

## Extending the Gardening Season with High Tunnels

High tunnels offer plants protection from wet, saturated soils and low temperatures in the spring and fall, thereby extending the gardening season. This can translate into earlier maturing fruits and vegetables. For centuries gardeners have been extending the gardening season using glass jars, hot caps, cold frames, and various types of greenhouses. High tunnels are a recent addition to this list in the United States. They have been used extensively in Europe, Asia, and the Middle East for early production of vegetables, fruit, and flowers. High tunnel technology was launched in the United States by Dr. Otho Wells at the University of New Hampshire. Recognizing the potential of high tunnels, Drs. Lamont and Orzolek developed the High Tunnel Research and Education Facility (HTREF) located at Rock Springs, Pa., in 1998. Currently, there are 36 high tunnels at the facility where different crop rotations and sequencing of vegetables, herbs, cut flowers, small fruit, and tree fruit are studied.

### What Are High Tunnels?

High tunnels are structures generally constructed of a metal frame covered with a single layer of 6-mil greenhouse-grade plastic and are considered nonpermanent structures. They have high ceilings comparable to those of greenhouses, which allow gardeners to comfortably enter and tend plants, even when it's raining. High tunnels differ from greenhouses in that plants typically are grown directly in the ground instead of in pots and they do not have permanent heating or automated ventilation systems. Portable propane or kerosene heaters can be used to heat high tunnels in early spring and fall when below-freezing temperatures are forecasted. Ventilation is accomplished by manually or mechanically rolling up the plastic sides of the tunnel to allow crosswinds to circulate through the high tunnel.

### What Are the Benefits of Gardening in High Tunnels?

Many benefits exist for growing plants in high tunnels related to temperature, pest management, harvest quality, and yield. Gardeners can reap (eat) the rewards of earlier harvests compared to plants grown outdoors. Temperatures in high tunnels are more constant than outdoor temperatures during the gardening season, which is optimal for plants that grow best in predictable temperatures. Researchers at the HTREF have not observed many pests when growing crops in high tunnels, which can translate into a reduction in the total amount of pesticides applied to plants compared to those grown outdoors. Pests that have been encountered tend to be those associated with greenhouses, for example, white flies or aphids. Some powdery mildew has also been observed on plants growing in the high tunnels. Gardeners who use biological pest management may experience more success in high tunnels compared to outdoors because predators are confined within the high tunnel. In general, all the crops grown in high tunnels at the HTREF have had higher yields with better quality than those grown outdoors. Finally, high tunnels are lower priced than greenhouses at a cost of about US\$2.38 per square foot compared to US\$19.89 to US\$37.48 per square foot for a hobbyist greenhouse\*.

### Temperatures in High Tunnels: It All Depends on the Sun

The intensity of the sun governs the temperatures inside a high tunnel. On a yearly average, the temperature in a high tunnel is 8.4°F (-13.1°C) higher than outdoors. Temperatures will vary depending on weather conditions, time of day, and time of year. For the most part, it will be cooler inside a high tunnel on a cloudy day than on a sunny day, in the morning and evening

than in the afternoon, and in the spring and fall than in the summer. Researchers at the HTREF recorded temperatures up to 130°F (54.5°C) in an unventilated high tunnel in the afternoon of a sunny day in July! This illustrates the importance of rolling up the sides of the high tunnel for ventilation in the morning to exhaust moisture that may build up at night due to transpiration of the plants and also to keep the air temperatures inside the high tunnel from exceeding 85°F (30°C).

## Getting Even More out of High Tunnels

Gardeners can use other season-extending technologies within a high tunnel to extend the gardening season beyond the capabilities of the high tunnel alone. Before planting in a high tunnel, soil temperatures should be a minimum of 10°C (50°F). Raised beds and plastic mulches can be used in the high tunnel to reach minimum soil temperatures early in the year. Until air temperatures within the high tunnel are above freezing, row covers, thermal blankets, or cold frames should be used to protect plant canopies from cold damage. Studies at the HTREF have examined annual and permanent raised beds covered with various colored plastic or organic mulches and row covers for growing diverse plants. Researchers concluded that the gardening season could be extended in high tunnels an additional 2 to 4 weeks when plants were grown on a raised bed covered with plastic mulch using row covers compared to plants grown in a high tunnel without additional season-extending technologies.

## Crop Possibilities

Researchers at the HTREF have grown many types of vegetables, herbs, cut flowers, small fruit, and even tree fruit in high tunnels. Vegetable crops have included broccoli, cauliflower, cabbage, various leafy greens, sugar snap peas, Brussels sprouts, celery, kohlrabi, carrots, parsnips, radishes, beets, rutabaga, tomatoes, bell peppers, potatoes, eggplant, onions, leeks, okra, summer squash, zucchini, cucumber, pumpkins, and ornamental gourds. Culinary herbs have included garlic, basil, fennel, garlic chives, dill, cilantro, and lemon grass. Cut flowers have included many herbaceous perennials, summer annuals, and spring bulbs. Small fruit have included strawberries, raspberries, blackberries, and hardy kiwi. For tree fruit, sweet cherries were planted. In general, all of these crops have preformed well in high tunnels. For the most part, these crops were planted in the high tunnel as transplants. However, radishes, beets, rutabaga, spinach, sugar snap peas, parsnips, and carrots were sown from seed.

