Principal Investigator

Dallas Flynn
48677 Rice Lake Rd.
Frazee, MN 56544-8908
218-841-6380
drusadal@hotmail.com
Otter Tail County

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2008 to 2010

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$17,692

Staff Contact

Jean Ciborowski
651-201-6217

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

ʾroject Summary

n 2008, we installed a 30' x 48' high tunnel hat uses solar heat to warm the soil below he tunnel. We pump hot air from two solar panels through a series of corrugated tile lines ɔuried beneath the structure. In addition to mproving plant health with warmer soils, the ıeated tunnel had much warmer nighttime emperatures, especially during the critical ɔeriod of early to late spring. During 2009 ınd 2010, our tunnel had no frost from the niddle of March to the middle of November, ınd the temperature rarely dropped below 15°F during the growing season, increasing growing degree days by a third. We harvested ome crops grown in the tunnel two months earlier than their counterparts grown outside ınd estimate that we could pay for the tunnel n 3 to 4 years by selling our early tomatoes ınd cucumbers at the farmers' market.

ʾroject Description and Results

My wife and I raise vegetables and shiitake nushrooms at a small farm just south of Frazee to sell at a nearby farmers' market and o restaurants. Several years ago, we started aising vegetables in a small 20' x 24' high unnel. The high tunnel extended our growing season from 120 frost free days to 150-170 days, but the traditional high tunnel did a poor job of warming the soil and preventing spring frost damage.

In 2008, we built a high tunnel that uses solar heat to warm the soil beneath. I excavated an area 4' deep next to my old high tunnel, separating the topsoil and the sand subsoil. I covered the bottom of the hole and the bottom 2' of the sides with 2" Styrofoam insulation. I used 4" thick insulation on the top 2' of the sides. The insulation at the bottom of the excavation was covered with 1' of sand and then I placed one layer of 4" corrugated plastic drain tile over the sand. 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. This line was covered with sandy subsoil. The corrugation in the tile increased the surface area 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. The topsoil was supported on the outside with 2" x 12" white oak boards. The special soil proved to be low in potassium, so we added compost made from cattle manure into the soil in 2009. I formed the soil into raised beds and covered the raised beds with black plastic.

Backfilling over the tile line during construction.

The high tunnel structure.

We installed a 30' x 48' FarmTek high tunnel over the heated soil area. The covering for the tunnel consists of two layers of plastic, which makes an insulating air chamber between the layers. While the double layer of plastic decreases the amount of sunlight reaching the crops, it increases insulation, which can be critical in early spring. It is important to note that the loss of sunlight from the double layer of plastic is not enough to negatively affect the growing of our plants.

We installed two solar panels to heat air that is pumped into the two layers of tile lines 3' below the soil in the tunnel. A fan pumps air back from the drain tiles in the soil through the solar panels. The fan is controlled by a thermostat, which turns the fan on when the temperature in the solar panel reaches 125°F, and turns it off when it drops below 85°F. We kept the thermostats operational all winter long.

2008/2009

The winter of 2008/2009 was colder than average. Although the heated high tunnel stayed much warmer than either the outside or the unheated high tunnel, the temperature was too cold for anything to grow during January and February. Key temperatures for both 2009 and 2010 are summarized in Table 1.

After March 7, soil and nighttime temperatures rose rapidly and we started planting tomatoes and cucumbers in the heated tunnel on March 15 when the soil temperature was 45°F. The tomatoes grew very well, but the first cucumbers either died or were permanently stunted by the cold. Radishes, lettuce, and chard were planted in the tunnel in early March as well. Spinach and kale that we'd planted in the fall overwintered in the tunnel.

We started selling cucumbers in early June. We started harvesting tomatoes on June 7 and started selling tomatoes on June 15, which was 8 weeks earlier than in the unheated high tunnel! We sold out every time we went to the farmers' market and we became known for quality cucumbers and tomatoes. Seventy-five percent of our sales in 2009 were from high tunnels. We calculated that the heated high tunnel helped our business and total returns were up 35%.

We planted kale and spinach in the fall for harvest next spring. We continued harvesting tomatoes until the end of November, then down the tunnel in December to give ourselves a rest and allow the tunnel to freeze in order to reduce disease and insect pests.

