Using Solar Energy to Heat the Soil and Extend the Growing Season in High Tunnel Vegetable Production

Principal Investigator

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Project Duration

2008 to 2011

Award Amount

$17,692.00

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Project Summary

This past year we installed a high tunnel that uses solar heat to warm the soil below the tunnel. We pump hot air from three solar panels through a series of corrugated tile lines buried beneath a 30' x 48' high tunnel. The hot air warms both the soil and dramatically increases nighttime air temperatures in the high tunnel. By December, the temperature in the high tunnel was too low and the light too dim for tomatoes and cucumbers. We were able to grow and harvest lettuce, spinach, and radishes in December.

Project Description

My wife and I raise vegetables and shitake mushrooms at a small farm just south of Frazee to sell at a nearby farmer's market. Several years ago, I started raising vegetables in a small 20' x 24' high tunnel. The high tunnel immediately improved my sales at the farmer's market because I was able to sell tomatoes and cucumbers 2 months earlier than from my outside garden. With the high tunnel, I was able to expand my growing season from 120 frost free days to 150-170 days.

Although the high tunnel was a big benefit to my market garden, I soon saw several weaknesses of traditional high tunnels which rely on passive solar heat. High tunnels heat up quickly at sunrise, but at night the air temperature falls to only a few degrees warmer than the outside air. As a result, we had to install an electric heater to keep our plants alive during long cold snaps in early spring. We tried a propane heater, but our heater released ethylene gas into the tunnel that caused

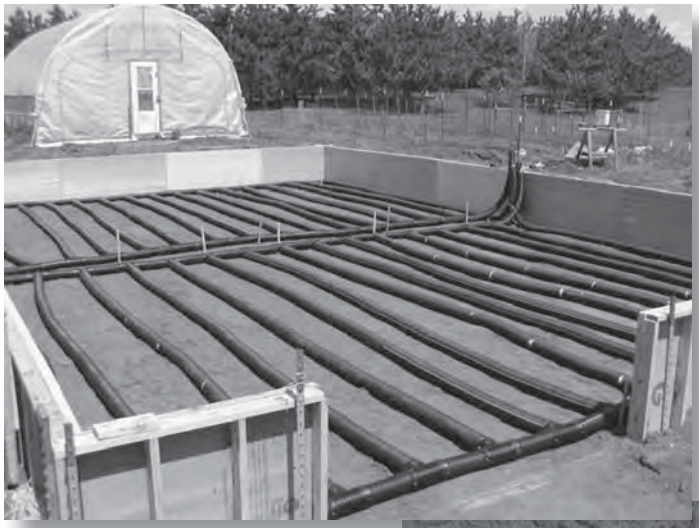

Figure 1. The lowest layer of tile line with the traditional high tunnel in the background.

Figure 2. The second layer of tile line. The tile line was hooked up to the solar panels in the center of the picture.

the tomato blossoms to fall off. Both the electric heater and sunlight warmed the air in the high tunnel, but they did a poor job of heating the soil. This past spring, cool soil temperatures caused both the cucumber and the tomato plants to become deformed. With my traditional high tunnel, I can't even grow cool weather crops like spinach past the middle of November. We wanted a high tunnel that could expand our growing season to 270 days for frost tolerant crops like tomatoes and longer for cool weather crops like spinach. I would like to plant tomatoes at the end of February and take advantage of the long, warm days and stronger sun in March and continue picking tomatoes until early December.

Figure 3. The interior of the high tunnel after it was completed.

Figure 4. The new high tunnel. The smaller traditional high tunnel is in the back.

Figure 5. Solar panels on the south and east side of the high tunnel.

