

## **Latest Techniques with High Tunnels**

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There has been a tremendous increase in the popularity and adoption of the use of high tunnels for extending the production season for vegetables, small fruits, cut flowers and tree fruits by growers, not only in the Northeast but also in many other parts of the country. One reason that the use of high tunnels has become popular with growers is their simplicity and effectiveness in protecting crops from low temperatures in both spring and fall. Because high tunnels can be viewed as affordable technology, this system is particularly appealing to new-entry growers who utilize retail-marketing channels.

High tunnels do not offer the precision of conventional greenhouses for environmental control, but they do sufficiently modify the environment to enhance crop growth, yield, and quality. Although they provide some frost protection, their primary function is to elevate temperatures a few degrees each day over a period of several weeks.

In addition to temperature control, there are also the benefits of wind and rain protection, soil warming, and in some instances control of insects, diseases, and predators such as varmints and birds. Overall, these growing systems should be considered protected growing systems that enhance earliness and higher yields, improve quality, and reduce the use of pesticides in some cases.

High tunnels have sufficient versatility to make them useful on a wide diversity of crops and in various cropping systems. **Vegetables, small fruits, flowers and even tree fruits are all suited to this growing system; but the specific crops which might be grown will to a large extent depend on marketing opportunities for individual crops by individual growers.**

### **High Tunnel Systems**

High tunnels are not conventional greenhouses. But like plastic-covered greenhouses, they are generally quonset-shaped, constructed of metal bows that are attached to metal posts which have been driven into the ground about two feet deep. They are covered with one layer of 6-mil greenhouse-grade polyethylene, and are ventilated by manually rolling up the sides each morning and rolling them down in early evening. There is no permanent heating system although it is advisable to have a standby portable propane unit to protect against unexpected below-freezing temperatures. There are no electrical connections. The only external connection is a water supply for trickle irrigation. Dr. Otho Wells, Professor Emeritus, from the University of New Hampshire was a pioneer in promoting the use of high tunnels in the northeastern United States and developed the New Hampshire design and system of production that involved covering the entire soil surface inside the tunnel with a solid sheet of 6-mil thick plastic. At Penn State we re-designed the endwalls so that they can be raised up to facilitate easy access into the tunnel of a small tractor and tiller and a system of production that uses 18-inch wide raised plastic mulch covered beds with drip irrigation tape buried 2-3 inches beneath the bed. The raised mulch beds are 44 inches apart, which allows 4 rows in a 17-foot wide high tunnel or 5 rows in a 21-foot wide high tunnel.

### **Details of the Penn State Design**

Erection of the pipe framing is the same whether the New Hampshire Design or the Penn State Design is used. The changes come in the construction of the endwalls and the hipboard and attachment of the plastic covering. For an excellent overview of the construction of a high tunnel

using the Penn State University go to the Center for Plasticulture website: <http://plasticulture.cas.psu.edu> and go to the high tunnel button. There is a PDF file of an article "Design and Construction of the Penn State High Tunnel" that has illustrations detailing the steps in construction of a high tunnel using the Penn State Design. This article first appeared in a 2002 issue of HortTechnology Volume 12(3): 447-453. A couple of suggestions on purchasing and positioning a high tunnel. One is to purchase a high tunnel with tall sides (approximately 5 feet from the ground to the hipboard). This will improve the ventilation capacity of the tunnel. In locating a site for the high tunnel make sure to orient the high tunnel so that the prevailing winds blow through the sides of the tunnel. The wind is your means of ventilation and temperature control and also pollination for some crops. For parts of the country that experience snow in the winter we recommend purchasing a high tunnel with a peak to protect against snow accumulating on the top of the tunnel. Fourth is to space the tunnels at least 12 feet but if room allows then 20-25 feet apart to ensure adequate ventilation in the tunnels and permit the removal of snow that could possibly buildup against the sides of the tunnels during severe winters.

At the Penn State High Tunnel Research and Education Facility we have purchased all our high tunnels from Ledgewood Farm Greenhouse Frames (603)-476-8829.

