Season Extension with High Tunnels in Kentucky

Michael K. Bomford, Anthony S. Silvernail, and Brian. A. Geier,
Kentucky State University Community Research Service,
400 E. Main St., Frankfort KY 40601
KSU Organic Agriculture Working Group - http://organic.kysu.edu

Introduction

Commercial vegetable growers in Kentucky have used high tunnels for season extension for more than a decade (1). Most of Kentucky is in USDA plant hardiness zone 6a, with average annual minimum temperatures between -21 and -18ºC and a frost-free period beginning in April or May, and ending in October (2,3). Rapid temperature changes during spring and fall leave little time suitable for cool season crop production outdoors. Between Feb. 2006 and Jun. 2007 we recorded temperatures inside and outside a 9 x 12 m high tunnel used for continuous organic vegetable production at the Kentucky State University Research Farm near Frankfort, KY. Our objective was to determine the effect of an unheated high tunnel on microclimate, in order to develop crop recommendations for Kentucky growers using high tunnels.

Materials and Methods

Tunnel construction and maintenance. The 9 x 12 m high tunnel is supported by 11 aluminum hoops, spaced 1.2 m apart. The tunnel is clad in two layers of 6 mil poly. A 60 W blower fan maintains an insulating air pocket between the two layers. Wood-framed walls at either end contain a screen door and two windows for passive ventilation. Sides roll up to 1 m above the soil surface for additional ventilation. Sides are kept down in winter and up in summer. Windows are kept open during summer, but opened most mornings and closed most evenings in the remainder of the year, according to local weather forecasts. Row covers of Reemay (Fiberweb, Old Hickory TN), supported by wire hoops, were placed over warm season crops when freezing temperatures were predicted in spring 2007.

Temperature recording. On 10 Feb. 2006, Hobo Temperature data loggers (Onset Computer Co., Pocasset MA) were placed in radiation/precipitation shields 2 m inside and outside the center of the high tunnel's north wall and 3 cm above the soil surface. On 15 Dec. 2006 the Hobo data loggers were replaced with air temperature probes attached to a 16-channel CR-10 data logger (Campbell Scientific Inc., Logan UT). Soil probes were added to the system on 30 Jan. 2007 to measure temperatures in the top 10 cm of soil below the air temperature probes. Additional air and soil temperature probes were added under Reemay row covers. Temperatures were recorded hourly until 21 Jun. 2007.

Analysis. Readings were used to calculate daily minimum, maximum, and mean temperatures. Relationships between indoor and outdoor minima and means and between air and soil temperatures were calculated with Excel (Microsoft Co., Redmond WA). These relationships were applied to historical temperature records for the region to predict seasonal temperature fluctuations inside high tunnels.

