Hard-Sided High Tunnel Construction

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Methods for protecting crops from environmental extremes have been considered by producers for many years (Ashton, 1994). The advent of greenhouse quality plastic films has allowed for experimentation in designs of High Tunnels (or Hoop Houses), structures that provide plant protection and have the capacity to extend the growing season without additional energy inputs for heating and cooling purposes. This quality alone makes a high tunnel an economical method to moderate challenging environmental conditions. Recently, high tunnel use and utility have become increasingly popular in locations such as Wyoming as a method to protect tender plants from unpredictable early and late seasonal variability and allow producers to extend the growing season for the production of a wide variety of specialty crops (Bachmann, 2005).

The Hard-Sided High Tunnel (HSHT) design was developed by Dr. Del Jimenez, Extension Area Specialist, New Mexico State University. Although pre-engineered kits are available from a variety of suppliers, Dr. Jimenez's program is a program of thrift, utilizing locally available materials where possible, and constructing a structure that can withstand a wide variety of environmental conditions (Jimenez, et. al. 2005). This document describes the construction methods required to build a 16'X32' HSHT (Figure 1). This structure can be completed in approximately 20 hours with a minimum crew size of four people. The materials list can be modified to fit your needs if you choose to change the project dimensions.

Figure 1. Completed 16' X 32' Hard-Sided High Tunnel.

FACTORS TO CONSIDER BEFORE BUILDING A HIGH TUNNEL

Hoop houses can be relatively inexpensive to construct, (ca. $2-3 per square foot). These are considered to be temporary structures and maintenance once constructed is minimal; however the "skin" and other materials do have a limited life expectancy. Depending on the skin material and quality of building materials selected the structure should survive several years. High tunnels are easy to build and

adaptable to a variety of land sizes and conditions to meet the needs of gardeners and farmers. Other considerations prior to final design selection are wind and snow issues specific to your location. Lower flatter structures perform best in windy conditions while taller structures will more likely shed snow. There are load limitations of these structures and understand that one may need to remove snow or add internal bracing to prevent collapse.

SELECTING A SITE FOR A HIGH TUNNEL

Select a site that is moderately level with good drainage and good soil for planting. A site can be modified by soil fill so that construction is on a level pad. Select a site in an open area where trees and other obstacles will not affect sunlight penetration. Consider the surrounding area so the structure will be protected against high winds and heavy snows, thus extending the life. Water is required and electricity may be needed for the hoop house, so a nearby source should be considered. Security and protection against vandalism of the hoop house and crop may also be a factor to consider when selecting a site (Jimenez, et. al. 2005).

CONSIDERATIONS FOR HIGH TUNNEL ORIENTATION

The single determining factor for setting the orientation of a high tunnel in Wyoming is the direction of the prevailing wind. In many locations, these structures are used to produce crops throughout the winter and shut down during the hot summer months; this is not possible in Wyoming. These structures in Wyoming are considered season extenders and are conducive to year-round production only if supplemental heating is utilized. The ability to vent excessive heat during mid-summer is critical to plant production strategies.

PROJECT PREPARATION

Depending on the type of building material you choose (Raw lumber, Redwood, Cedar, Pressure Treated or Biocomposite recycled plastic), there is a certain amount of material prep work that goes along with this structure. For the purpose of discussion, this project will be using untreated lumber. A complete listing of materials required for this structure is located in the Appendix.

When using power tools please read and follow the manufactures instructions for use and wear recommended safety equipment.

Lath Material

Approximately 550 linear feet of lath material is required for this size of project. Taking a 1/8" kerf of the table saw blade into account, approximately 90 linear feet (9-3/8" lath strips) can be yielded from each 10-ft 2"X4". In order to acquire the required amount of lath for this project, rip six (6) the 10-ft 2"X4" boards into 3/8" lath strips and set aside for painting (Figure 2).

Figure 2. Ripping lath material.

Painting the Lumber

Paint all wood surfaces for this project, including the lath strips using an exterior latex paint. One coat is sufficient. Allow enough time for the paint to dry prior to handling.

4"X4" Posts

Once the paint has dried, cut two of the 10-ft 4"X4" posts in half (into two (2) – 5-foot 4"X4" sections) and lay aside. These will be used as the corner posts, the remaining posts will be cut to fit.

