

Thermal Protection for Winter Lettuce in High Tunnels

Brian Leib, Zackary Emery, Muzi Zheng, Tim Grant and Wesley Wright
Biosystems Engineering and Soil Science, University of Tennessee

Annette Wszelaki, Jenny Moore and David Butler
Department of Plant Sciences, University of Tennessee

Quick Facts

1. In Tennessee, high tunnels can be used to grow and retain lettuce through the winter months. During very cold periods, lettuce growth can stop and there is the risk of freeze damage.
2. Thermal protection can be added to high tunnels to prevent freeze damage and promote lettuce growth without using heaters.
3. On average, row covers, water bags and thermal blankets increased nighttime canopy temperature by 3.4, 3.5 and 10.1 F, respectively (Fig. 1). Combining these methods of thermal protection results in an additive increase in nighttime canopy temperature.
4. During the coldest winter nights, combining all three thermal protection methods can increase canopy temperature by as much 30 F compared to air temperature outside the high tunnel.
5. Thermal protection methods can reduce the time required for lettuce heads to mature and thus shorten the time to harvest by nearly one month.

High Tunnel Overview

High tunnels are greenhouse-like structures that most often use plastic film instead of rigid glaze, natural soil instead of container growth media, natural ventilation instead of fans and solar radiation alone as a source of heat. They are used to extend the growing season by transforming sunlight into thermal energy to obtain better growing temperatures for the crop. For cool-season crops, like lettuce, high tunnels can allow for year-round production. Crops harvested earlier and later than usual can be sold at a higher price because the produce is available outside of peak season.



Figure 1: Thermal protection in high tunnel

During a Tennessee winter, high tunnels can increase daytime temperature by as much as 25 F; however, night temperatures inside can fall to within a couple degrees of the outside temperature. These low nighttime temperatures can slow growth, cause foliar freeze damage and/or require the lettuce to regrow from the surviving roots, which increases production cost and time before harvest. In order to further extend the growing season and combat potential freeze damage, several methods were tested for their ability to capture and retain heat during winter production of romaine lettuce in a high tunnel at the East Tennessee AgResearch and Education Center Organic Crops Unit in Knoxville.

The test consisted of eight thermal protection treatments deployed inside the high tunnel:

1. A control — no protection beyond the high tunnel and the black plastic mulch
2. Row covers (RC)
3. Thermal blankets (TB)
4. Water bags (WB)
5. Row covers and thermal blankets (RC + TB)
6. Row covers and water bags (RC + WB)
7. Thermal blankets and water bags (TB + WB)
8. Row covers, thermal blankets and water bags (RC + TB + WB).

All methods utilized black plastic mulch on the soil surface because of its proven ability to capture and store heat in past high tunnel and open-field studies. The parenthetical information is a treatment abbreviation that is used in Figure 5.

Row covers both capture solar energy and insulate the crop at night (Fig. 2). The row cover material was a porous spun fabric (9 oz/yard²) with 75 percent light transmission and a 4 to 6 F temperature protection rating. Row covers were left on the crop day and night during most of the growing season.



Figure 2: Row covers

Thermal blankets made from a two-sided radiant barrier with 3/16-inch of closed cell foam insulation in between were used to protect the crop as well (Fig. 3). In addition to providing a radiant barrier and insulation, this material also reduced heat loss by serving as a vapor barrier. The thermal blankets were made from a lightweight material (7oz/yard²) so that they could be easily placed over the plant canopy. Thermal blankets were only used during nights when the temperature was predicted to be less than 42 F.



Figure 3: Thermal blankets

The water bags were 10.2-inch diameter, 6-mil black polyethylene tubing used to store water on both sides of crop rows as shown in Figure 4. These poly tubes stored around 4.2 gallons of water per foot of tubing. During the day, the water inside the tubing can store 8.33 BTUs of heat per gallon for every degree F increase in temperature. The water then releases that stored heat at night when the temperature drops. Air can only store 0.003 BTUs per gallon per degree F of temperature change.