I designed a way of heating high tunnels where hot air from solar panels is pumped into tile line buried beneath the tunnel. This past spring, I excavated an area next to my old high tunnel that is 4' deep. My soil is sandy loam over a sand subsoil. The excavator put the topsoil and the sand subsoil in separate piles. I covered the bottom of the hole with 2" styrofoam insulation. I installed 2" thick insulation on the bottom 2' of the sides, and 4" thick insulation on the top 2' of the sides. I covered the insulation at the bottom of the excavation with 1' of sand and placed one layer of 4" corrugated plastic drain tile over the sand (Figure 1). After covering the tile with sand, I installed a second layer of drain tile 8" above the first line, with the lines perpendicular to the first line. The line was covered with sandy subsoil. I used 2,000' of tile line for the two layers (Figure 2). The corrugation in the tile increased the surface contact between soil and tile so that there is 8' of surface area for every 5 linear feet of tile. On top of the sand, I put 18" of "Dicks Super Soil," a decomposed peat topsoil bought from a nearby dealer. The topsoil was supported on the outside with 2" x 12" white oak boards. The special soil had a higher nutrient holding capacity than my native soil. I formed the soil into raised beds and covered the raised beds with black plastic (Figure 3).

We used hot air instead of water to transfer the heat from the soil to lower the cost. The cost of a solar panel that heats water is significantly higher than the solar panel we are using. Pipes would have been more expensive and have required more maintenance than plastic tile line.

We put a 30' x 48' FarmTek high tunnel over the heated soil area (Figure 4). The covering for the tunnel consists of two layers of plastic with an insulating air chamber between the layers. Finally, we installed solar panels to heat air going into the tile lines (Figure 5). Small fans in the tile lines move the heated air from the panel through 4" plastic pipe into the soil. The thermostat kicks on when the temperature of the air in the solar panel reaches 125ºF and turns off when the temperature falls to 95ºF.

In September, we planted tomatoes, cucumbers, spinach, Swiss chard, lettuce, and onions in the heated high tunnel. In late winter, we will plant warm season crops such as tomatoes and peppers for both the farmer's markets and restaurants.

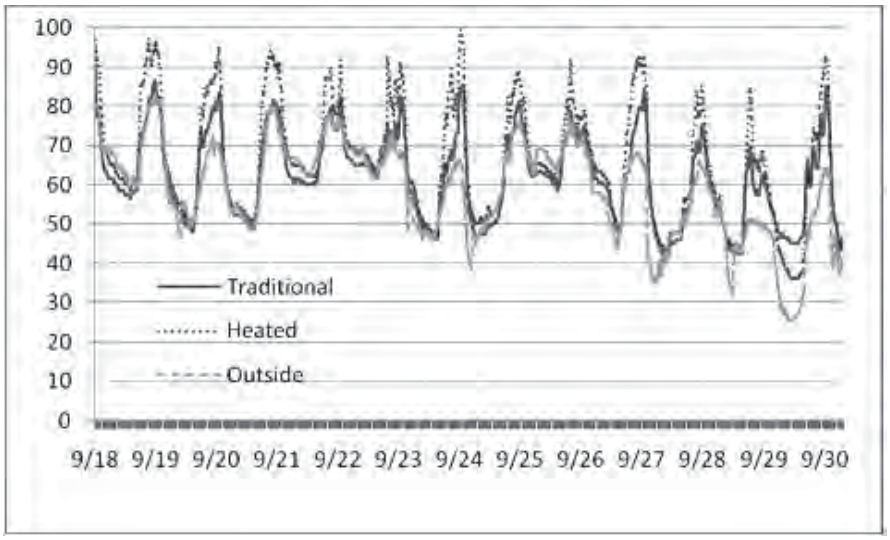

Figure 6. Temperature in the soil-heated and traditional high tunnels before the heating system was hooked up. Nighttime temperatures were similar in the traditional high tunnel and the new high tunnel, except during the heavy frost on September 30, when the temperature in the new high tunnel was lower than the traditional high tunnel.

Results

The new high tunnel took more time to construct than we had planned. The time when we wanted to install the high tunnel corresponded to the peak of our workload for our market garden. Many high tunnels were built in 2008, and the people who installed the high tunnels had previously contracted with other jobs. We finished the excavation in June and the installation of the tile lines by July 1. During July, we constructed the high tunnel and we finished installing the plastic over the tunnel in late August.

