Engineering High Tunnels for Better Performance

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At a cost of $1 to $2 per square foot, a high tunnel can add low-cost growing space for season extension or plant protection. Growers and researchers are finding many innovative ways to utilize these structures.

By definition, the high tunnel is a walk-in, hoop or gothic-shaped, pipe frame structure that is covered with a single layer of film plastic. It generally does not have electricity and the only heat is provided by the sun. Ventilation is by rolling up the sidewalls and opening the doors. Irrigation water is provided by piping from another building or water from a nearby pond or stream. Plant production is usually in the soil or soil beds.

These structures have their roots in Europe where they have been used for growing off-season vegetables. Development work in the U.S. has been done at the University of New Hampshire, Penn State University, Cornell University and several other states.

Tunnel Construction

Site selection is important. A site that gets at least 6 hours of daily sunlight should be selected. As solar heating and natural ventilation are the means of temperature and humidity control, it is important to locate the tunnel away from buildings and trees. If the crops are to be grown in the soil, organic matter and amendments should be added and the soil should be tested. A swale or rock filled trench should be installed around the tunnel to drain rainwater away and prevent water from getting inside.

Tunnels located in northern states should have a gothic shape to shed snow. Galvanized steel tubing or fence pipe is the standard material used for the hoops and should have the following minimum dimensions:

- 1.90” diameter x 14 gauge for tunnels ≥ 26’ wide
- 1.66” diameter x 14 gauge for tunnels < 26’ wide
- 2.00” square x 16 gauge for all width tunnels
- 1.625” x 2.750” oval for all width tunnels

Bows/hoops should be spaced no greater than 4’ on center. There should be at least 3 purlins on tunnels less than 26’ and 5 on those with greater width. Cross ties/collar ties or trusses are needed on tunnels greater than 26’. The frame should have diagonal bracing on the four corners to keep it from racking in strong winds. In snow country, if the tunnel will remain covered during the winter 2 x 4 wood posts should be placed under the ridge for support about ever third or fourth hoop. Although tunnel length can be any multiple of the 4’ hoop spacing, a 48’ or 96’ length will better utilize the 100’ sheets of plastic that are typically available.

The original use of the high tunnel was for season extension, usually one month in the spring and one month in the fall. The plastic was removed before winter set in. Growers seeing the results that are produced and the increasing demand for the produce grown are now using tunnels for year round production. This presents the problem of keeping the tunnel from collapsing or tipping over from heavy snow and wind conditions.

A 3” wet snow or 12” dry snow adds about 5 pounds/sq ft (psf) to the roof. A 30’ x 72’ high tunnel would have to withstand a load of 10,800 lbs. Bracing, good connectors, adequate length posts and good plastic attachment are very important. To resist collapsing from heavy snow loads, a few 2 x 4 posts fastened under the ridge have proven to prevent the collapse of many tunnels and greenhouses.

An 80 mph wind creates a force of about 16 psf. The 12’ sidewall of the above tunnel would have to be able to take a 13,824 lbs load. The uplifting force on the roof from an 80 mph wind is about 220 lbs/linear foot. To resist this uplifting, the weight of the building and the withdrawal resistance of the posts have to withstand about 300 lbs/post. To anchor the tunnel to the ground, posts are driven into the ground 24” to 30” deep to support the hoops. In windy locations, additional anchors are needed. These can be auger or screw type and placed about 10’ apart. An alternative is to install deadmen.

A 2” x 12” baseboard should be attached to the posts with bolts to help make the frame rigid and provide a place to attach the plastic.

The endwalls should have openings at least 6’ x 6’ for ventilation and access for equipment. The endwall frame and doors can be made of 2” x 4” lumber or steel tubing. Covering for endwalls can be 6 mil ultra -violet resistant polyethylene, double wall polycarbonate or exterior plywood. Solid endwalls are not as desirable as these create a shade that will reduce plant growth.

Plastic

Most greenhouse grade polyethylene film is manufactured as a coextrusion of three layers with different polymers and additives. Each of them contributes to the quality of the film and enhances its performance. If the plastic will be removed before winter a 4 mil greenhouse grade should be adequate in most locations. If it will be left on all winter then it is best to utilize the stronger 6-mil greenhouse grade. In windy locations, a woven polyethylene has given better service. For heated tunnels, a double layer with air inflation will reduce heating costs by about 35% and allow snow to slide off easier.

Plastic with an infrared (IR) inhibitor traps the inside radiant heat from escaping. In heated greenhouses, the savings have been measured to total from 10 – 20% depending on whether the sky is cloudy or clear. Research at several universities has been inconclusive as to whether the IR additive slows warming of the tunnel in the morning. In research at Penn State University during October, the tunnels warmed up significantly faster in the morning than outdoor ambient but there was no difference between standard poly and IR poly. During the day, the IR film did not increase the overheating problem as compared to standard clear poly. At night, the tunnels with the IR film retained heat better than the standard poly by 2 - 3ºF but with both types the tunnel was cooler than outdoor ambient.   In heated tunnel, double layer poly installations, the IR film is always placed as the inner layer to retain nighttime heat. IR film costs about 1 - 2¢/ sf more than regular poly.

Early failure of poly can be attributed to stress on attachment points, abrasion on rough surfaces and sharp edges or heat build-up in that area of rafters, purlins and extrusions. Contact with chemicals from pesticides or pressure treated lumber can also affect the life of the plastic. Poly that is left on the tunnel during the winter is subject to cuts from blowing ice especially if there are multiple tunnels adjacent to each other. A scrim reinforce poly may be desirable in this situation.

A hip board, attached to the frames, 3' to 4' above the baseboard will hold the plastic when the roll-up sides are installed. The plastic is attached to the baseboard and hip board with aluminum extrusions or a double furring strip for a tight seal and easy replacement. Guy ropes from the hip board to the baseboard keep the plastic from billowing out in the wind.

Movable tunnels

If the crops will be grown in the soil, the structure could be installed so that it can be easily moved from one plot to another. This allows a cool season crop to be started early in the spring and then when the temperature warms up the tunnel is moved to another plot for the production of tomatoes, cucumbers or peppers. One method is to weld the hoops to a 3" x 3" x ¼" thick steel angle. The ends of the angle are bent up to form a skid. The tunnel can be pulled by a couple of tractors or by two winches. Another method is to attach "V-groove wheels to the bottom of the hoops and have them ride on an inverted angle iron. There are several manufacturers that sell movable tunnels.