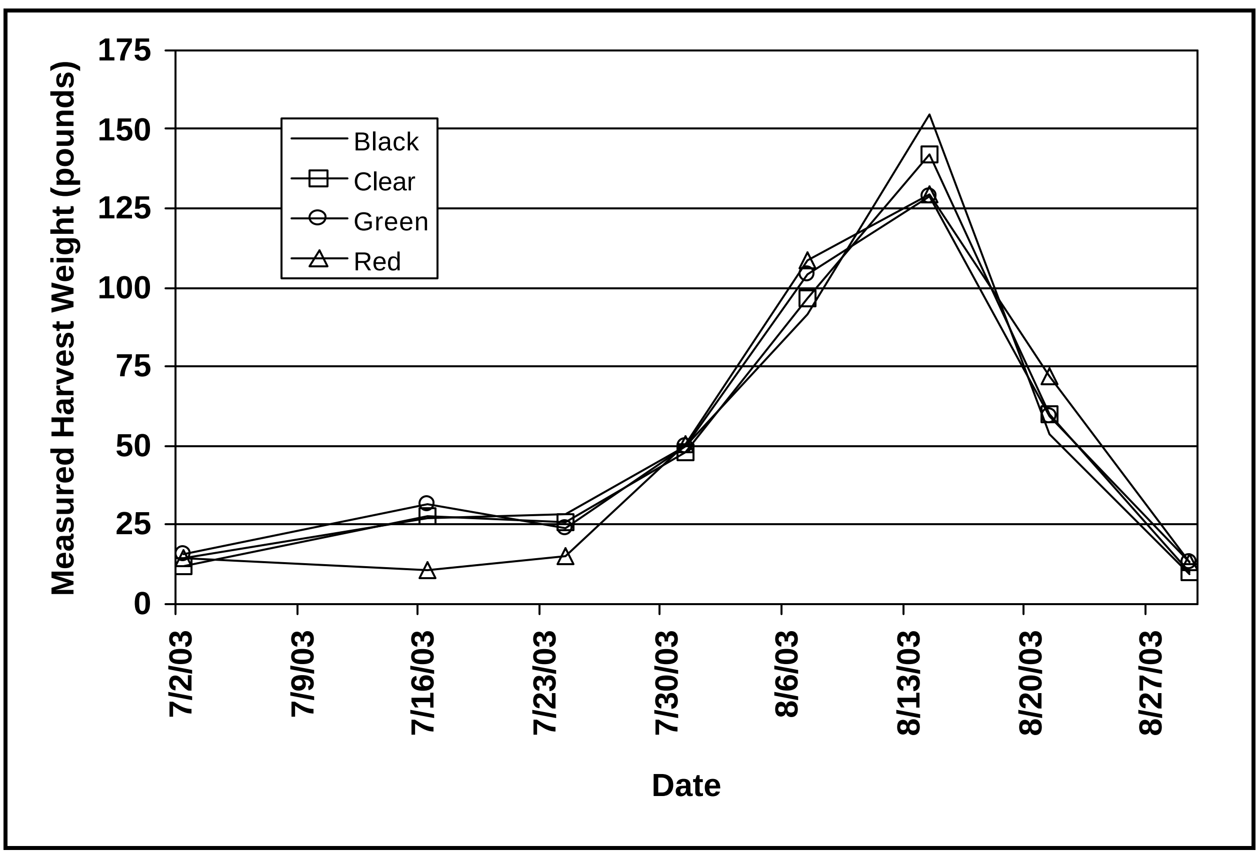

Figure 3. Measured harvest weights for different colored mulches.