For all practical purposes, high tunnels are protected growing structures that should result in high returns. Therefore, they should be situated on the best soil -- soil that is well drained and that has had pH and nutrient adjustments as for a field soil. The soil should be smooth, firm, and moist at planting.

The high tunnels come in widths of 14 feet wide up to 30 feet wide and in any length of 4-foot intervals. Most commercial lengths are 96 feet long. After researching and using different size high tunnels we recommend purchasing a 21 feet wide by 96 feet long tunnel which would cost between \$4,500 and \$5,000 completely finished not including labor cost. The tunnel could be erected and ready to plant in 2-3 days.

There are other high tunnel structures being marketed which should be evaluated keeping in mind the comments made above about snow loads.

The Haygrove Multibay Tunnel System is a different type of tunnel than what we have been discussing and it is currently being used in Pennsylvania for the production of plasticulture strawberries, raspberries, cut flowers, tomatoes and sweet cherries. This type of tunnel can cover from 1/3 to 5 acres and is operated differently than the single high tunnel units discussed in the preceding paragraphs. In the Haygrove Multibay Tunnel System, the plastic covering is completely removed, covered with black plastic and stored in the gutter area between the bays for the winter whereas the single Penn State high tunnel units remained covered the entire winter.

## **High Tunnel Management**

High tunnels are not automated but can be but then you are getting closer to a conventional greenhouse. Consequently, for maximum efficiency, they require regular daily attention, especially in the morning and evening, and during heavy rain or strong winds. Temperature and humidity are the two critical factors that should be controlled as much as feasible. Early each morning, the sides should be rolled up to flush out the humidity and to keep temperature in check. The temperature in a closed high tunnel rises very rapidly on a clear morning! In other words, don't put off rolling up the sides. In early evening, roll-down the sides to entrap as much heat as possible. Close the sides each evening until the night temperature reaches about 65°F. In northern states, this could mean that the sides will be rolled down each day well into the summer. Ventilation is best accomplished when the prevailing wind moves through the tunnel from side to side; therefore orient the tunnel accordingly. The width of the tunnel also impacts ventilation. It is hard to be specific on the maximum width, but from experience, about 21 feet wide seems to be the maximum which allows for good ventilation, especially as plants grow taller such as, tomatoes and block the air flow.

**Benefits of Tunnels.** The primary benefit of tunnels is earliness. Tomatoes in a high tunnel mature on average about one month before field tomatoes. Earliness is the combination of being able to plant in high tunnels about two weeks earlier than in the field and faster ripening (about two weeks) inside the tunnel. Overall, the cost of a tunnel is recovered the first year when selling at retail prices. Another highly beneficial advantage of tunnels is disease control. The plastic cover is a rain shelter, the raised plastic mulch bed is a barrier against evaporation of soil moisture, and early morning ventilation reduces relative humidity. Therefore, the leaves of crops are dry for most of the day and night. Because of low humidity, plant leaves remain dry, impeding the incidence and spread of disease. For example, early blight of tomatoes, a serious foliage and fruit disease on field tomatoes, is not a problem in high tunnels when the tunnels are vented daily, though powdery mildew, especially in cucurbit crops can be a problem because the conditions in a high tunnel are more favorable for the development of this disease.

Although tunnels do require more manual attention than do greenhouses, the benefits of high tunnels in a diversified farm operation have proven to be a valuable asset in overcoming a short growing season. Both cool- and warm-season crops do well in the spring. With cool season crops, the season may easily be extended into early winter and even throughout the winter depending on the location, for some hardy crops. Fall-planted strawberries ripen the following spring about six weeks earlier than field-grown berries.

One of the greatest benefits of a high tunnel is that it allows a grower to plant and harvest regardless if it is raining, etc. This allows a degree of scheduling that is sometimes difficult to obtain with field production.

## Crops

At the Penn State High Tunnel Research and Education Center we have been evaluating a wide variety of crops and cropping schedules. We use a lot of row covers and thermal blankets to protect the crops inside the high tunnel and further manipulate the microclimate around the crop. The following is a brief review of what we have found so far. For a more detailed description of the production system used at the facility go to the Center for Plasticulture website listed above and go to the high tunnel button and the PDF file with the article "Production System for Horticultural Crops Grown in the Penn State High Tunnel" which first appeared in HortTechnology Vol. 13(2): 358-362.

