# Building High Tunnels

## Selection, Construction & Operation

John W. Bartok, Jr., Agricultural Engineer - Emeritus
NRME Department, University of Connecticut, Storrs CT

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 to produce food and flowering crops.

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. Plant production can be in the soil or in containers on top of a weed mat. High tunnels are available from most greenhouse suppliers. A multi-bay tunnel is available from Haygrove Tunnels, 116 Trail Road, North Elizabethtown NJ, 17022.

**Tunnel Construction**

**Site selection** - 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 should be installed around the greenhouse to drain rainwater away.

**Frame** - Steel tubing and fence pipe are the standard materials used for the hoops. A gothic shape is desired as it sheds snow easier. A frame with trusses or collar ties is needed for widths greater than 14'. Posts are driven into the ground about 2' deep to support the hoops. To get a higher ridge and therefore better ventilation, the ground posts are sometimes extended 2' to 4' above grade. A 2" x 12" pressure treated lumber baseboard is attached to the posts with bolts to help make the frame rigid. Diagonal bracing should be installed at the four corners to prevent the frame from racking from wind.

The endwall frame and doors are made of 2" x 4" lumber. Doors large enough to allow access for a small tractor in are desirable if the ground will be tilled. If the crops will be grown in the soil, the structure should be installed so that it can be easily moved from one plot to another. A movable tunnel design is available from Four Season Tools, 602 Westport Road, Kansas City MO 64111. It can be moved with a tractor or winches.

Widths of 14' to 20' are most common but some manufacturers make structures as wide as 30'. Although the length can be any multiple of the 4' hoop spacing, a 48' or 96' length will utilize the 100' sheets of plastic better.

**Glazing**

It is best to utilize the stronger 4 or 6-mil greenhouse grade of polyethylene that will give 4-years of service rather than the agricultural grade which usually deteriorates in less than one year. A hip board, attached to the frames, 3' to 4' above the baseboard will hold the plastic when the roll-up sides are open. 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.

**Life** – the life of polyethylene films is limited due to degradation processes induced by sunlight and heat. Co-poly is a low-cost material that is good for one season. This is a better choice on tunnels than construction grade material that has less strength. Greenhouse grade poly is warranted for 4 years or more and costs about double that of co-poly. It contains an ultra-violet (UV) stabilizer that reduces degradation. If additional strength is needed, such as a windy location, a nylon scrim-reinforced material is available from several manufacturers.

**Condensate control (AC)** – also referred to as anti-drip is a wetting agent that reduces surface tension allowing condensation to flow rather than form droplets. Condensation droplets reduce light transmission and can lead to disease problems where they drip onto plants.

**Reduced nighttime heat loss (IR)** – this is additive that 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 - 3°F but with both types the tunnel was cooler than outdoor ambient. In double layer poly installations, the IR film is always placed as the inner layer to retain nighttime heat.

**Reduced daytime heat gain** – in areas with strong sunlight, blocking part of the infrared spectrum can lower inside temperature up to 10°F. Selective reflective pigments are added to the outside layer. Along with greater diffusion of the light, the advantages include lower cooling costs, greater worker comfort, less irrigation needed, reduced plant stress and improved fruit taste.

**Light transmission** – photosynthetically active radiation (PAR) light transmission varies with the type of additive in the film. Typical values are UV stabilized film – 88 - 91%, IR-AC film – 82 - 87%, IR-AC with diffusion – 77 - 88%. Dust, smog and plastic deterioration can also reduce light transmission. A "rule of thumb" for winter and early spring use is one percent increase in light equals one percent increase in plant growth.

**Single or double layer poly** – for normal operation, a single layer is adequate. If you are growing early in the spring or late into the fall

and are providing supplemental heat, an inflated double layer may be desirable. It reduces heat loss at night by about 40%. It also reduces the stress at the attachments and the rippling of the plastic on a windy day. Air inflation at ¼" water static pressure is best.

**Plastic failure** – early failure of poly can be attributed to stress as noted above, 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.

**Cooling**

**Natural ventilation** - Roll up sides are normally provided with high tunnels. This is a natural ventilation system that operates on the principle that heat is removed by a pressure difference created by wind and temperature gradients. Wind plays the major role. In most cases, a wind speed of 1 mile/hour is adequate to keep the inside temperature within two degrees of ambient. There are very few days that the wind is less than 1 mph especially if the outdoor temperature is above 80 deg F. Solar-powered vent openers that can be installed in high tunnel roofs are available form Ken-Bar, Inc., 25 Walkers Brook Dr., Reading MA 01876-0704.

