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High Tunnels for Crop Production in Texas

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High tunnels are also known as hoop houses. These structures are similar to greenhouses, but they have no permanent floors or heating systems (Figure 1). They are usually made of arched supports that are covered with plastic. Hoop houses can optimize specialty crop production by allowing you to:

- Plant earlier and extend the growing season in order to garner higher market prices
- Better control the crop production environment to improve yield and quality
- Protect high value crops from heavy rain, hail, high winds and freezing
- Increase farm potential and economic profitability

Hoop houses keep rain out, so producing crops in them typically uses drip irrigation and black polyethylene or biodegradable mulches. Unlike greenhouses, tunnels are usually covered with a single layer of plastic rather than the two. Depending their size, small farm equipment can be used inside tunnels to prepare the soil for seeding or transplanting.

High tunnels can extend the season in colder climates by using sunlight to warm the growing environment (Figure 2). In places like West Texas, they can also protect sensitive crops against high winds, dust storms, moderate hail and other severe weather conditions.

Depending on a tunnel's design and location, you can vent excess heat by opening its sides and/or end panels. High tunnels are considered temporary structures, and generally do not require a building permit; however, check with local zoning authorities before starting construction.

What type of tunnel is right for me?

Selecting the appropriate high tunnel depends on:

- The region where it will be built
- The crops you plan to grow
- Funding and anticipated costs

Commercial high tunnel manufacturers offer many designs and sizes. You can also build hoop houses with locally purchased materials. The round Quonset-shaped tunnels (Figure 3) are popular in Texas, though Gothic-shaped (Figure 4) tunnels are also used. Gothic arch tunnels are common where crop production requires high sides, or where heavy snowfall is a concern.

Sidewall height ranges from 3 to 5 feet. A 5-foot sidewall is best for accommodating small tractors, and for growing taller crops near the tunnel edges. Though dimensions can vary, high tunnels are typically 26 feet wide by 96 feet long and approximately 13 feet high at the center. Select the tunnel that best meets your production needs.

High tunnel construction principles are similar regardless of models and sizes. However, for tunnels on the High Plains and the Panhandle, wind protection is a priority and will increase the cost accordingly. Regardless of region, using natural windbreaks can help you lower construction costs and reduced potential struc-

FIGURE 1.

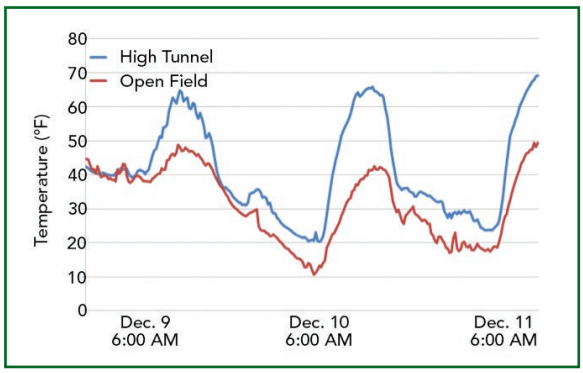

FIGURE 2.

FIGURE 3.

FIGURE 4.

tural damage. Research the prevailing wind direction and speeds, as well as the snowfall potential before you build.

To protect your crops, secure your tunnels during hail, wind, and heavy rains. An ideal high tunnel should be made of strong materials and the plastic covering should be able to withstand minor tears.

The wind in West Texas blows dust and can reach 30 to 80 mph in the spring. Tunnels on the High Plains and the Panhandle must be anchored securely to the ground. The type, number, and weight of tunnel anchors you use depend on the potential for severe weather. Other factors include the type of soil you are anchoring to and how far the tunnel is from a natural windbreak. Tunnels that are built on sandy soils should have ground posts that are at least 24 inches deep to prevent lift during high winds. When you secure a tunnel, it is better to have too many anchors than too few.

Though not necessary for small homemade models, most large units require a gearbox roll-up curtain system on both sides of the tunnel for ventilation. Side, front and back ventilation are essential if the plastic remains on during the summer. It can be 20 to 40°F hotter in a tunnel than in the open field and heat stress can lower crop yield and quality. Opening the side vents, along with the front and back end panels, will let heat escape. You may need to open and close the vents daily, but the tunnel must be closed during high winds to prevent crop damage. To prevent frost damage, you can close the side vents and end panels to passively heat the air inside the tunnels.

Constructing a high tunnel can cost from $0.50 to $3.50 per square foot or more depending on the size and manufacturer's specifications, or whether the high tunnel is built from locally purchased materials. As of 2013, the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) has a Seasonal High Tunnel Initiative cost-sharing program for qualified growers to help with purchasing high tunnels. Contact your local NRCS representative for further details or visit www.nrcs.usda.gov. Before constructing a high tunnel, discuss your production plans with your county Extension Agent, Vegetable Specialist, or Risk Management Specialist. For additional information on high tunnel choices, visit www.hightunnels.org.