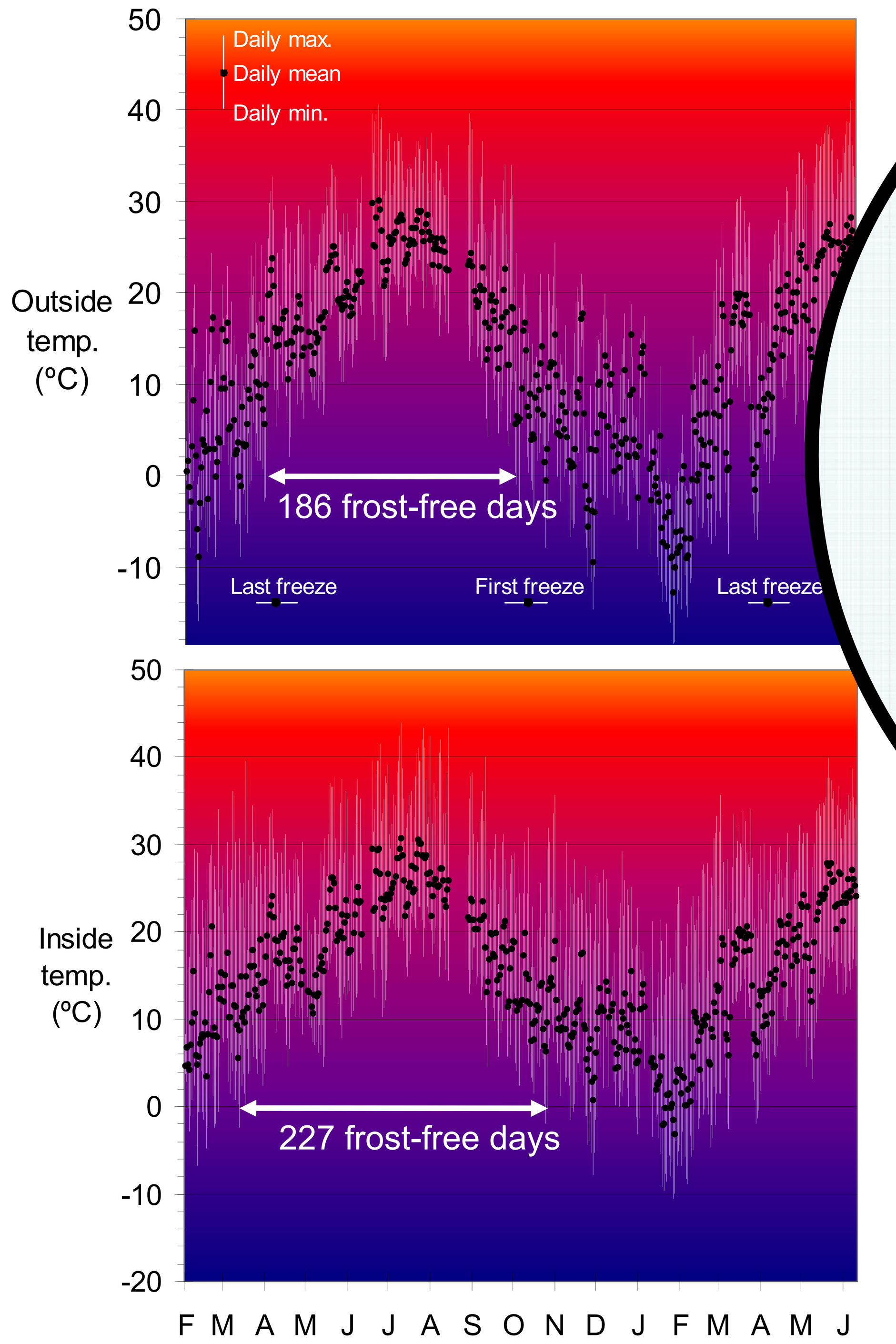
Results and Discussion.

The average temperature inside the tunnel (15.5 ± 0.3°C) was 2.6°C warmer than outside (12.9 ± 0.5°C) (Fig. 1). Outside temperatures ranged from -18 to 41°C and inside temperatures ranged from -11 to 44°C. The average daily temperature range was greater inside the tunnel (18.2 ± 0.3°C) than outside (14.6 ± 0.2°C).

The outdoor and indoor frost-free periods in 2006 were 186 d (1 d less than the Frankfort average) and 227 d, respectively. Tomatoes transplanted into the tunnel on 10 Mar. 2006 were killed by the last frost of the year (22 Mar.); those transplanted on 28 Mar. 2007 survived the last frost (5-10 Apr.) under row covers, where air temperatures did not fall below freezing (Fig. 1, close-up). Outdoor soil temperatures fell below freezing each night during this period, but indoor soil temperatures did not.

Indoor and outdoor air temperatures were related by second-order quadratic, with differences greater when temperatures were lower (Fig. 2). Outdoor soil temperature and air temperature were also related by second order quadratic (Fig. 3). Soil temperature indoors varied less than outdoors, and bore a straight-line relationship to indoor air temperature.

The calculated temperature relationships predict that high tunnels will boost minimum and mean air temperature by 5 and 7°C, respectively, in mid-winter, but have little effect in mid-summer (Fig. 4). The mean daily temperature indoors will remain above freezing in all months, but the average minimum temperature indoors will dip below freezing between late-December, and mid-February. A high tunnel can be expected to extend the frost-free period by approximately 6 weeks in our region of Kentucky, allowing frost sensitive crops to be planted approximately 3 weeks earlier, and extending the fall harvest of frost-sensitive crops by approximately 3 weeks. Annual minimum temperatures between -12 and -10°C can be expected inside Kentucky high tunnels, boosting the USDA plant hardiness zone from 6b to 8a.