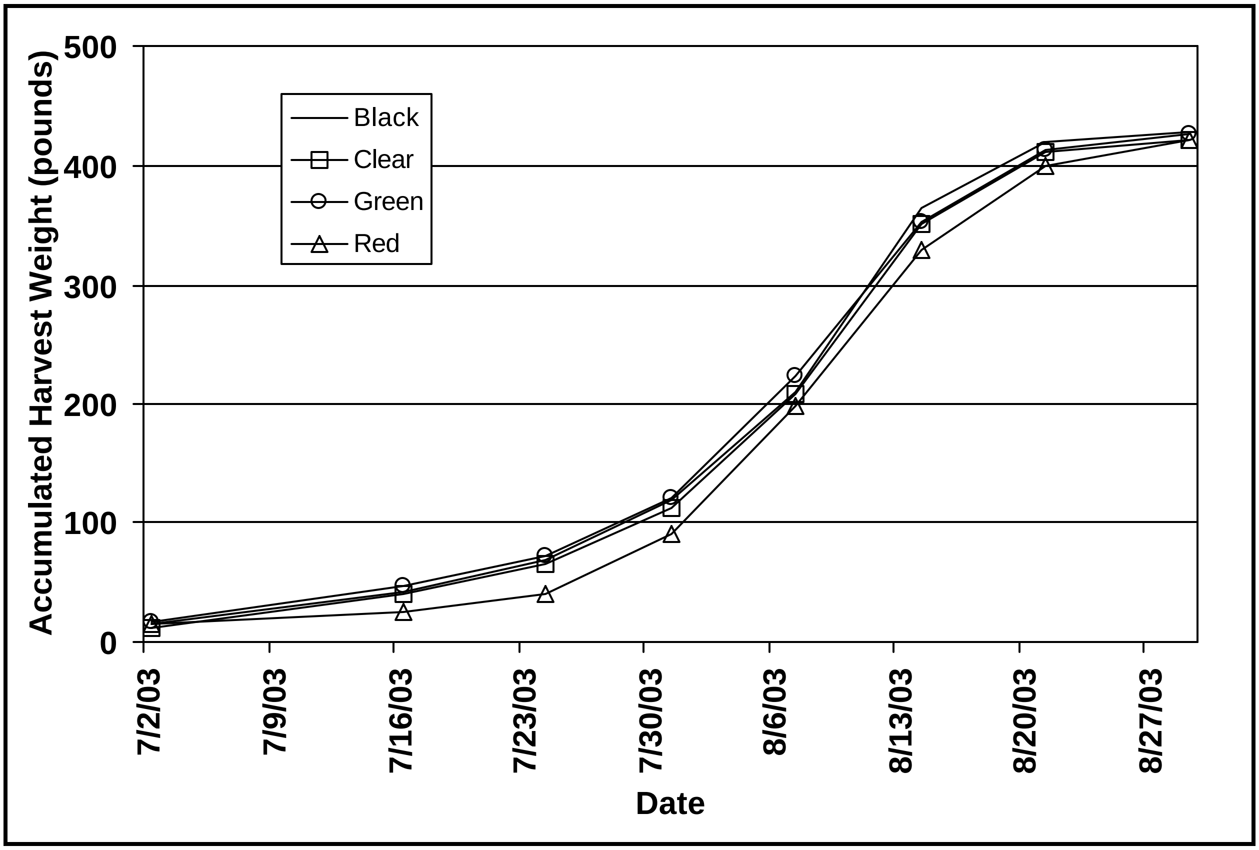

Figure 4. Accumulated harvest weights for different colored mulches.