FIGURE 5.

FIGURE 6.

Site selection

Site selection is critical, especially in the Panhandle and on the High Plains. Considerations include soil quality and the slope of the land.

Before building, you should have the soil tested for pH, organic matter content, soil type, etc. It helps to add composted material to heavy clay soils each year. Grading heavy soils 6 to 8 inches higher before construction may alleviate potential flooding inside the tunnels during heavy rainfall (Figure 5). Sandy and sandy loam soils generally have good drainage so this type of soil may not need to be raised.

Some slope can help by allowing runoff during heavy rainfall. For tunnels on level or heavy soils, you may need to install an internal drainage system to improve soil health. Internal drainage lines spaced well below the soil surface can help reduce waterlogged soils. You can build an external drainage system by digging 8- to 12-inch-deep trenches along the tunnel sides and filling them with gravel or rock (Figure 6).

During moderate to heavy rainfalls, close the side vents and the front/back panels to keep excess runoff out of the tunnels. Unplanned water in the tunnels will promote weeds and diseases, and can make it harder to inspect and harvest crops.

How you orient a high tunnel will vary by location, but all tunnels should be set for maximum sunlight and wind ventilation during high temperatures. South of the Nebraska border, a north-south orientation gives the maximum winter sunlight that is critical for growing crops during short days (Figure 7). Build high tunnels away from tall trees and buildings to reduce shading.

FIGURE 7.

In Texas, prevailing winds are out of the south-southwest—constructing tunnels north south will reduce the surface area exposed to high winds. Well-constructed fences or even perennial shrubs, hedges, and small trees can help protect tunnels from high winds. To reduce shading effects, windbreaks should not be within 20 to 30 feet of the tunnel. On the High Plains and Panhandle, it is best keep the plastic cover in place because windy conditions can delay planting and reduce the benefits of a longer growing season.

Finally, high tunnels must have an adequate supply of quality irrigation water. Unless it gets flooded, or the covering is removed, no rainfall will reach the soil within the tunnel. Capturing rainfall in barrels with a gutter system is an alternative for irrigating high tunnel crops. Drip irrigation systems will increase water use efficiency. Drip lines used for irrigation can be subsurface between the rows of plants, or placed beneath the plastic mulch or between seeded crops. Avoid salt buildup when using with alkaline water—salt buildup can damage seedlings and plug drip line emitters.

Example of high tunnel construction on the high plains

The following describes the construction of four commercial high tunnels at the Texas A&M AgriLife Research and Extension Center at Lubbock. This particular model was chosen because it is well suited to the high winds of the Texas Panhandle. The construction and components described are specific to the model used in this project, however, the process and components are similar across most high tunnels.

The tunnels were purchased as packaged kits, which included:

- Preformed hoop joints
- Ground posts
- Wiggle wire
- Poly latch U channel
- Couplers
- Braces
- Ground post drivers
- All required nuts, bolts and screws
- Plastic covering

FIGURE 8.

If you build a tunnel with locally purchased materials, you will need a hoop bender (Figure 8). These are available online from high tunnel manufacturers and seed companies.

The high tunnel model constructed in Lubbock was selected because the frame is made of heavy steel tubing that could be spaced 4 feet apart instead of

FIGURE 9.

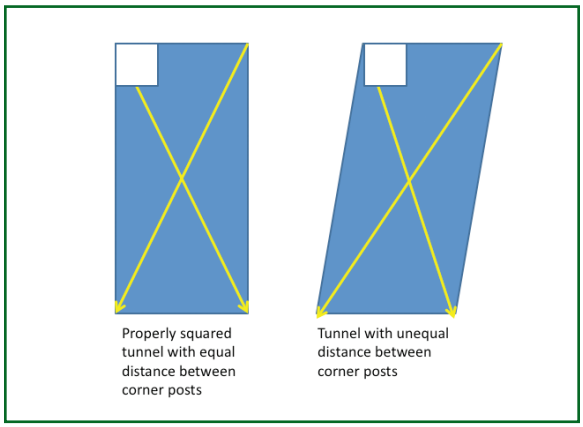

FIGURE 10.

FIGURE 11.

FIGURE 12.

the standard 6- or 12-foot distance. The extra hoops increased initial cost, but also increased the tunnel's strength and stability in high winds.

The covering included was a single layer of 12 mil (5.2 oz.) clear interwoven poly plastic. Though more expensive than standard greenhouse plastic, the interwoven poly covering reduces the potential for small tears to rip completely—even during high winds. This type of plastic covering is recommended for the High Plains and Panhandle regions.