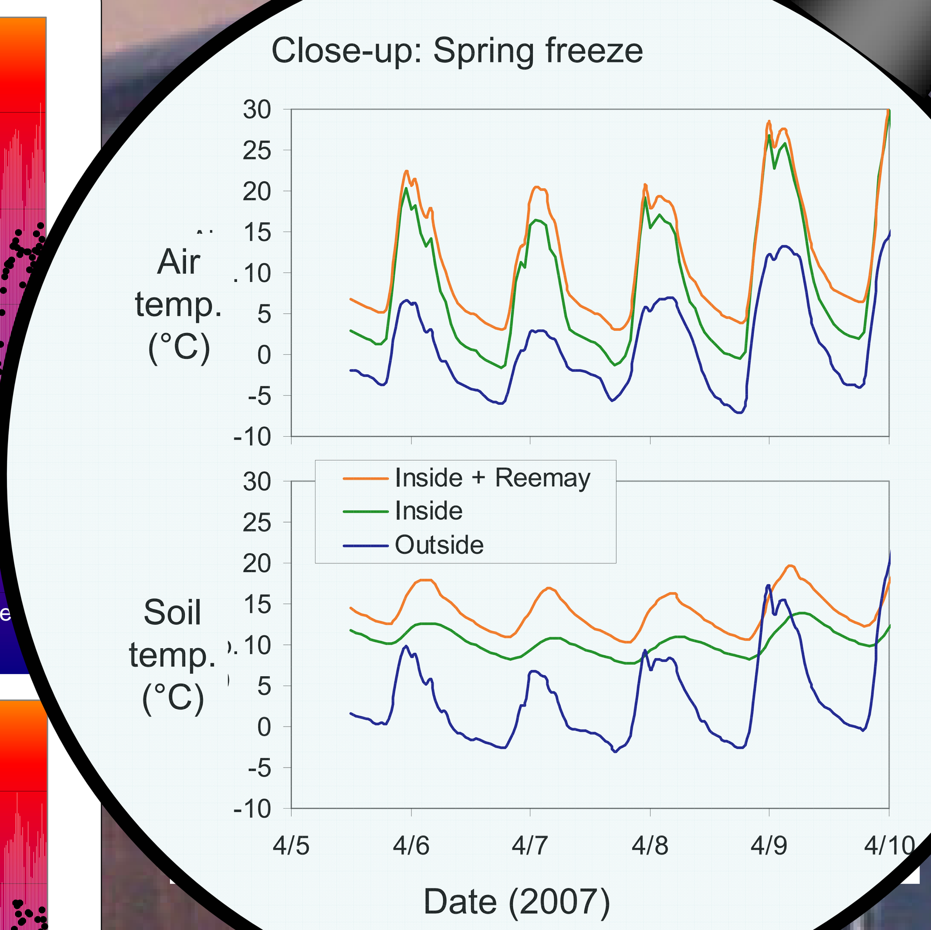


Fig.1. Daily air temperature readings outside (top) and inside a Kentucky high tunnel from Feb. 2006 to Jun. 2007. Dots show daily mean; vertical lines show range. Average first and last freeze dates (1971-2000) are near the bottom of the upper chart, with horizontal lines depicting 90% confidence intervals. The 'close-up' magnifying glass shows air and soil temperature fluctuations over five days in April 2007 when consecutive nightly frosts following unseasonably warm weather caused severe crop damage in the region. Outdoor temperatures (blue) are compared with temperatures inside the high tunnel (green) and temperatures beneath Reemay row covers inside the tunnel (orange).