## Plant Spacing

Proper plant spacing is important when growing in a high tunnel. When spacing is too close, the plants can overrun the high tunnel, making entering and maneuvering in it difficult. Spacing is particularly critical with members of the squash family (Cucurbitaceae). When developing a plan for planting in a high tunnel also consider hanging plant pots from the purlins, cross-braces, or metal bows, if their weight can be supported.

## Watering and Fertilizing

Various means of watering crops in high tunnels have been studied at the HTREF. The most economical method is hand watering and it is useful for direct-seeded crops. One of the advantages of planting in a high tunnel is that moisture, i.e., rain, on the crop is eliminated and thus potential for disease development decreases. This is an important point to keep in mind when hand watering a crop. When hand watering, researchers at the HTREF found the use of guides or tracks for water hoses helpful in avoiding damaging the plants when moving the water hoses throughout the high tunnel. Lawn and garden sprinklers did not perform as well in high tunnels. Uniform application of water was difficult to achieve because water ran down the sides of the plastic of the high tunnel and tended to pool on the ground. Drip irrigation has proven very effective for watering plants in high tunnels. In using drip irrigation, water is efficiently and precisely delivered to the plant at its root zone. Water pooling has not been a problem, and weeds and diseases can be minimized in the high tunnels as a result of using drip irrigation. The high tunnels at the HTREF are all equipped with drip irrigation systems. A disadvantage of using drip irrigation is that plants where seed is broadcast over the ground of the high tunnel (for example, cover crops or green manures) are difficult to impossible to establish using drip irrigation. At the HTREF an overhead irrigation system suspended from the framework of the high tunnel was developed that works effectively for establishing those types of plants.

Water-soluble fertilizers and compost have been used for fertilizing plants in high tunnels. Since the ground in a high tunnel is not subjected to precipitation, soluble salts can build up in high tunnels. Gardeners should use soil tests to determine the fertility status of the soil in a high tunnel and when fertilizing use the lowest recommended rate provided by the soil test results.

\*Hobbyist greenhouse cost per square foot is based on the Territorial Seed Company 2003 Spring Catalog.

## Where to Find Supplies

This is not a comprehensive list; it is only intended to provide a starting point to help gardeners find supplies.

### High Tunnels

Ledgewood Farm Greenhouse Frames  
Route 171  
Moultonboro, NH 03254  
1-603-476-8829

### Row Covers

Johnny's Selected Seeds  
www.johnnyseeds.com  
184 Foss Hill Rd  
Albion, ME 04910  
1-207-437-9294

Gardener's Supply  
http://www.gardeners.com/  
12 Acme Rd., Suite 212  
Brewer, ME 04412  
1-888-833-1412

Park Seed Company  
www.parkseed.com  
1 Parkton Ave.  
Greenwood, SC 29647  
1-800-213-0076

### Plastic Mulch

Johnny's Selected Seeds  
www.johnnyseeds.com  
184 Foss Hill Rd.  
Albion, ME 04910  
1-207-437-9294

W. Atlee Burpee Company  
www.burpee.com  
300 Park Ave.  
Warminster, PA 18974  
1-800-888-1447

### Drip Irrigation Technology

Johnny's Selected Seeds  
www.johnnyseeds.com  
184 Foss Hill Rd.  
Albion, ME 04910  
1-207-437-9294

Rain-Flo Irrigation  
884 Center Church Rd.  
East Earl, PA 17519

## Sources

Center for Plasticulture Web site: <http://plasticulture.cas.psu.edu/>

W.J. Lamont, Jr., M.R. McGann, M.D. Orzolek, N. Mbuga, B. Dye and D. Reese. 2002. "Design and Construction of the Penn State High Tunnel." *HortTechnology* 12:447-453.

W.J. Lamont, Jr., M.D. Orzolek, E.J. Holcolm, K. Demchak, E. Burkhart, L. White and B. Dye. "Production System for Horticultural Crops Grown in the Penn State High Tunnel." *HortTechnology* 13:358-362.

*High Tunnel Production Manual*. Center for Plasticulture, Department of Horticulture, College of Agricultural Sciences, The Pennsylvania State University. Available for \$25.00 from Dr. Lamont, 206 Tyson Building, The Pennsylvania State University, University Park, PA 16802 or e-mail: [wlamont@psu.edu](mailto:wlamont@psu.edu)

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