Rib Assembly

The rib assembly consists of 2" Schedule 40 PVC pipe "**ribs"** and "**spacers**" that must be cut to size ahead of time. The PVC **ribs** are on 4-foot centers, a 32-foot long structure requires nine, 20-foot sections for the ribs. If the sections of pipe have "bell" joint ends, cut off the bells (in front of the bell flair) as they are not used in this project, measure the usable length of pipe and be certain that all rib pieces are cut the same maximum length (may not be 20 feet exactly, *however, all ribs must be the same length*). From the remaining 2" PVC pipe, cut 16 - 45 ½" **spacers**.

Complete all PVC cement work on a hard flat surface. Use PVC pipe cleaner and cement to begin building a total of four PVC "**rib rectangles**". **Be certain to align all joints while gluing so that they are straight.** The first two rectangles-each consist of 2 **spacers**, 2 **ribs**, and 4-**2" PVC T's** (note: do not use low pressure drain fittings, as there is limited surface to cement together). Experience in the construction of these structures has proven that gluing the "T's" and/or 90° elbows to the "Spacer" first, and then to the ribs makes the assembly process easier (Figure 3). Align the "T's" so that the top of the "T" can receive the **spacers** and the bottom of the "T" can receive the **ribs** (Figure 4). Next, in the same manner, build two additional rectangles each consisting of 2 **spacers**, 2 **ribs**, and 2-2" **PVC T's** and 2-2"

PVC 90° elbows. The rectangles with the 90° elbows are for either end of the structure. Finally, orienting the "T's" as described above, clean and cement a 2" "T" to both ends of the single remaining rib. This single rib is considered the "key" rib when erecting the ribs onto the wooden base. The "key" will allow adjustment of the final spacer length which permits the end rib rectangle assembly to fit flush with the outside edge of the wooden base. Set these structures aside and allow PVC cement to cure according to the cement manufacturer's instructions (Note: **Do not** glue additional spacers and connect the individual rectangles as more than two ribs together create complications while attaching the ribs to the wooden base).

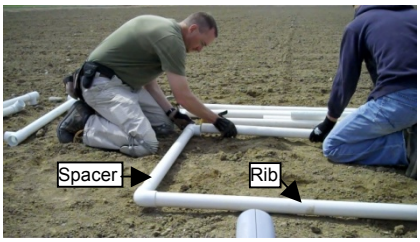


Figure 3. Spacer assembly first and adding the Ribs.