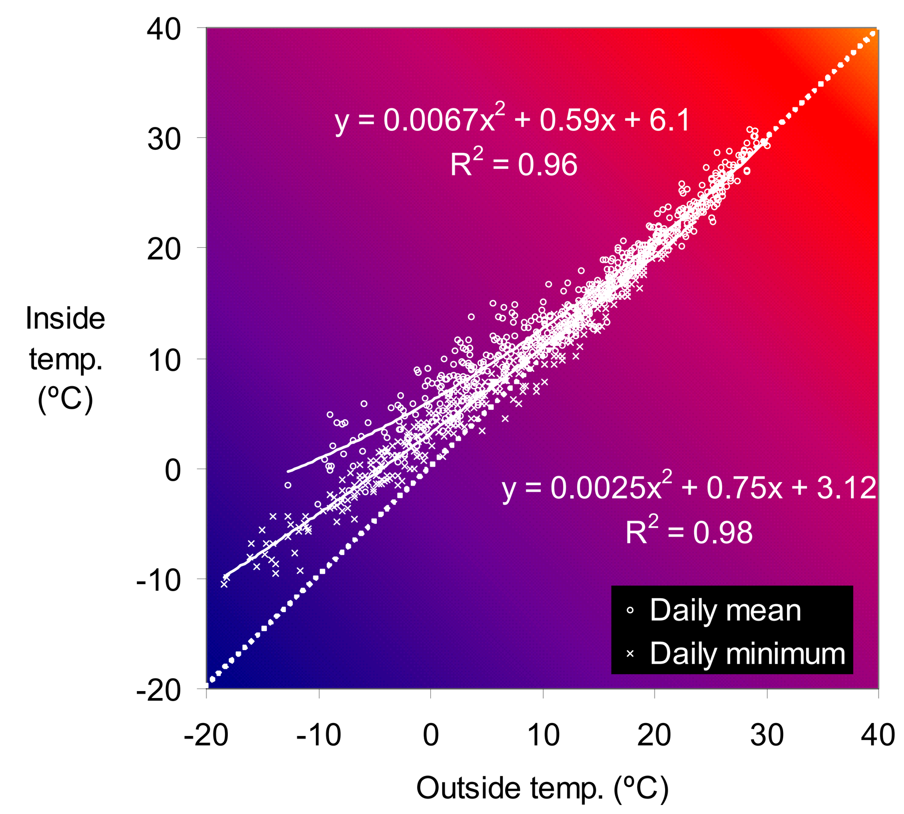


Fig. 2. Relationships between temperature outside and inside a Kentucky high tunnel. Upper and lower equations describe relationship for daily means and minimums, respectively.