2009/2010

The winter of 2009/2010 was fairly mild, and spring arrived early. The coldest temperature we recorded for the winter was -34°F, but lowest recorded temperature in the high tunnel was only -1.6°F. The soil temperature in the tunnel first rose above freezing on March 1; the last freezing air temperature recorded in the high tunnel occurred on March 19. After March 22, the temperature in the high tunnel did not fall below 45°F for the rest of the growing season. As in previous years, we were able to add about two months to the growing season in the spring.

When the soil is adequately warmed, the air temperature in the heated tunnel typically stops dropping 2 hours after sunset and stays at the same temperature the rest of the night. In 2010, we had a cloudy and rainy spell from March 8 to March 16, before the soil in the tunnel had warmed up sufficiently. When sunny weather returned on March 16, it took three sunny days before the soil temperature rose sufficiently to keep nighttime temperatures warmer than outside. We think the availability of sunlight is more important in heating the tunnel in the spring than what the outside temperature is.

In the spring, before the soil warms it can act as heat sink, cooling the air in the tunnel. By contrast, in the fall when the soil is warm from summer heat, the tunnel stayed at the same nighttime temperature during more than a week of cloudy weather (Figure 4). During the second week of cloudy weather, the temperature in the tunnel dropped into the mid 40's, but was still 20° greater than the outside temperature.

Table 1: Comparisons between March 1-21, 2009 and March 1-21, 2010

Year	Date soil thawed	Date air remained above 40°F	Average air temperature	Days with sunshine
2009	March 8	March 14	25°F	19
2010	March 1	March 20	35°F	8

In both 2009 and 2010, the number of growing degree days (GDD) in the heated high tunnel was a third higher than outside (Table 2). The biggest difference between the outside and the high tunnel occurred during March, April and October, which are the months we are trying to extend our growing season.

A local restaurant ordered produce even before the farmers' market started. In March, we started harvesting the kale and spinach we had planted last fall. We planted lettuce and radishes in March and started harvesting both crops in April. The radishes grown in the high tunnel were double the size of those grown outside. We started selling fresh vegetables at the Detroit Lakes Farmers' market in the middle of May, which helped increase the customer count at the market.

All our crops produced quite well in 2010, except for tomatoes. Cucumbers had high yields through October. Because we had a poor pepper crop in 2009, in 2010 we purchased and released bumble bees in the tunnel for pollination of the peppers and eggplants. Our eggplant, pepper and bush bean yields were quite high this year.

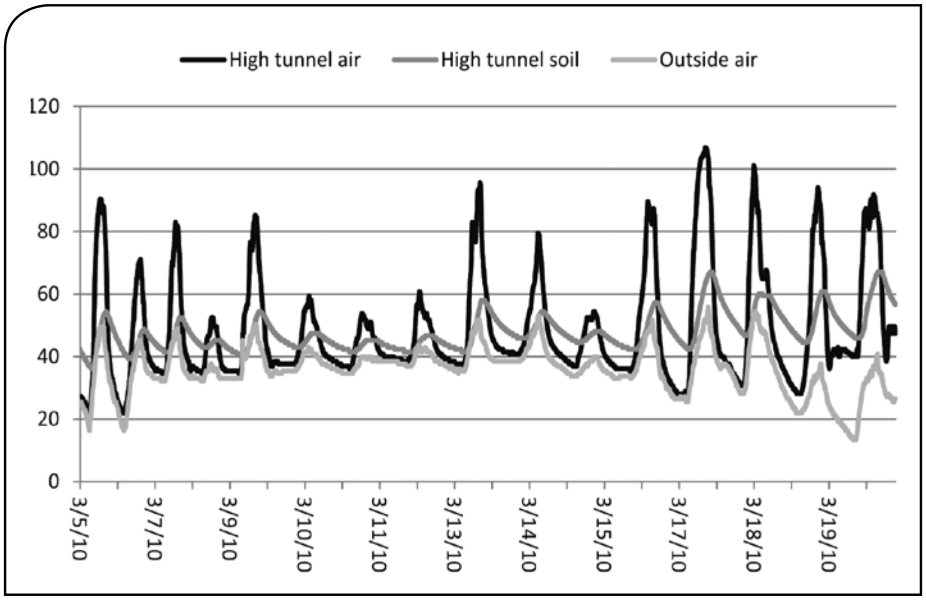
The 2010 growing season was a bad one for tomatoes grown both inside and outside. Outside, there was high disease pressure. In the high tunnel, high humidity contributed to disease pressure, including leaf spot and gray mold. The gray mold attacked some tomato vines which caused the tops of the vines to die. We think the milder winter temperatures inside the high tunnel might also have allowed more fungi to survive the winter. Out of the tomato varieties we grew the Cherry tomatoes had the fewest diseases.