A forklift was needed to move the kits from the delivery trailer to the building site (Figure 9). We checked the parts from each box against the packing list and organized the components on the ground nearby. These kits, like other commercial products include detailed assembly instructions. Follow the instructions carefully or you may void the warranty.

It is critical that the tunnel footprint be marked accurately with four corner posts. To square the high tunnel corners, use the Pythagorean Theorem ($A^2 + B^2 = C^2$) for measuring the right angles. Ensure that the footprint corners are square by measuring the diagonal distance between opposite corner posts (e.g. left back to right front). If the diagonal distances are not equal, the footprint is a trapezoid and you must realign the corner posts to form a true rectangle (Figure 10). The ground posts must be squared exactly for the tunnel to build properly.

Stretch a string tightly one foot above the ground from each corner post to its counterpart at the other end of the footprint. These strings will mark the desired line and height of the ground posts that will support the tunnel walls. Before driving the ground posts, mark them all at the depth they should be driven. For example, 36-inch steel ground post driven 24 inches into the ground will leave 12 inches of post exposed. This method takes time but it ensures the walls will be straight and level. Ground posts must be perpendicular to the ground or the frame will be uneven. Check each ground post with a bubble level in all directions as you drive them and straighten them as needed. If you want to improve tractor accessibility, you can buy angled couplers and connect them to the ground posts to raise the sidewalls (Figure 11).

Once the ground posts are set, it is time to assemble and raise the hoops (rafters). Assemble the hoops on level ground or on wooden pallets to ensure they align correctly (Figure 12). Each hoop goes together by placing the swaged ends into the plain end of another hoop section. After you assemble each hoop, ensure they are aligned then use self-drilling screws to secure the rafter joints. The screws must go in only from the bottom to avoid tearing the plastic that will cover the outside. As the hoops are completed, carry them to the tunnel site and set the ends into the opposing ground posts and secure the inside edge of the joints with self-drilling screws (Figure 13).

Once you secure three or four hoops to the ground posts, stabilize them with three to four evenly spaced purlins. The purlins should be perpendicular to the hoops and, in this case, are connected with end and cross connector clamps. Continue to add the purlins as you raise hoops (Figure 14).

Cover each joint and clamp with duct tape before you cover the frame with plastic. The duct tape will keep sharp edges from tearing the plastic during installation or in high winds (Figure 15). In high-wind regions, put an extra screw at each end of the purlins just inside the end clamps. This extra screw was not in the instructions for this particular kit, but it secures the end wall to the purlin clamps during high winds.

Once all the purlins are connected to the hoops, the frame is ready for the end walls. The end panels can be zippered plastic or can be framed in. Zippered end panels work well where wind is not a concern. However, High Plains winds will split the zippers in four to six months.

Framed end panels make the structure stronger and will keep the end plastic from splitting. Ends should include windows for ventilation, and one end needs an opening that is big enough for tractors and other equipment (Figure 16). For this project we had a local tent company sew in the zippers.

The two-door opening at one end allows small tractors and equipment to enter for soil preparation (Figure 17). At the back of the each tunnel, three windows near the top allow ventilation and heat capture. We secured the plastic end panels to the outside of the wooden frames using drip tape and roofing nails. We then cut out the windows and doors with a sharp knife (Figure 18).

After completing the frame, connect 1- by 6-inch hip boards—not provided in this kit—to the hoops about 4 to 5 feet high along the length of the frame. The hip boards are the attachment point for the aluminum U channel that will hold the plastic cover with wiggle wire (Figure 19). Attach each section of U channel to the hip with evenly spaced 4-inch bolts. The U channel must be level across the tunnel frame; a string stretched tightly lengthwise will help you keep the U channel even.

High tunnels on the Texas High Plains and in the Panhandle must be anchored securely to the ground. This helps stabilize the tunnel and keeps it in place during high winds. You can buy screw-in anchors, but they will loosen over time. A more permanent option is to anchor a hooked piece of rebar into 3-foot hole with two or three bags of cement. Set the hooked end so it extends about 1 foot above soil level. After the concrete dries, you can fill

FIGURE 13.

FIGURE 14.

FIGURE 15.

FIGURE 16.

FIGURE 17.

FIGURE 18.

FIGURE 19.

FIGURE 20.

in the hole with soil and secure the frame with cargo straps (Figure 20). Use at least three anchors on each side of the tunnel—one at each corner and one in the middle.

One by six-inch baseboards will give additional support and keep the ground posts and hoops from shifting or sinking further into the ground. Bolt the baseboards to the outside of the ground posts at the soil line or a few inches below the surface (Figure 21). Once the bolts and screws are tight, the sharp edges taped, the end walls set, and the hip and baseboards secure, it is time to cover the tunnel with plastic.