**Fan ventilation**

A small fan system could be installed in one endwall to provide the initial automatic stage of cooling before the roll-up sides are opened. Locate a motorized shutter on the opposite endwall. A ¼ hp, 24" fan is adequate for a 14' x 48' tunnel and a 1/3 hp, 30" fan for a 14' x 96' tunnel. These should be controlled by a thermostat located at plant height in the middle of the tunnel. The thermostat should be shaded from direct sunlight.

**Heating**

Supplemental heating is not very common with high tunnels. The basic concept of the tunnel is to extend the season without much added expense. When heating systems and mechanical ventilation are added, the cost jumps up significantly and may be difficult to justify for short growing seasons. A low-cost root zone heating system may, however, have a short payback period especially for a high-value crop such as spring tomatoes.

A rule of thumb for calculating heat loss is to multiply the floor area of the high tunnel by 1-1/2 and multiply this by the degrees of protection that is desired. This will be the approximate heater input needed.

**Passive heat** - Research by Dr. Craig Storlie, Rutgers University showed that a few degrees of temperature modification can be achieved with thermal tubes filled with water placed next to the plants. The water captures heat during the day and gives it back to the air at night.

**Non-vented heaters** - should be used for emergency or short term use only. Long term use is likely to result in sulfur dioxide or ethylene gas injury to sensitive plants. Salamanders and fan forced or convection propane heaters are available with outputs up to 400,000 Btu/hr. Southern Burner Company, P.O.Box 885, Chickasha OK 73023 makes gas units that can heat smaller high tunnels. These have a mechanical thermostat that doesn't require electricity.

**Vented heaters** - Gas or oil fired hot air unit heaters are easy to install and provide air circulation. They are generally supported on a pipe frame off the ground and directed to blow the heated air down an aisle or above the crop to avoid drying the plants. A hot air furnace connected to poly ducts that are run between the rows have been used by some growers. Holes in the duct should be located to direct the heat to the base of the plants and not onto the foliage.

**Root Zone Heating** - Because root temperature is more critical than air temperature for most plants, root zone heating may be the best choice. A simple system using polyethylene pipes and a domestic hot water heater works well. Water temperature of about 100 deg F is circulated through the pipes.

For soil crops, the pipes are placed 8" to 12" deep to allow rotary tilling above. One pipe is located under each row although more runs can be installed to provide more heat. The piping is installed as loops fed by a supply header with the other end connected to a return header. Using a reverse return system, the flow through each loop travels the same distance giving uniform heating. Heat loss from plastic is relatively slow so lengths of 200' for ½" and 400' for ¾" pipe will give good results with minimum friction loss. You can estimate that heat output is about 10 Btu/hr per linear foot of pipe.

A tank-type domestic hot water heater (30,000 to 40,000 Btu/hr) fired by natural gas or propane will provide the root zone heat for a tomato crop growing area up to 3000 sq ft. Water is moved through the system with circulating pumps. A combination of root zone and air heating will usually be needed on cold nights. The system should be drained during the winter if not in use to avoid freeze damage.

**Air circulation**

To eliminate cold spots and large differences in temperature, air circulation may be desirable. The horizontal air flow (HAF) system that uses small 1/15$^{th}$ horsepower circulating fans works well. Fans are placed to circulate air down one side of the tunnel and back the other. In a 14' x 96' tunnel, locating two fans on the center frame, above the crop, one pointed in one direction and the other pointed in the other will give good results. In a 14' x 48' tunnel the fans should be located in opposite corners of the tunnel about 8' from the endwall. The fans should operate continuously except when the sides are rolled up. Air circulation will also help to reduce moisture related disease problems.

**Irrigation**

Irrigation water is needed for the plants. If zoned properly, several high tunnels may be supplied by a 1" poly pipe line. Where the tunnels are located a distance from water, a trailer mounted tank could be used for the water supply. For crops grown in rows or containers, a drip system will reduce the amount of water needed.

# Reduce Storm Damage to Your Greenhouses

Nature seems to be getting more violent in recent years with frequent earthquakes, increased numbers of hurricanes and record breaking snowstorms. Insurance damage claims have increased considerably. The International Building Code has revised upward its wind and snow loading requirements for some areas of the U.S.

Each year there are reports of greenhouses that have been damaged by weather and natural events. Greenhouse design is different than conventional farm buildings in that the structural profile has to be small to allow maximum light to reach the plants. Most farm buildings are over designed to handle severe weather conditions.

