

Thermal Protection for Spring Tomatoes in High Tunnels

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Quick Facts

1. In Tennessee, high tunnels can be used to plant tomatoes one month earlier than open-field tomatoes. A freeze can still damage tomatoes grown in high tunnels when transplanted before mid-March and these tomatoes may need to be replanted.
2. Thermal protection can be added to high tunnels to prevent freeze damage and promote early tomato growth without using heaters.
3. On average, row covers, water bags and thermal blankets increased nighttime canopy temperature by 3.0, 4.1 and 7.3 F, respectively (Fig. 1). Combining these methods of thermal protection results in an additive increase in nighttime canopy temperature.
4. During the coldest nights of late February and early March, combining all three thermal protection methods can increase canopy temperature by as much as 33 F compared to air temperature outside the high tunnel.
5. Early tomato yield can be increased by nearly 50 percent due to increased solar heat storage during the day and reduced heat loss at night from thermal protection in high tunnels.

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 for warm-season crops by almost a month (earlier planting in spring or delayed harvest in fall) by transforming sunlight into thermal energy to obtain better growing



Figure 1: Thermal protection in high tunnel

temperatures for the crop. Crops harvested earlier and later can be sold outside of peak season at a price premium. High tunnels can increase daytime temperature by more than 50 F in the spring; however, at night, the temperature can fall to within a few degrees of the outside temperature. Some producers use heaters to combat cold temperatures that can stunt growth or kill plants. However, running heaters can greatly increase production costs. In order to extend the growing season without using heaters or risking freeze damage to plants, several thermal protection methods were tested in a high tunnel for their ability to capture and retain heat for spring tomatoes that were transplanted in late winter at the East Tennessee AgResearch and Education Center 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 the early growth period (March 1 until April 26).



Figure 2: Row covers

Thermal blankets made from a two-sided radiant barrier with 3/16-inches 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 minimum temperature was predicted to be below 50 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 an 'Early Girl' tomato crop started in the late winter of 2017. The tomatoes were transplanted on two different dates: March 1, 2017, as an early planting and March 16, 2017, as a second planting. Both plantings were strip harvested on June 7, 2017.

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 7.3 F for an individual treatment while row covers and water bags provided about half the protection of thermal blankets. Row covers and water bags also provided an increase in daytime canopy temperature. This effect was expected for row covers since they act somewhat as a greenhouse within a greenhouse. However, the water bags absorbed heat as expected during the day, but also emitted some of that absorbed heat during the day, which was not expected. 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 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 additive when used in combination. **The combining of all three materials inside the high tunnel maintained a 52 F canopy temperature on the coldest night of the testing period (March 16) when the outside temperature dropped to 19 F** as shown in Figure 5. This increased canopy temperature by 33 F and soil temperature by 8 F as compared to black plastic mulch only. Some tomato plants in the black plastic mulch plots froze and needed to be replanted while the thermally protected tomatoes survived the freeze and thrived in the warmer environment without using heaters.

