RUTGERS HIGH TUNNEL RESEARCH UPDATE (2005)

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Like the second year (2004) of tomato trials in our high tunnels, the third year (2005) was also a mixed success. An early season trial with the commercial varieties SunBright and SunShine was started at both the New Brunswick (HF3: Hort Farm 3) and Centerton (RAREC: Rutgers Agricultural Research and Extension Center) locations. At both sites, two identical tunnels as well as similarly sized (17 by 36 feet) outside plots were used for this trial. The tomato seedlings were transplanted into the tunnels on March 28 and 29 for the RAREC and HF3 locations, respectively. On April 29 and May 9, tomato seedlings were transplanted into the outside beds at RAREC and HF3, respectively. However, due to an inadvertent chemical application on June 28, plants inside and outside the tunnels at HF 3 suffered enough foliar damage to make all HF3 harvest data suspect (the outside plants suffered the most since the application was conducted on a neighboring plot). In addition, white mold (*Sclerotinia sclerotiorum*) was discovered on several plants at both locations. Infected plant parts were removed as soon as discovered in an attempt to stem the progress of the disease. Some plants had to be removed entirely.

At each location and during the early stages of crop growth and development, one of the tunnels was operated with a manually operated energy curtain that was pulled at the end of the day in an attempt to reduce the heat loss to the outside environment. The light transmission and energy retention properties of the curtain material used (XLS 10) are shown in Table 1 and compared to other commonly used shading materials manufactured by the same company (Please note that no endorsement of this product is implied and that products made by other manufacturers may perform similarly). The XLS 10 curtain material consists of 4 mm wide polyester strips woven together with a polyester filament yarn. The XLS 10 material was selected over the other materials listed in Table 1 because: 1) it has a high light transmission, and 2) it has respectable energy retention properties compared to the other types of curtain material that are listed in Table 1 and that have varying amounts of aluminum strips interspersed with the polyester strips. Since our curtains were operated manually, and usually at the start and end of the workday (approximately 8:00 am and 5:00 pm), they would be closed several hours of the day when sunlight was present, but before or after someone had operated the curtain. Using the XLS 10 material significantly reduced the negative impact the curtain would have on the amount of available sunlight, and still realized significant energy retention. Curtain operation was stopped when minimum nighttime temperatures exceeded 60°F. The operating strategies followed for the curtains and the roll-up sides (for ventilation) are summarized in Table 2. It is clear from Table 2 that both temperature and relative humidity (RH) measurements are needed to implement these operating strategies.

Table 1. Light transmission and heat retention properties of several commonly used shade/energy curtains manufactured by Ludvig Svensson, Inc., Charlotte, NC. (Data copied from company literature and not independently verified)

	Light transmission		
Curtain type	Direct light	Diffuse light	Energy saving
XLS 10	85%	78%	47%
XLS 13	70%	65%	49%
XLS 14	56%	53%	52%
XLS 15	46%	43%	57%
XLS 16	36%	34%	62%
XLS 17	25%	24%	67%
XLS 18	18%	17%	72%

Table 2. Operating strategies implemented for the energy curtain and the roll-up sides. These strategies were implemented manually between approximately 8:00 am and 5:00 pm (mostly at the start and end of the workday, but occasionally adjustments were made during the workday).

Curtain:	
Night	If predicted minimum temperature < 60°F, then close curtain.
Day	Open curtain when inside temperature > 60°F.
After 2 cloudy days	Open curtain on third day when RH > 80% and outside RH is lower.
Roll-up sides:	
Between trans-planting and the onset of flowering	Start venting when inside temperature > 75°F. If inside temperature < 75°F and RH >80%, then vent for up to 5 minutes at a time to dehumidify.
During and after flowering	Start venting when inside temperature > 65°F in an attempt to keep the temperature in the 65-75°F temperature range. If inside RH >80%, then vent for up to 5 minutes at a time to dehumidify.

The remainder of this research update will focus on the high tunnel trials and in particular on the impact the energy curtain had on the recorded inside temperatures and light levels, and on how these measurements differed in tunnels with and without such a curtain. Because any impact of such a curtain is most significant during the first several weeks after transplant, data collected during the March 29-May 16 period was used for the evaluations. Since early-season trials with energy curtains were conducted in our tunnels during both 2004 and 2005, data for two years and two locations could be evaluated.