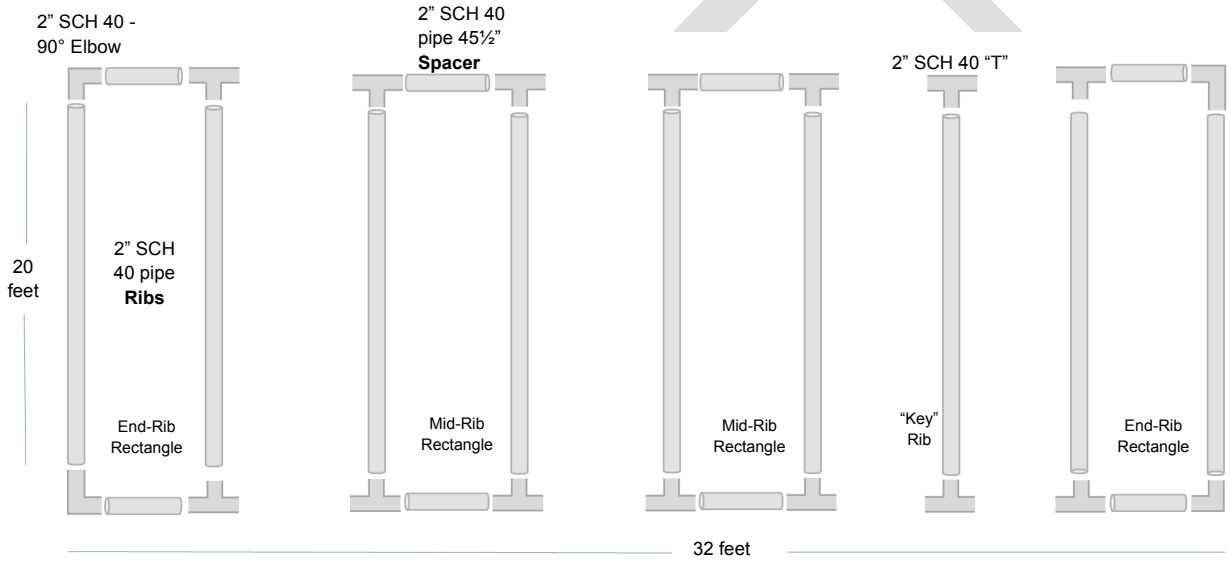


Figure 4. Schematic of 16' x 32' High Tunnel Rib assembly. Additional spacers between the rib assemblies will be added when the ribs are attached to the wooden base.

PLACING THE HIGH TUNNEL

Prep your site as needed and establish the structure perimeter. Square the perimeter of the high tunnel by using the Pythagorean Theorem.

$$a2+b2=c2$$

Where: (a = Length of Building) ^{2} + (b = Width of Building) ^{2} = (c = Hypotenuse of Building) ^{2}

Example: a (32-ft.)^2 + b (16-ft.)^2 = c^2

256-ft.^{2} + 1,024-ft.^{2} = 1,280-ft.^{2}

√1,280-ft. = 35.77-ft.

c= 35.77-ft. = 35-ft. 9 1/4-in.

(Figure 5).

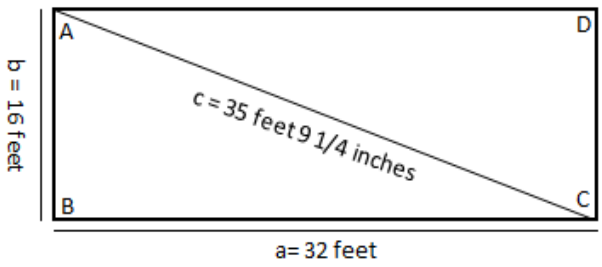


Figure 5. Perimeter Points used to establish a square structure.

Establishing the perimeter

Place a marker in corner A, using a tape measure (greater in length than the length of the structure) measure from corner A, 16-feet and locate corner B. Place a second marker to indicate corner B. Place a second tape measure on corner B. Simultaneously, measure from corner A, 35-feet 9 ¼-inches and from corner B, 32-feet. Corner C is where these two measurements intersect. Place a marker at this intersection indicating corner C. To locate corner D, place a tape measure on corner C and another on corner A. Simultaneously measure 16-feet from corner C and 32-feet from corner A and place a marker at their point of intersection (Figure 6). To check your measurements run a diagonal measurement from corner B to corner D (the measurement should be 35-feet 9-1/4 inches).

Setting the Corner Posts

Dig a two foot deep hole 6 to 8 inches in diameter at each of the four corners. *Note: Set the lowest corner first if the building site is not level*. To set the first corner post, place one of the 5-foot 4" x 4" posts painted end down, attach a post level near the top, hold the post level in both vertical directions, and align the face of the post with what you perceive as in-line with the rest of the structure. Slowly return soil back into the post hole (additional gravel and fines may be required to hold the post firm-this will prevent the posts and top rail from bowing out when setting the ribs). Use a tamping bar to assist in setting the post. Also, as you are back-filling and tamping, lightly jiggle the post to force the fine material closer to the post. The gravel and fine material worked in this manner will assist in creating a tighter hold of the post. The post should have limited lateral movement under light force when completely back filled and tamped in place. Once in place, remove the post level and attach the level to a second post.

Drop the second post-painted end down in either adjacent (to the first post) corner post hole. Whichever direction, be certain that the post measurements from outside to outside do not exceed either 16 or 32 feet (or other specific outside dimensions that fit your project). Run a taught string line with a line level from the top of

the first post to the top of the second post. While checking the line level, adjust the post either up or down so that the level line just touches the top of the second post. Level the post vertically, and align the post face with the structure. Back fill, jiggle and tamp the post into place, all while checking the post for level on the vertical faces (Figure 7). Remove the post level and attach to the third corner post. Repeat above procedure for the two remaining corner posts, check level by running the line level from opposite corners. Outside post faces should not exceed the outside dimensions of the structure.