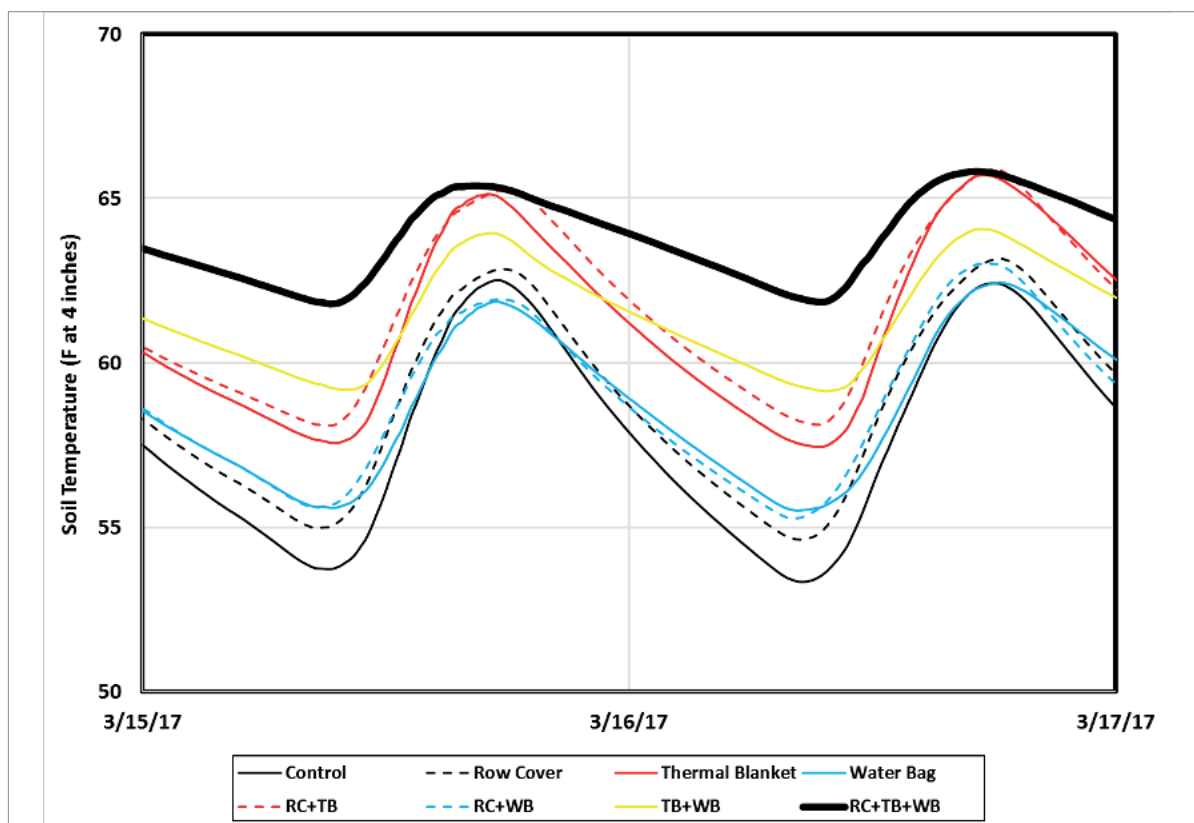
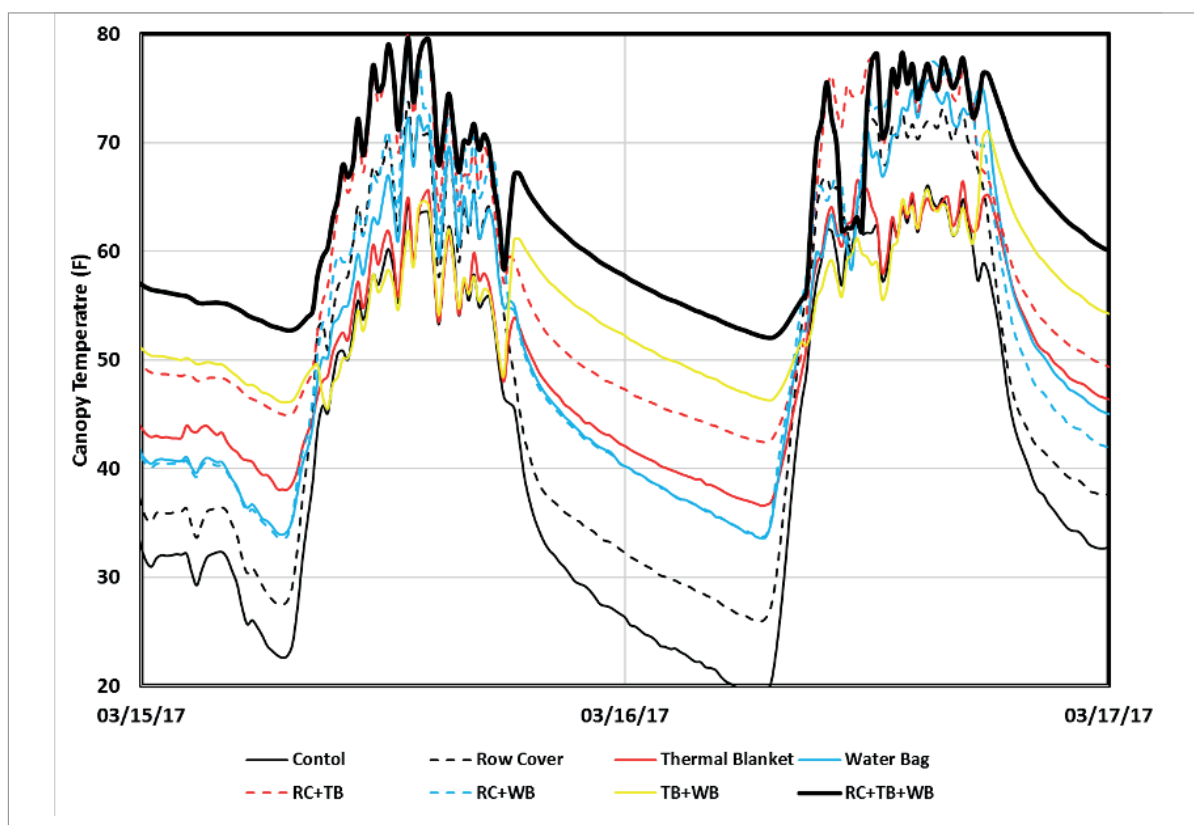
These thermal protection practices showed great promise for starting production of warm-season crops in late winter and there is further potential for