These kits included a sheet of 12 mil (5.2 oz.) clear poly plastic interwoven fabric. This plastic fabric is more expensive than standard greenhouse plastic, but it is more durable and tears less easily in high winds. The rolled up fabric weighs about 100 lbs., and takes at least two people to move it. Unroll it the length of the tunnel, tie ropes on the ends and about every twenty feet along the fabric, and toss them over the tunnel frame to pull the plastic over the top.

In high-wind areas, pull the plastic early in the morning when winds are 5 mph or less. It takes four to five people to pull the plastic over tunnel evenly. It helps to have someone inside the tunnel on 12-foot ladder to help should the plastic snag on the frame (Figure 22). When the fabric is spread across the frame, center it side-to-side and front to back.

FIGURE 21.

FIGURE 22.

Pull the plastic over the frame and the poly latch U channel—but not too tightly. The fabric should be just loose enough to allow the wiggle wire to go into U channel but not so tight that it is difficult to secure. Begin with the wiggle wire at one end of the tunnel and work it to the other end (Figure 23). You may need to cut excess wiggle wire at the end of the tunnels.

Once you secure the plastic to the tunnel frame with the wiggle wire, assemble the poles for the roll-up side ventilation system. Use self-drilling screws to secure the swaged joints in the roll-up poles. Here again, duct tape the joints and screws to protect the plastic when rolling the sides up and down (Figure 24). When the roll-up pole is assembled and taped, set it alongside the tunnel and space the fabric clamps about 4 feet apart. Attach the plastic to the pole at ground level. This will ensure the plastic is even when rolled up and down. Cut off excess plastic with a sharp knife or scissors from inside the roll-up system, but leave 4 to 6 inches for future leveling.

You can now install the gearboxes on the end panels for the roll-up ventilation system. Attach the aluminum channel for the gearboxes to the frame using one large bolt. Once the gearbox is on the aluminum channel, install the roll-up ventilation poles into the gearbox (Figure 25). If the sides do not roll up evenly or smoothly, adjust the plastic and fabric clamps until they do.

Once the roll-up side ventilation system is adjusted correctly, connect eyebolts by drilling through the hip boards and U channel. The eyebolts should be spaced evenly along the length of the tunnel. Once they are secure, loop the antibillow rope through the eyebolts alternating from top to bottom (Figure 26). The antibillow ropes keep the roll-up sides from moving too much in high winds. The high tunnel is now complete and ready for crop production (Figure 27).

Keeping the high tunnel sound is critical. Inspect the frame regularly and do the following every 6 months:

- Check ground posts and all joints for integrity
- Tighten all bolts and screws
- Repair small holes and tears in the plastic
- Replace worn duct tape on all the joints
- Detail the roll-up ventilation system and gearboxes
- Tighten all anchor straps.

FIGURE 23.

FIGURE 24.

FIGURE 25.

FIGURE 26.

FIGURE 27.

Additionally, the frame and all components should be evaluated following any severe wind events over 50 mph to ensure the tunnels are safe to enter.

High tunnel startup can be expensive and crop production costs are typically higher when using them. What you grow in your tunnels will depend on your market and customer preferences, as well as its potential to pay off startup costs as quickly as possible. For information on specific crops for tunnel production, refer to publication HT-029 *Specialty Crops for High Tunnels in Texas*.

Total cost analysis ($) for the tunnel described above.

High tunnel and construction	Unit	Cost/Unit	# of units	Cost
High tunnel (ClearSpan Colossal 30'x96')	Kit	Shipped	1	8,140.56
Wooden framed end panels 2x4s	Feet	0.49	465	227.85
Drip tape support strapping (used)	Feet	0	240	0
Hip boards and baseboards	Feet	0.66	384	253.44
Construction labor	Man-hrs	10	60	600
Irrigation setup	Man-hrs	10	10	100
Duct tape	Case	180.70	1	180.7
Anchor straps	1 strap	11.66	6	69.96
Cement bags (80 lbs)	Bag	3.55	18	63.9
Gravel rock	1 trailer	43.31	1	43.31
High tunnel maintenance supplies		2-year average		416.15
Total				**10,095.87**

High tunnel suppliers and manufacturers

AgraTech Greenhouses: http://www.agra-tech.com
Conley's Greenhouses: http://www.conleys.com/cf_1000.htm
CropKing Greenhouses: http://www.cropking.com/
FarmTek: http://www.farmtek.com
Gothic Greenhouse Supply: http://www.gothicarchgreenhouses.com
Haygrove Tunnels: http://www.haygrove.co.uk/index.php
Quiedan Hoop Houses: http://www.quiedan.com
Rimol Greenhouses: http://www.rimolgreenhouses.com

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