Last year, we had "gray wall" on our tomatoes, which is a physiological disorder of the tomato fruit caused by low potassium. During the winter, we amended the soil with

Table 2: Temperature and growing degree days (base 50) for 2009 and 2010.

Month	Outside				Heated High Tunnel			
	Mean Air Temp 2009 (°F)	Mean Air Temp 2010 (°F)	GDD 2009	GDD 2010	Mean Air Temp 2009 (°F)	Mean Air Temp 2010 (°F)	GDD 2010	GDD 2009
Apr.	42.5	51.5	69	173	63.4	63.1	391	319
Jun.	64.0	66.0	432	470	68.6	67.2	510	526
Aug.	66.0	71.3	494	643	67.0	72.5	692	534
Oct.	41.4*	51.3	0*	3	54.2*	59.0	280	51*
Total			2,072	2,383			3,470	2,920

**The temperature in October 2009 was only recorded for the first 12 days of the month.*



Outside temperature, soil temperature and the temperature inside the high tunnel throughout March, 2010.

green sand to add potassium. We still had gray wall this year, but not as bad as in 2009.

The temperature in the heated high tunnel stayed above 45°F through the middle of November, and we could have continued harvesting through the middle of December. However, the farmers' market closed by the end of October and the restaurant buying our produce closed for the season due to a fire. We were tired and ready for the growing season to end so we pulled the tomato and cucumber plants on November 5.

Conclusions and Future Plans

The heated high tunnel cost $23,000 for materials and labor. Our financial outlay would have been lower if we had done more of the construction work ourselves instead of hiring it out. The heated high tunnel gave us a frost-free growing season from the middle of March through the middle of November in a Zone 3 climate. The longer growing season gave us increased yields and we were able to sell vegetables at a time when there were no other locally grown vegetables at the local farmers' market. We estimate that we could pay for the tunnel in 3 to 4 years by selling our early tomatoes and cucumbers at the farmers' market.

We have more ideas to improve our heated high tunnel system. To improve soil warming I would like to install a third tile line that collected air from the top of the tunnel and moved the air back through the soil. High tunnels increase humidity around the plants and also increase the amount of dew; water vapor is often trapped inside the plastic, causing the humidity to rise and contributing to disease. In 2010, we kept the sides of the tunnel rolled up both day and night after the middle of April. If we were to do this project over, we would have designed the high tunnel with drop down top doors at the ends to get rid of the humidity that was coming off the high density of plants.

We would like to be organic in our high tunnel. Although we did not use chemicals on cabbages and radishes we did use two products that were not allowed in organic production on tomatoes. With the extremely long growing and harvest season, it is very difficult to supply tomatoes with adequate nutrients only using organic fertilizers and disease pressure.

We would and have recommended the heated high tunnel to other farmers. It would be beneficial if research was done to see if a high tunnel could financially support a family. Most of the people who have seen our high tunnel want to adopt its design, especially if they are involved in farmers' markets. The fact that the high tunnel is heated is a special benefit for farms that are this far north. Growers like us would benefit from attending seminars on disease and pest management. We also need to find cultivars that are more suited for this system.

Although there is always room for improvement, we are generally very happy with the design and performance of our solar heated high tunnel and are going to try growing small fruit trees in it next.

Management Tips

1. Install and use an exhaust fan in the high tunnel because it is critical to reducing humidity in early morning.

2. Always place solar panels to receive the maximum amount of sunlight throughout the day.

3. Be vigilant about rolling up high tunnel sides in the morning during early and late season. Consider installing a computer-controlled mechanism that automatically rolls up the sides when the temperature reaches a certain point.

4. Plant nutrition is critical in high tunnels. Always do soil tests in fall in order to make sure soil nutrients will be adequate the following growing season.

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. approximately 1.5 miles. The road will "T". At the "T", go right on Rice Lake Rd. approximately 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*