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 warm-season crops like tomato since excess heat can increase water use and create calcium deficiency. 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	3.0	7.3	4.1	9.8	7.1	11.6	16.0
Daytime canopy	6.1	0.1	5.8	8.4	10.0	0.3	9.4
Nighttime soil	0.9	2.2	0.8	2.1	1.7	2.7	4.7

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



Tomato Yield

To avoid the possibility of freeze damage to all treatments, tomatoes were planted at two different timings: early planting on March 1 and second planting on March 16. The entire crop was strip harvested on June 7. Strip harvesting was used to emphasize earliness and to avoid the difficulty of harvesting over a longer period and tracking the yield data when plot vegetation had grown together. The yield data for each planting date was analyzed separately because strip harvesting on the same date meant that the March 16 planting had a shorter growing season than the March 1 planting. Total weight was used because the smaller and cull tomatoes in strip harvesting may have become viable tomatoes later in the season had they been given the chance to grow and ripen.



Figure 6: Tomato harvest

Thermal protection created greater yield increases for early planted compared to later planted plots (Table 2). This may be because there was less need for thermal protection after the second planting date. The thermal blankets were only applied a couple of nights after the second tomato planting. The largest increase in tomato yield was caused by the combination of all thermal protection practices. The increased temperature during the day and night in the early season allowed the tomato plants to grow more quickly and increased the total yield. The level of thermal protection gained from these heat storage and insulation methods could have allowed for an even earlier planting date, which would have been expected to create greater yield increases between thermal protection practices.

Cost to Achieve Benefits

Providing thermal protection is not limited to the materials selected for this trial; there are other materials that could be suited to protect and heat crops that can increase profits and reduce production costs. The row cover, thermal blanket, and plastic mulch material used for small plots in this small 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 individual plots; however, these methods or combinations of them should be scaled up to be more efficient and practical in full scale high tunnel operations.

Conclusion

Tomato crops can be planted much earlier in a high tunnel with the addition of row covers, thermal blankets and water bags. The additional thermal protection provided by these materials protects tomatoes from freeze events in the early season and provides better soil and canopy temperatures for tomato growth. The materials used to increase thermal protection are reusable, except for black plastic mulch, which can defray the cost over multiple growing seasons. Overall these methods, or a combination of them, could be an important addition to any high tunnel operation growing tomatoes or similar crops in early spring.

Table 2: Total tomato weight per three plants from strip harvest in pounds (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
March 1 planted	24.2 A	34.5AB	23.9 A	30.8 AB	34.7 AB	33.4AB	35.0 AB	37.5 B
March 16 planted	18.5 A	20.5 A	21.8 A	16.8 A	18.7 A	22.8 A	15.8 A	24.9 A



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