In September, the new high tunnel was heated with passive solar heat like a regular high tunnel. We were still installing the solar panels and air pumps and we had not started heating the soil. Using passive solar heat, the daytime highs in the new tunnel were slightly higher than in our other high tunnel, but at night the temperature in the larger tunnel was the same or even lower than the traditional high tunnel (Figure 6). The old high tunnel was filled with mature cucumber and tomato plants, while the new tunnel was largely empty at the time. The vegetation in the traditional tunnel kept daytime temperatures lower and nighttime temperatures higher than in the new high tunnel before we started pumping hot air below the tunnel.

On October 2, I hooked up the tile lines to the solar panels and began pumping warm air into the soil beneath the tunnel. Daytime temperatures in the two tunnels remained similar, but the nighttime temperature in the heated high tunnel fell to 53ºF shortly after sundown and remained at the same temperature the rest of the night (Figure 7). The air temperature in the old high tunnel continued to rise and fall in a typical diurnal pattern, with overnight lows near 40ºF just before sunrise. Nighttime lows outside the tunnel were near freezing every night the first week of October. Following a cool, cloudy and rainy spell between October 10 and 12, the nighttime temperature in the heated high tunnel fell to 46ºF every night, while temperatures in the traditional high tunnel were falling into the low 40's and high 30's.

At night, the air is heated by the soil whether in a field or a high tunnel. By heating the soil, we were able to keep the nighttime air temperature in the high tunnel from falling to levels that hurt warm season crops during the month of October. Growth in cucumbers and tomatoes will slow when the temperature at night falls below 45ºF.

In November, we went through a long, cloudy spell. We only had 10 days during the entire month when the temperature in the solar panels was high enough to trigger the thermostat to pump hot air through the soil. From November 4-24, there were only 3 days with sun. In spite of clouds and below freezing weather, the heated high tunnel stayed above freezing the whole month. We were losing considerable heat in the tile lines between the solar panel and the soil, so we covered the tile lines with foam insulation in late November. The soil temperature in the traditional high tunnel dropped to near freezing the month of November, while the temperature in the heated high tunnel remained in the mid 40's (Figure 8).

Plants

We planted cucumbers, tomatoes, lettuce, spinach, kale, Swiss chard, onions, and radishes in the heated high tunnel in early September. The cucumbers were stunted by the end of October and died in the middle of November due to a lack of light and cool weather. The tomatoes were still alive, but the temperature was too cool and the light too weak for the plants to set fruit. The greens are growing quite well. I have been able to fill 9 weekly orders of lettuce, spinach, kale and Swiss chard to a local restaurant.

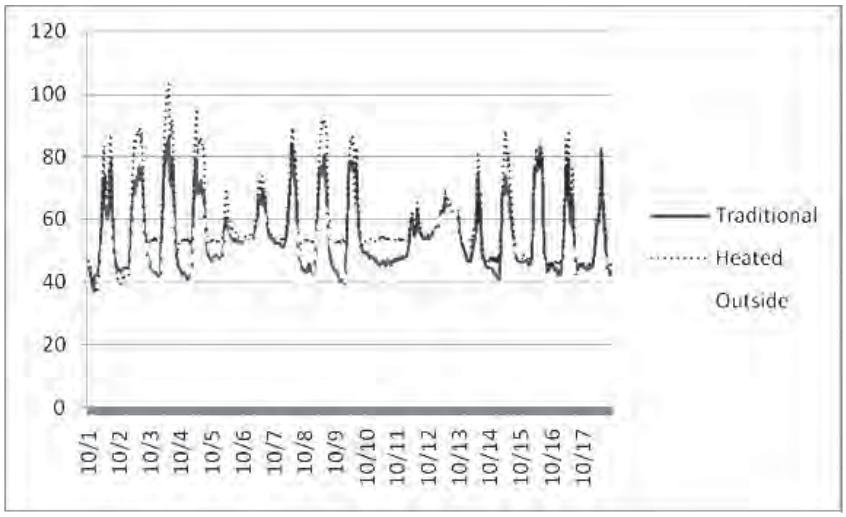

Figure 7. Air temperature in the soil-heated and traditional high tunnels in October. Neither high tunnel had supplemental heat. The temperature in the soil-heated high tunnel dropped to 53ºF each night from October 3 through October 12, regardless of the outside temperature.