Setting the internal posts if the base

The remaining internal posts are located on 8-foot centers down either side of the structure. To mark these post locations, unreel and lay a tape measure along the length of either side (From points A to D or B to C-Figure 8). Hold the tape measure taught and mark every 8 feet from the first corner to the next (there will be three markers at 8, 16, & 24-feet). Repeat this measurement and mark the same distances along the second side (post placement will be more consistent if measurements start from the same end). Dig 6 to 8-inch diameter post holes, 2-feet deep at each of these locations (a total of 6 post holes). Attach a taught string line from the top-middle of post A to the top of post D and another along the inside or outside face between post A and post D. The top line will assist with vertical leveling and the face line will assist in post orientation to the rest of the structure. Pick one of the post holes, measure the distance from the hole bottom to the top string line, and cut the 4”X4” post to length, drop the 4”X4” post, painted end down, attach post level, adjust vertical height so that the post is just touching the top string line, align face of post to side

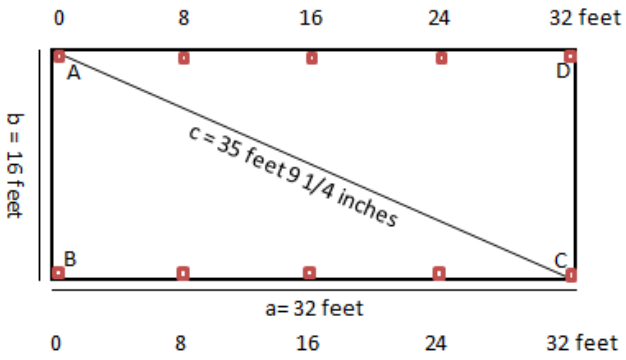


Figure 8. Post placement indicated by red squares.

string, check level while back filling hole, jiggle tamp into place, repeat until all posts are in place. At this point the structure should resemble Figure 9.

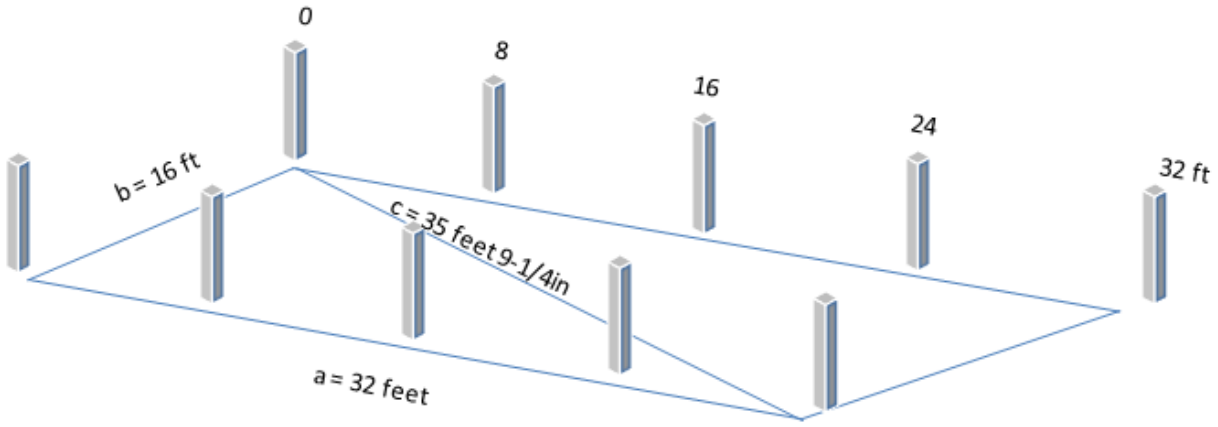


Figure 9. Rendering of Structure once all posts are set.

Attaching the top rail

The PVC ribs are attached to and supported by a top rail. The top rail consists of two - 2”x4”X16’ lumber boards per side butted together and cut to fit. Aligned the top rails over the top of the previously set posts. The 2”X4” rails are attached to the posts using 3” deck screws screwed through the top of the 2”X4” into the 4”X4” post. Temporary side rails are required to assist in the placement of the PVC ribs. Side rails (2”X4”X16’ or other dimension) are turned 90 degrees to the top rails and attached to the entire length on the outside of the top rails using 3” screws (Figure 10). Place the 3” screws 18” to 24” apart that so that they hold the temporary side rails in place. The side rails will be removed once the PVC ribs are attached.