Damage to greenhouses can include racking of the frame, bending of the hoops, broken glass or torn plastic and uplifted foundation posts. Preparation ahead of time can minimize the damage.

**Wind loading**

Wind forces that act on a greenhouse are influenced by numerous factors including the basics wind speed, building orientation, exposure, height and shape of doors or vents that may be open. The wind passing over a greenhouse creates a positive pressure on the windward side and a negative pressure on the leeward side. These can combine to create a force that wants to collapse or overturn the building. An 80 mph wind can produce a pressure of 16 pounds per square foot (psf). For example, the 10' by 100' sidewall of a gutter-connected greenhouse would have to resist a 16,000 pound force.

Wind can also create a force similar to an aircraft wing that wants to lift the greenhouse off the ground. An 80 mph wind blowing perpendicular to the side of a 28' x 100' hoophouse can create a lifting force of 220 pounds per foot of length or 22,000 pounds of uplift on the whole structure. When you consider the total weight of materials and equipment in the greenhouse is about 6000 pounds, the foundation must have a withdrawal resistance of about 300 pounds each. This is why building inspectors frequently require that the posts be surrounded by concrete.

Although you have no control over the force or direction of severe winds, here are a few tips to help minimize storm damage:

- Check the area for loose objects. Anything that can be picked up and hurled through the glazing should be secured or moved indoors. Metal chimney (stove pipe) sections should be secured with sheet metal screws.
- Inspect for dry or weak tree limbs that could fall on the greenhouse.
- Close all openings including vents, louvers and doors. The effective force of the wind is doubled when it is allowed inside the building. The wind on the outside puts a pressure or lifting force on the structure. The wind inside tries to force the walls and roof off.
- On air inflated greenhouses, increase the inflation pressure slightly by opening the blower's intake valve. This will reduce the rippling effect. Check to see that the plastic is attached securely and that any holes are taped.
- Disconnect the arm to the motor on all ventilation – intake shutters and tape the shutters closed. Then turn on enough exhaust fans to create a vacuum in the greenhouse. This will suck the plastic tight against the frame.
- Windbreaks can reduce the wind speed and deflect it over the greenhouse. Conifer trees (hemlock, spruce, pine, etc.) in a double row located at least 50' upwind from the greenhouse can reduce the damaging effects of the wind. Wood or plastic storm fencing can be used as a temporary measure.

**Snow loading**

Snow that accumulates on a greenhouse can put significant weight on the structural members. Snow loads vary considerably from 0 along the southern coastline to more than 100 pounds per square foot in Northern Maine. Local building codes specify the design snow load.

Snow can be light and fluffy with a water equivalent of 12" of snow equal to 1" of rain. It can also be wet and heavy with 3" equal to 1" of rain. Snow having a 1" rain water equivalent will load a greenhouse with 5.2 psf. This amounts to 6.5 tons on a 25' x 96' greenhouse.

The following are a few pointers to consider before the next snow season:

- The foundation piers or posts should be large enough to support the weight of the building including crop and equipment loads.
- All greenhouses should have diagonal bracing to keep it from racking from the weight of the snow or force of the wind.
- Collar ties and post connections should have adequate bolts or screws. This is a weak point in some greenhouse designs.
- Allow 10' to 12' between individual greenhouse for snow accumulation and to prevent sidewalls from being crushed in.
- When building new hoophouses, consider using a gothic design that sheds snow easier. In hoop shaped houses, install 2" x 4" posts under the ridge every 10' when heavy snow is predicted.
- The heating system should be large enough to maintain 60°F to melt snow and ice. It takes 250 Btu/hr per square foot of glazing to melt a wet snow falling at a rate of 1"/hour. Heat should be turned on in the greenhouse or under the gutter several hours before the storm begins.
- The plastic should be tight and inflated to at least 0.25" water pressure. This can be checked with a monometer. Any cracked or broken glass should be replaced.
- Energy screens should be retracted to allow heat to the glazing.
- A standby generator should be available with adequate fuel for the duration of the storm to power heaters, fans and blowers.

Selection of greenhouses that meet the International Building Code and good construction techniques are important considerations when building new greenhouses. A little preparation before a storm can minimize damage from severe weather events.

**By John W. Bartok, Jr., Agricultural Engineer,**
**Natural Resources Mgt. & Engr. Dept.**
**University of Connecticut, Storrs CT**