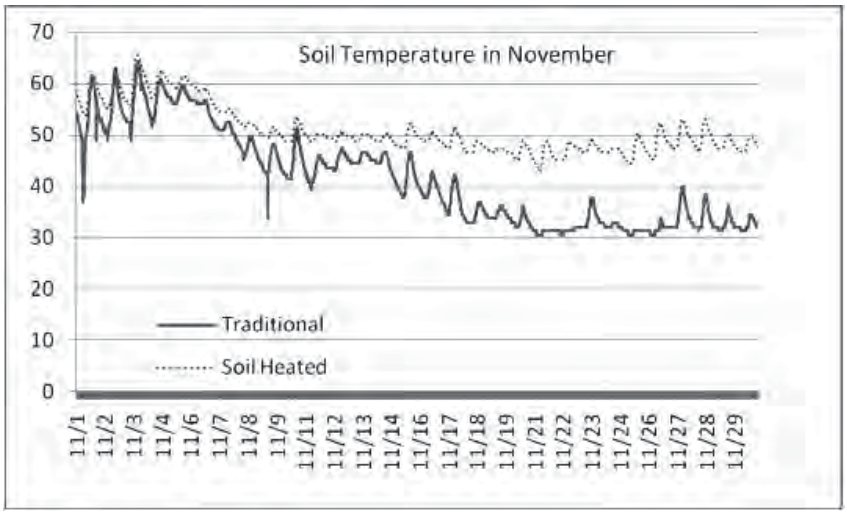

Figure 8. Soil temperature (2 inches) in the traditional and soil-heated high tunnels during the month of November. We used an electric air heater in both tunnels from November 1-15. We shut the electric heater off in the traditional tunnel on November 16 and kept the air heater on all month in the soil-heated tunnel.

Management Tips

1. Heating the soil does keep the air temperature from cooling at night.

2. The forced air adequately transfers heat from solar panels to the soil. The 4' of soil provides an adequate heat sink.

3. We do not recommend using a timer to turn the drip irrigation system on and off. Instead, we manually turn the water on and off. Water use decreases sharply when days get shorter and the timer does not adjust to the lower usage on its own.

4. Always use raised beds, because they keep the soil softer and allow for faster root development. Root crops are especially easier to harvest from a raised bed.

5. We would have preferred to hook up the system in early September instead of early October.

Cooperators

Terry Nennich, University of Minnesota Extension, Bagley, MN
Thaddeus McCamant, Northland Community and Technical College, Detroit Lakes, MN

Project Location

Forest Glenn Farm is 4 miles southeast of the town of Frazee. Take Hwy. 10 east of Frazee and go south on Black Diamond Rd. approx. 1.5 miles. The road will "T". At the "T", go right on Rice Lake Rd. approx. 2 miles. Our farm is located at the end of the road. Go through the public access and then you are at our farm.

Other Resources

FarmTek high tunnels.
Website: *www.farmtek.com/farm/supplies/home*

High Tunnels website sponsored by Kansas State Research and Extension, University of Missouri Extension, and University of Nebraska Cooperative Extension.
Website: *www.hightunnels.org/*

Nennich, T., David Wildung, and Pat Johnson. 2004. Minnesota High Tunnel Production Manual for Commercial Growers.
Website: *www.extension.umn.edu/distribution/horticulture/M1218.html*

Pennsylvania State University High Tunnel
Website: *http://plasticulture.cas.psu.edu/H-tunnels.html*