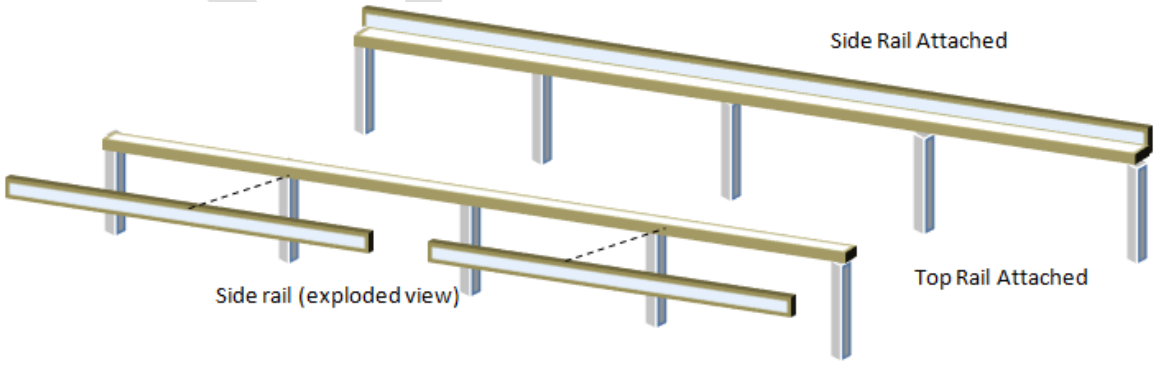


Figure 10. Top rail assembly, including temporary guide rail attachment.

PVC Rib Placement

Begin by placing the *individual* PVC rib assemblies (4 assemblies plus the "key rib") on the top rails of the base structure in the same order as shown in Figure 2. Select one side of the top rail as the "wedge side"; slip the spacer ends of the rib assemblies into one corner of the "L" created on the top rail/temporary side rail configuration of the designated wedge side (Figures 11 & 12). The rib assembly will rest on top of the opposite side rail and approximately 4-feet will hang over the outside of the opposite side rail. Add a piece of scrap lumber vertically to the outside edge base In order to keep the end rib assemblies flush with the exterior of the structure (Figure 13). Using a piece or cord or rope, tie the spacer end of the first rib assembly onto the wedge side of the rail structure, this will assist in keeping the rib assembly in place while preparing for permanent attachment to the structure. It is also important to assign an individual the responsibility of holding this end of the rib assembly.

Figure 12. Rib assembly placement prior to attachment to top rail.

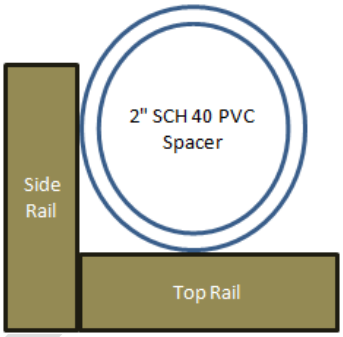


Figure 11. Cross section of Rail assembly with 2" SCH 40 Pipe "spacer" in place.

Lifting the Rib Assemblies into place

The rib rectangle assemblies are put into place on the top rails with one person designated as the "holder" on the tied down "wedge side", one or two people in the middle pushing up on the ribs and two people on the opposite side pushing the rib assembly in toward the base structure-in one swift and clean motion. With some force, place the spacer side being pushed into the structure (creating the arc with the ribs) into the opposite side rail assembly and hold (or tie) in place **(*Warning: you have just created a giant spring, with tendencies to force itself outward…do not let go of either side of the rib assembly that is resting on the top rail until the PVC rib assembly is permanently attached to the wooden base*)** (Figure 14).

Figure 14. Method used to position rib assembly onto wooden base.