Figure 4: Water bags

The thermal protection methods were tested on ‘Breen’ romaine lettuce (a compact mini type of Romaine) during the late fall of 2017 through the winter of 2018. Lettuce was transplanted on December 1, 2017. Lettuce plots were harvested as the heads matured with the last lettuce being harvested on March 23, 2018.

Thermal Protection

Adding thermal protection to the high tunnel increased canopy and soil temperature, thus improving the growth environment during the time they were used (Table 1). Thermal blankets provided the greatest nighttime increase in canopy temperature at 10.1 F for an individual treatment while row covers and water bags provided less than half that level of protection. Row covers also provided an increase in daytime canopy temperature since they act somewhat as a greenhouse within a greenhouse. However, there was an unexpected decrease in daytime canopy temperature when thermal blankets were used without row covers. This may be due to low solar radiation available during winter and the reflective thermal blanket lying near these treatments. The overall increases in canopy temperatures created a corresponding increase in soil temperature for all treatments. There was a concern that the thermal blankets would cause condensation on the crop canopy increasing the potential for foliar disease because this material is also a vapor barrier. However, condensation and foliar disease were not observed during the trial.

The individual effect of the row covers, water bags, and thermal blankets were almost additive when used in combination. **The combining of all three materials inside the high tunnel maintained a 30 F canopy temperature on the coldest night of the testing period (January 2) when the outside temperature dropped to 0.0 F** as shown in Figure 5. This increased canopy temperature by 30 F and soil temperature by 7 F as compared to black plastic mulch only. Some lettuce plants in the black plastic mulch plots froze and needed to regrow from the roots while the thermally protected lettuce survived the freeze and thrived in the warmer environment created by the thermal protection practices.