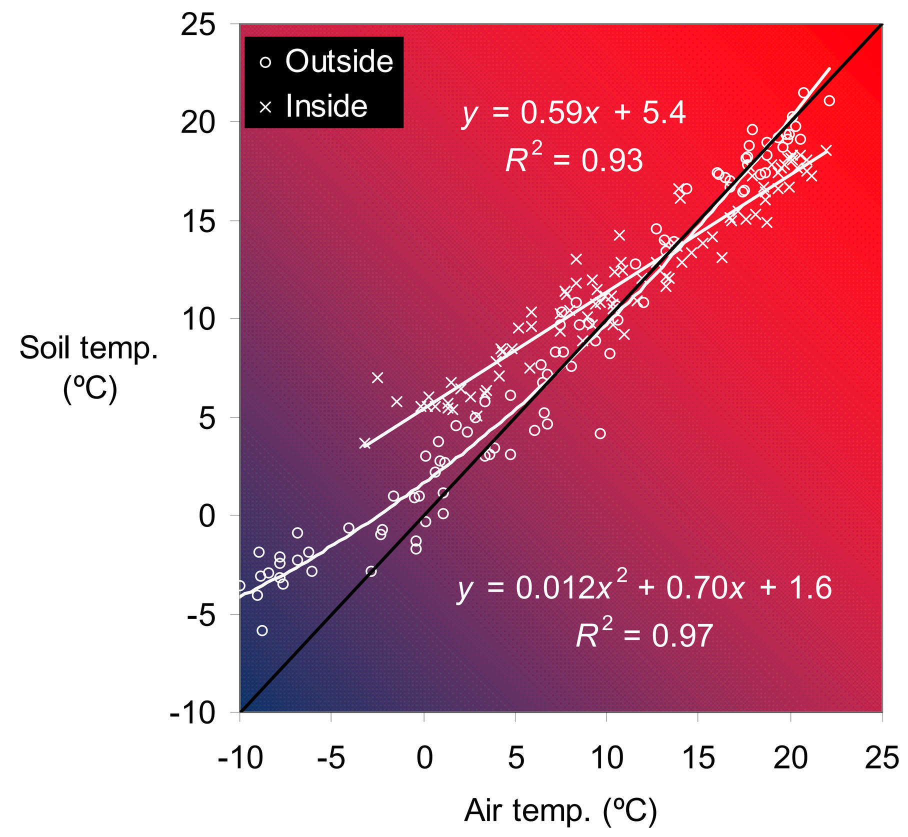


Fig. 3. Relationships between mean daily soil and air temperatures inside (upper equation) and outside a Kentucky high tunnel.

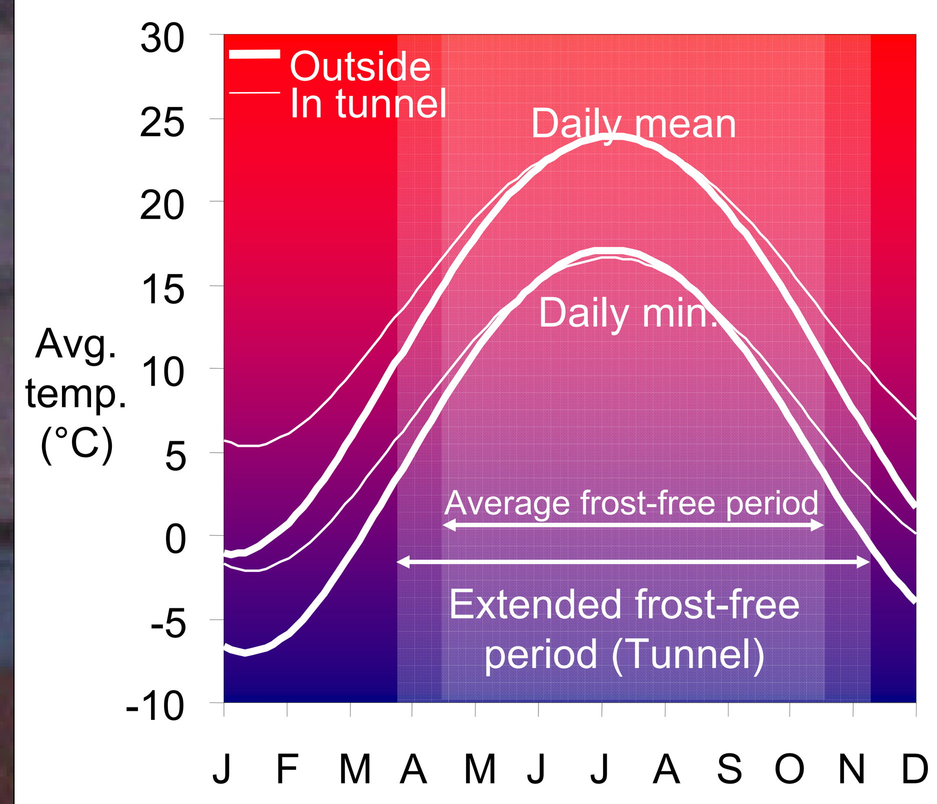


Fig. 4. Predicted mean and minimum daily temperatures inside a Kentucky high tunnel (thin line), based on observed mean and minimum daily temperatures outdoors (1970-2000; thick line) and the relationships presented in Fig. 2. Heavy and light shading shows expected frost-free periods outdoors and in the high tunnel, respectively.

Conclusions

A Kentucky high tunnel with two layers of plastic modifies microclimate in several ways:

1. The frost-free period is extended by approximately six weeks;
2. Average annual minimum temperatures increase by 8-9°C;
3. Daily mean temperatures increase by 2.6°C, with a stronger warming effect at lower temperatures; and
4. The USDA plant hardiness zone rating increases from 6b to 8a.

References

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