**Tomatoes** - This is probably the number one crop in high tunnels. Production can be at least month ahead of field production. There are very few if any diseases, not even early blight. Insects, especially white flies, can be controlled with biologicals (*Encarsia formosa*). The key management strategy is daily (every morning and every evening) opening and closing the high tunnels to manage temperature and humidity. This is critical to successful production of crop in a high tunnel. Another tip: do not plant so early as to have to use continual heating.

**Summer Squash** - Yellow, zucchini, patty pan, and other summer squashes grow very fast in tunnels. Earliness is the general rule, but not as consistently so as with tomatoes. The range of earliness is as high as a month but also as low as 7 days. Outside conditions make a big difference in squash maturity. Also, pollination is necessary; a series of bad bee days could reduce both earliness and total yield. A half hive of greenhouse bumblebees is the best insurance against casual pollination by honeybees. Incidentally, if there are several high tunnels in close proximity, the bumblebees will fly from tunnel to tunnel but go back to the hive at night. Later in the summer, powdery mildew can be a problem on squash and other cucurbits.

**Cucumbers and Muskmelons** - These crops also need bees for pollination. When using black plastic mulch beds in the tunnel, the cucumbers will stay clean without having to trellis them. From a retail point of view, the yield of non-trellised cucumbers is quite profitable. Trellising cucumbers certainly increases the labor bill. European greenhouse cucumbers can be grown quite

successfully in a high tunnel but need a trellis system and pruning similar to traditional greenhouse production system. Muskmelon production in high tunnels is questionable from the standpoint of economics. We recommend that growers try early varieties with and without trellising to determine if this crop has a place in high tunnels. Use a specialty melon.

**Pepper** - Fruit set of peppers (bell types) in a high tunnel is far more dependable than with field-grown peppers. We have used Paladin and had excellent results. Some of the newer Dutch varieties should be ideal for tunnels. The economics of pepper production looks good. Pricing peppers for retail markets will be the key. Hot pepper varieties also grow very well and yield superbly in high tunnels. The use of colored peppers for specialty markets is also recommended. Excellent red peppers can be grown in high tunnels because of the protected environment.

**Leafy Green Crops** - If you are looking to grow the ingredients for a salad the high tunnel is the place to grow them. The extra heat provided by the tunnels will greatly accelerate the maturity and thereby make way for succession cropping. A wide variety of lettuce, spinach and leafy greens (mustard and turnip) respond well to production in high tunnels and the use of a floating row cover can even be incorporated into the system to provide an even earlier and more favorable growing environment. The lettuce and spinach can be the first crops of the season and also the last crops of the season in a high tunnel. In the high tunnels at the Horticulture Farm, Rock Springs, PA we can grow leafy greens all winter. Micro-greens or spring salad mixes are excellent in high tunnels. They also do quite well on permanent raised bed.

**Broccoli, Cabbage, Cauliflower, Kale and Collards** - These crops also have great potential for production in high tunnels. Most of these crops can be used in a rotation scheme in tunnels as an early spring crop, which is then followed by a summer crop and then followed by a late fall/early winter crop of these vegetables. We have had excellent broccoli up to Christmas and would have had it even longer if we had put a thermal blanket over the crop.

**Onions and Garlic** – These crops do extremely well in high tunnels. They are transplanted on raised, plastic covered beds using drip irrigation. The return of garlic is 10 lbs of garlic for every 1 lb planted in the high tunnel. In addition, the crops are earlier and of better quality than those produced in the field. The variety Candy, a sweet Spanish onion type is planted in the early spring and harvested in late June or early July and the onions can be pulled and dried on the plastic beds in the high tunnel.

**Other Vegetable Crops** – Almost any crop can be grown in a high tunnel but the economics and individual growers marketing opportunities will dictate if crops like okra, sweet potatoes, asparagus, sweet corn, bush pumpkins, snap beans, lima beans, peas, radishes, beets, turnips and carrots will be produced in high tunnels

**Herbs** - There are dozens of herbs that are used in a variety of ways. High tunnels offer an excellent protective environment for these crops, including the capacity for drying and storing. The high tunnels maintain the high quality of the herbs. Opportunity for herbs used in ethnic foods.