The environmental conditions inside and outside the tunnels were recorded with a datalogger. At HF3, this data was recorded using a 1-minute measurement frequency, while a 5-minute frequency was used at RAREC (where more plots were used and hence more data was collected, necessitating the longer recording frequency). In order to evaluate the impact of the energy curtain, the time period between 8:00 pm and 6:00 am was evaluated (selecting this time period ensured that the curtain was always closed during these hours). Measurements of individual parameters (particularly the nighttime soil and air temperatures, as well as the accumulated light level during the preceding daylight period) were converted into single data points for each day (or measurement period). The average temperatures and summed light levels over the March 29-May 16 period are shown in Table 3.

Table 3. Average air (inside an aspirated box) and soil (six inches below the surface) temperatures (in °F) calculated for the 8:00 pm-6:00 am time period and summed light levels (in mol/m²) for March 29-May 16. The terms 'curtain' and 'no curtain' refer to the tunnels with and without an energy curtain, respectively.

March 29-May 16, 8:00 pm-6:00 am	HF3 2004	HF3 2005	RAREC 2004	RAREC 2005	Average	Percentage
Tair, outside	52.1	49.4	52.8	48.7	50.8	100%
Tair, no curtain	54.5	50.3	54.8	49.6	52.3	103%
Tair, curtain*	56.8	53.6	58.0	51.3	54.9	108%
Tsoil, outside	53.1	52.1	56.5	55.2	54.2	100%
Tsoil, no curtain	66.4	65.6	67.4	65.6	66.3	122%
Tsoil, curtain*	66.8	66.8	68.7	66.5	67.2	124%
Summed light, outside**	1684	1925	1686	2069	1841	100%
Summed light, no curtain**	1333	1468	1383	1433	1404	76%
Summed light, curtain**	1213	1296	1319	1401	1307	71%

*Underneath the curtain; **Accumulated during the daylight period immediately preceding the nighttime measurement window (8:00 pm-6:00 am) and summed over the March 29-May 16 period.

While the data presented in Table 3 summarize the recorded environmental conditions in a very condensed form, and thus fail to show the instantaneous effect the energy curtain can have, they provide a basis for some general conclusions for early season tomato production in high tunnels located in Central and South Jersey:

1) The use of an energy curtain inside a high tunnel increased the inside nighttime air temperature on average by 2.6°F (or 5%) compared to a tunnel without a curtain. A tunnel without an energy curtain maintained an inside nighttime air temperature that was 1.5°F (or 3%) higher compared to the outside nighttime air temperature.
2) The use of an energy curtain inside a high tunnel increased the inside nighttime soil temperature on average by 0.9°F (or 2%) compared to a tunnel without a curtain. A tunnel without an energy curtain maintained an inside nighttime soil temperature that was 12.1°F (or 22%) higher compared to the nighttime outside soil temperature.

3) The use of an energy curtain inside a high tunnel decreased the summed inside light level on average by approximately 100 mol/m² (or 5%) compared to a tunnel without a curtain. A tunnel without an energy curtain maintained an inside accumulated light level that was approximately 440 mol/m² (or 24%) lower compared to the outside accumulated light level.

Given these conclusions and the fact that: 1) only a modest increase in early tomato harvests (because the earlier harvests are relatively small when expressed in number of pounds of fruit harvested per plant) was observed (data not presented here) when comparing the curtain and no-curtain treatments, 2) pulling the curtain twice a day requires a reasonable amount of labor, and 3) the use of a curtain further reduces the amount of light available for crop production, it is not clear the benefits of the curtain outweigh the costs. Of course, the curtain will certainly be very useful on clear nights that result in a significant amount of radiation from the inside of the tunnel to the cold sky. On such nights, the use of an energy curtain may well prevent serious damage to a crop caused by low temperature exposure.

Finally, the potential correlation between the average (for the 8:00 pm-6:00 am time period) soil temperature and the amount of light (and thus energy) received during the preceding daylight hours was investigated, resulting in the following equation:

$$T_{soil} = 0.26*(DLI) + 57.11 \quad (R^2 = 0.42)$$

Where:

Tsoil = average nighttime (between 8:00 pm and 6:00 am) soil temperature (°F)
DLI = daily light integral; accumulated light level during the preceding day (mol/m²)

However, the low correlation coefficient indicates that the data varied significantly and that likely other factors contributed to the resulting nighttime soil temperatures (e.g., the management strategy –and its implementation-- for the roll-up sides used for ventilation, radiation conditions at night, wind conditions at night, etc.). The equation shown above indicates that the average nighttime soil temperature at the start of the trials (March 29) was approximately 57°F.