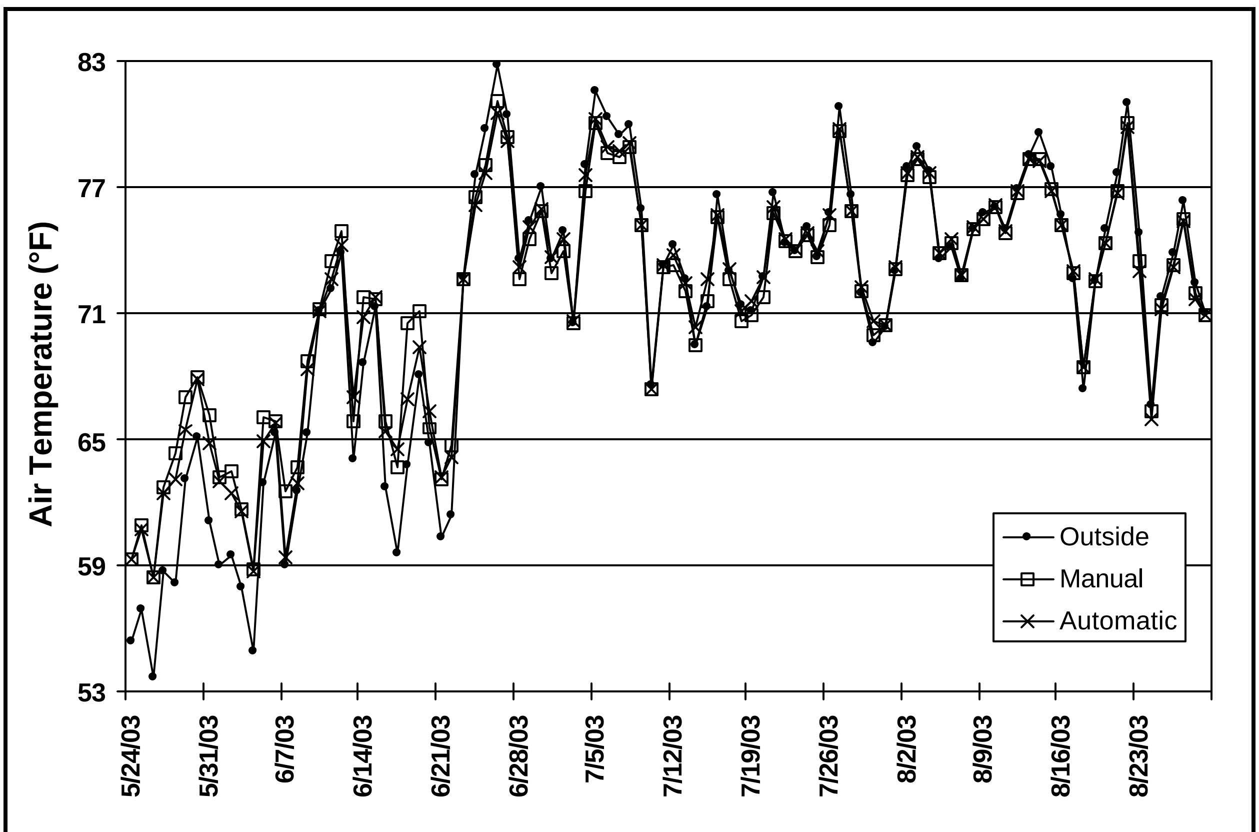

Figure 5. Measured daily air temperatures outside and inside the high tunnels.