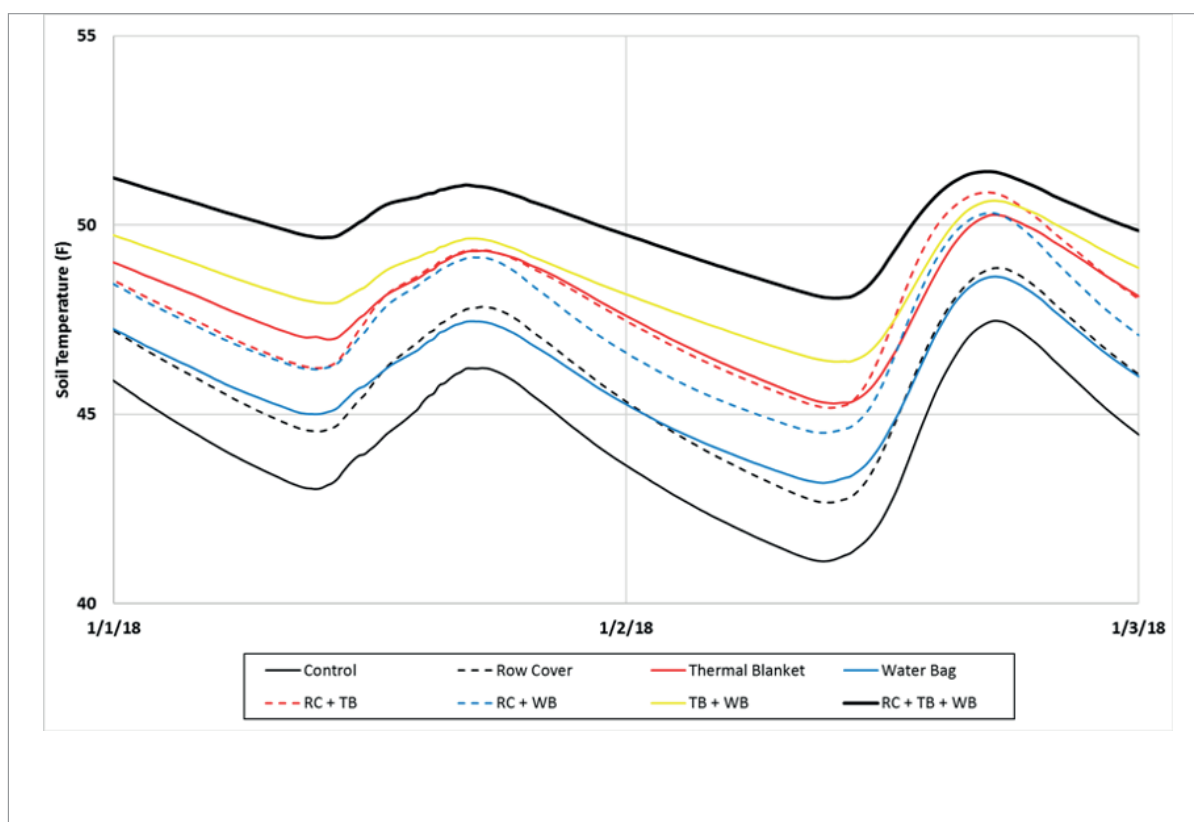
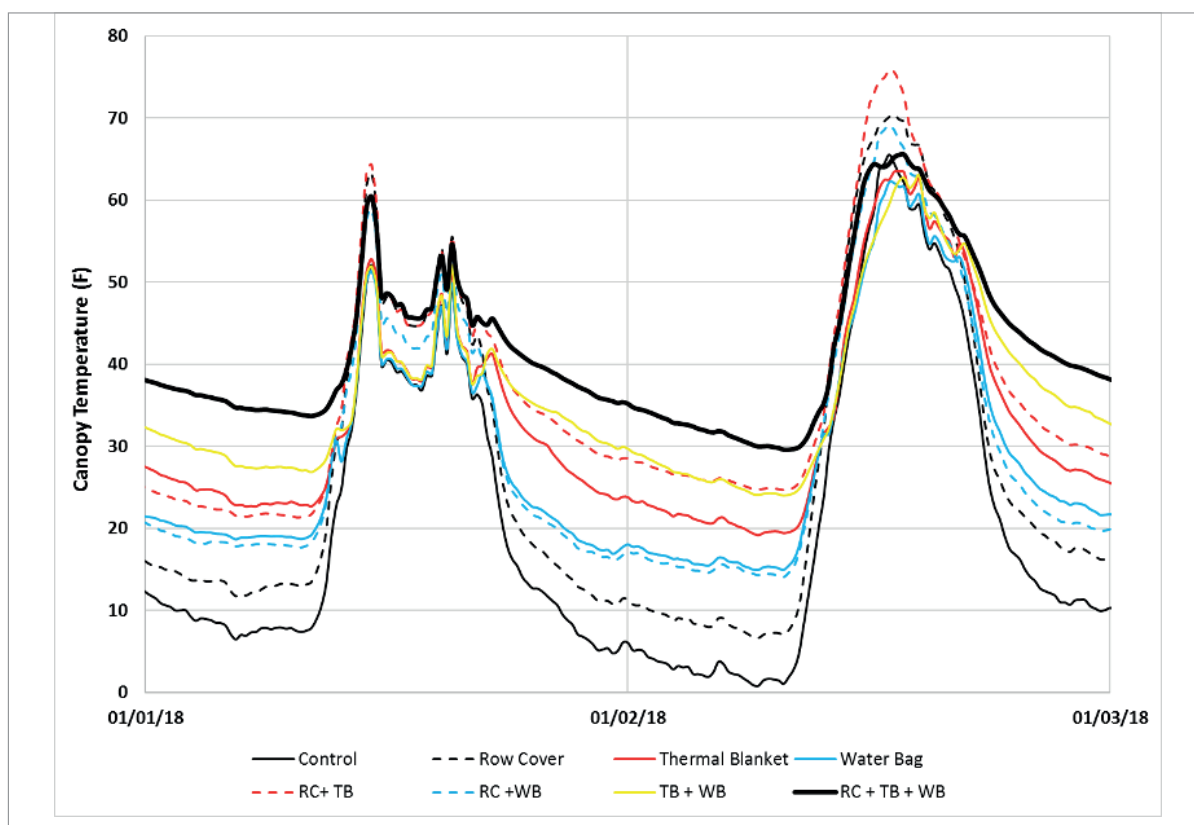
These thermal protection practices showed great