**Strawberries and other Small Fruit** - Strawberries grown from plugs and planted in the fall on raised beds covered with plastic mulch is a way to get fruit production about six weeks earlier than in the field. The use of ‘Chandler’, a California/Florida variety, has been one of the best varieties because it over winters quite well in high tunnels. The goal is to get a minimum of one pound per plant. Other small fruit crops that have really performed well are raspberries (equivalent of 19,000 lbs/A), blackberries. The yields and shelf life are excellent. Also blueberries may be another crop, depending on marketing opportunities. We also have hardy kiwi planted and growing in an overhead trellis in the a large 30-foot wide by 48-foot long high tunnel.

**Niche Crops** - The definition of “niche or specialty” crops is wide ranging, but the potential to grow crop that may be considered niche, ethnic or even exotic is excellent for high tunnels. Because temperature can be further manipulated inside the tunnels by using various colors of plastic mulch, row covers, and thermal blankets there is a good possibility that many of these crops can be grown year around. One niche market is specialty potatoes, that have a different skin type or flesh color or a very early crop of “new” small red potatoes that can command a high price on the early spring retail market. One can even make the “Spud Flag” for the 4<sup>th</sup> of July sales using the following potato varieties: Dark Red Norland, Eva, and Michigan Purple.

**Cut Flowers** - On a square foot basis, the value of cut flowers is near (or at) the top of the charts. Inside a high tunnel, flower stems are longer than outdoors, the foliage is nearly disease free, and the flowers themselves are brilliant in color. The plants are almost always completely dry; therefore, disease problems are minimized. Both traditional spring planted flowers and spring-flowering bulbs (planted in the late fall) grow very nicely in high tunnels.

**Tree Fruits** – The tree fruit being produced in high tunnels at Penn State are sweet cherries. The reason that sweet cherries were chosen is that they are a high value crops and the two main problems associated with sweet cherry production, bird feeding and fruit cracking can be eliminated in the high tunnels. It seems that the production of sweet cherries in high tunnels has a tremendous potential. Currently the cultivars Bing and Ranier, on a Gisela 5 rootstock, which is a semi-dwarfing rootstock, are being grown in a 17-foot wide by 36-foot long high tunnel. This size high tunnel is too small for the production of cherries, as we have seen tremendous growth of the trees in the high tunnel. This is one crop that could use the 30-foot wide high tunnel because of the increased height that comes with that size tunnel.

High tunnels provide an ideal protective growing environment for any number of crops, but all crops might not be economical for any number of reasons. Therefore, a good approach to take would be to try different crops in light of market demands and marketing strategies

There are temperature limitations to a high tunnel, which is not designed to be as warm as a greenhouse. Some type of supplemental heat should be available just in case there is a sudden unexpected drop in the temperature that would permanently injure the crop. The critical low temperature will depend on the crop. If the intent is to have a permanent heat source in a high tunnel, then it would be well to consider constructing a bona-fide greenhouse, which easily could be used year around.

### **Innovative Approach to Heating High Tunnels in the Future**

We are currently in the process of constructing a 30-foot wide by 96-foot long high tunnel at the Penn State University Horticulture Farm that will be heated using Plastofuel (nuggets of used agricultural plastic waste) burned directly in a boiler unit generating hot water, that was developed in South Korea. This project is a partnership between Jim Garthe in the Department of Biological and Agricultural Engineering and the High Tunnel Research and Education Facility and a private entrepreneur from South Korea. This utilization of this currently perceived waste material to generate heat might allow even more year around cropping options in high tunnels in the future.

**For addition information on the plasticulture and high tunnels contact the following websites:**

American Society for Plasticulture: <http://www.plasticulture.org/>

Center for Plasticulture, Penn State University: <http://plasticulture.cas.psu.edu>

2003 High Tunnel Production Manual- a157 page manual is available for \$25.00 from Dr. Bill Lamont at the above address. Checks should be made out to The Pennsylvania State University.