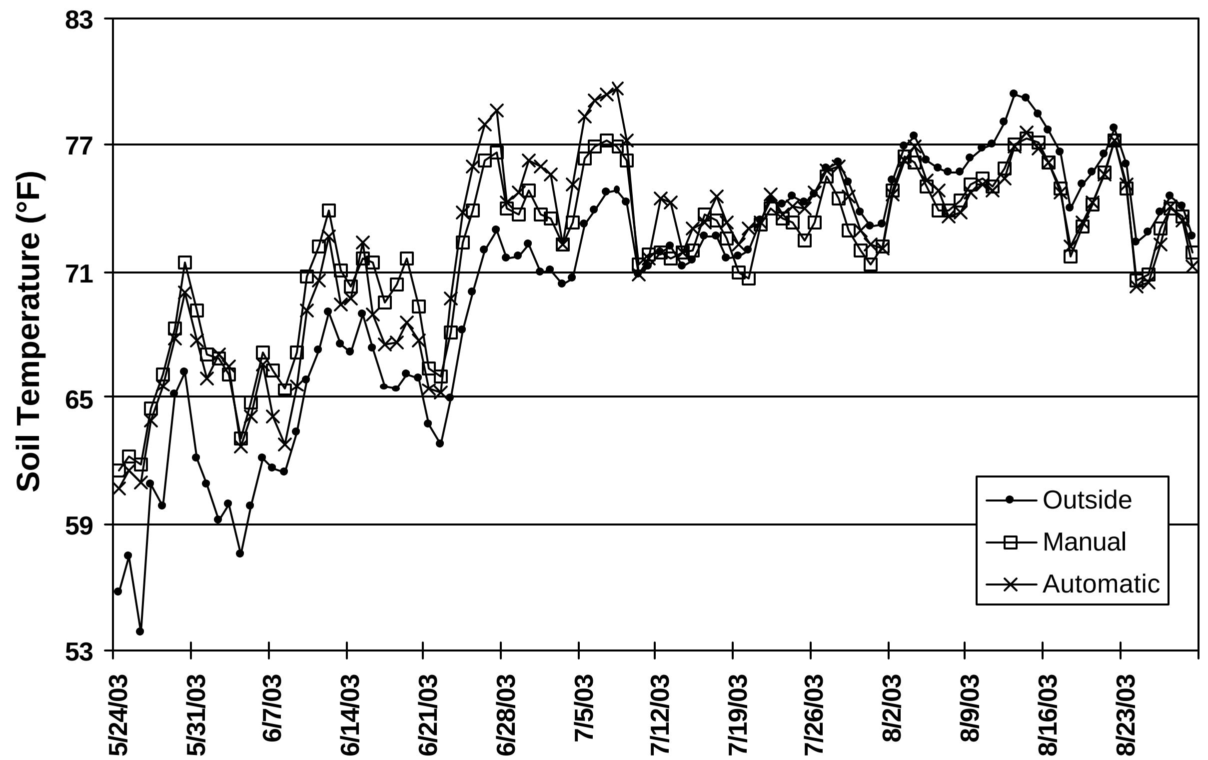

Figure 6. Measured daily soil temperatures outside and inside the high tunnels.

Floor Heating Update
Eugene Reiss
Research in the Rutgers University open-roof greenhouse during the 2002-2003 winter resulted in the following observations:

On nights when inside and outside environmental conditions along with floor inlet pipe temperatures were constant, a mean heat transfer coefficient from the floor heating pipes to the greenhouse air was determined to be 5.97 W/m^2-K (1.05 Btu/hr-ft^2-˚F).

An unplanned boiler failure showed that even after 29 hours without heat, and outside temperatures averaging –5 ˚C (23 ˚F), the inside air temperature did not drop below 7.2 ˚C (45 ˚F). At that time the floor was providing 86.7 W/m^2 (27.5 Btu/hr-ft^2), only 14% less than it typically provides. This also shows another important feature of floor heating systems: they can provide valuable time to correct heating system failures.

Maintaining a fixed pot temperature using the floor heating system and a typical PI feedback control strategy was found to be unsatisfactory and quite inefficient, particularly in combination with a DIF air temperature strategy. The feedback control strategy caused considerable overshooting of the temperature set point resulting in inefficient control. A comparison of the second (controlling greenhouse air temperature) and third (constant supply water temperature) control strategies suggested that the third strategy allowed the floor to deliver a higher percentage of the total heating requirement of the greenhouse compared to the second strategy. In addition, during implementation of the third strategy, more heat was vented from the greenhouse than during the second strategy. However, because the outside temperature and solar radiation conditions were so different when the two strategies were being evaluated, it could not be concluded that these findings were solely a result of the control strategies.

Because of the difficulties in evaluating different control strategies during changing outdoor conditions, the need to develop an accurate model of the floor's thermal performance became evident. More instrumentation must be installed so the temperature gradients in the floor as well as growing media can be accurately determined. This will allow the model to be calibrated and verified.

For a complete description of these preliminary findings, please visit: http://aesop.rutgers.edu/~horteng/presentations.htm and look under the topic "greenhouse energy conservation".