promise for winter season production and there is further potential for increasing the level of protection and improving the growth environment in high tunnels. For instance, the water from the black water bags could be pumped through underground pipes allowing for more heat storage in the soil, or thicker thermal blankets and row covers could further insulate the crop and soil. However, it should be noted that higher temperatures are not the only goal for some crops like lettuce since excess heat can create bitter flavor. It is important to manage a high tunnel’s ventilation system in conjunction with thermal protection to obtain the best growing environment possible.

Table 1: Average temperature increase in the high tunnel from individual treatments and treatment combinations in degrees F as compared to black plastic mulch plots.

	Row cover	Thermal blanket	Water bag	Row cover & thermal blanket	Row cover & water bag	Thermal blanket & water bag	All treatments
Nighttime canopy	3.4	10.1	3.5	11.9	6.5	13.8	16.9
Daytime canopy	4.6	-1.2	0.5	4.6	4.8	-1.4	2.7
Nighttime soil	0.8	2.5	0.4	2.3	2.1	3.2	4.1

Figure 5: Thermal protection in the high tunnel on the coldest night during the test period.



Days to Lettuce Harvest

There was no correlation with increased temperature and yield by plot weight for winter lettuce since heads were harvested when mature; however, the warmer daytime and nighttime temperatures led to the treated plots being harvested two weeks to almost a month sooner than the lettuce grown with black plastic mulch alone (Table 2). Also, all marketable heads (16 possible) were able to reach maturity in the treated plots as compared to those without thermal protection (Table 3). The less mature heads in the control plot were harvested early to allow for the spring crop cycle and these heads would only be marketable at farmers’ markets at a lower price. The less mature heads were related to the lettuce that that needed to regrow after die back during the January 2 freeze.



Figure 6: Lettuce harvest

Cost to Achieve Benefits

Providing thermal protection is not limited to the materials selected for this trial. Other materials could be used to protect and warm crops, increasing profits by reducing production time. The row cover, thermal

blanket, and black plastic mulch used for small plots in this high tunnel were \$0.025/ft², \$0.50/ft², and \$0.0068/ft², respectively. The water bags used to store water for heat capture and release cost \$0.26/foot or \$0.06/gallon. The row covers and water bags only required one-time set-up and removal while the thermal blankets required 20 minutes in the morning and in the evening on the days that they were used.

Due to the need for treatment replication, the thermal protection methods used for the experiment were scaled down to create many small individual plots; however, these methods or combinations of them could be scaled up to be more efficient and practical in full scale high tunnel operations.

Conclusion

Lettuce crops grown out of season in high tunnels can benefit from additional thermal protection. Thermal protection increased the canopy and soil temperature, allowing for a shortened growing season and increased the number of mature lettuce heads. The materials used to increase thermal protection are reusable, with the exception of black plastic mulch, which can defray the cost over multiple growing seasons. Thermal protection strategies, used individually or in combination, could be an important addition to a high tunnel operation growing lettuce or similar crops during the coldest time of the year in locations with moderate climates like Tennessee.

Table 2: Lettuce harvest (letters indicate mean separation)

	BP mulch only	Row cover	Thermal blanket	Water bag	Row cover, thermal blanket	Row cover, water bag	Thermal blanket, water bag	All treatments
Days to harvest	118.0 A	99.6 C	97.4 D	102.0 B	94.6 E	99.7 C	97.5 D	92.5 F
Days early	0.0	18.4	20.6	16.0	23.4	18.3	20.5	25.5

Table 3: Maturity of lettuce

	BP mulch only	Row cover	Thermal blanket	Water bag	Row cover, thermal blanket	Row cover, water bag	Thermal blanket, water bag	All treatments
Mature heads	6.3	13.7	14.3	16.0	15.0	13.3	14.3	15.7
Immature heads	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



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