PVC Rib Attachment

Without letting the rib assembly jump out of the top rail, pull the rib assembly in slightly from the temporary top rail and place a 3/8" spacer (a piece of the lath material can be used) between the "T" and/or 90° PVC joints **and** the temporary side rail – repeat on the opposite side top rail. This spacer pushes the joints in from the outer edge of the structure base and allows the poly skin material to lay flat on the structure.

Figure 15. Attachment of Rib assembly to wooden base. Drilling hole for carriage bolt; note 3/8" lath spacer at joint and holding the rib in place with rope.

Using a ¼-inch drill bit that is at least 6 inches long, drill one ¼ -inch hole through the PVC pipe spacer and through the wooden top rail, 6 to 8-inches inside both the "T" and/or 90° joint (Figure 15). Place a

washer onto a 5-inch long ¼-inch diameter carriage bolt, drive the carriage bolt with washer through the previously drilled hole, place a washer and nut on the threads and tighten until firm, **do not** tighten to the point of crushing the PVC as this will weaken and potentially crack the PVC. Repeat carriage bolt assembly for each of the holes drilled. There will be four carriage bolts placed per each rib assembly (two carriage bolts on either side of the structure per rib assembly). Once all carriage bolts are tightened in place for the individual rib assembly, untie the rope and move to the next rib assembly to be pushed into place.

Prior to lifting and permanent attachment of the next rib assembly, one must glue in place a rib spacer into the receiving "T" on either side of the rib assembly attached to the wooden base. Clean and cement a previously cut rib spacer into the "T" of the rib assembly that is bolted to the top rail (Figure 16).

Repeat the steps outlined in the **Lifting the Rib Assemblies into place** section for the next rib assembly. Then clean and apply cement to the other end of the spacer and the receiving end of the "T" joint on the rib assembly not yet attached. Slide the rib assembly onto the glued spacer (while holding the unattached rib assembly on the top rail). Place 3/8" spacers between the rib assembly "T's" and the temporary side rail, and repeat the drilling and carriage bolt placement process of attachment of the rib assembly on both sides of the structure. Also, drill and place carriage bolts through the spacer between the rib assemblies.

Continue gluing spacers, lifting the rib assemblies and attaching the ribs assemblies and spacers to the wooden base in this manner until you are ready for the "key rib".

Key rib

The key rib (Figure 17) is added to the structure in a similar manner as the other rib assemblies: Tie one end to the temporary side rail and hold in place, one person will push up on the center of the rib as one to two others push the rib in towards the opposing side rail; apply PVC cement to the inside of the "T" and the outside of the adjacent spacer and slide the rib

Figure 17. Key Rib prior to installation and attachment to top rail.

"T" onto the spacer; place a 3/8" spacer between the "T" and the temporary side rail; drill and bolt the PVC spacer in place on the side rail (repeat the attachment procedure to the opposite side).

Final rib assembly placement

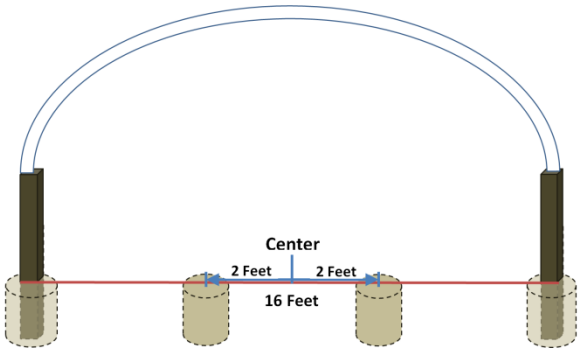
In order for the poly skin material to fit properly, the final rib assembly must be flush with the outside face of the end of the structure (similar to the opposite end as described in Figure 13). Rest one side of the rib assembly in the tray formed by the temporary side rail/top rail. Hold a board onto the face of the end 4"X4" post and push the rib assembly so the 90 elbow is touching this board. Measure the distance from the raised bench (the raised bench on the inside of the joint is the maximum depth that the joining piece (PVC spacer) will fit into the pipe fitting) on the inside of the "T" of the key rib, to the raised bench on the inside of the "T" of the outside rib assembly. Cut one of the last two remaining 45 ½" PVC spacers to match this measurement. Prime/clean and cement this spacer into the "T" of the key rib. Because of various factors in the construction process it is highly likely that this measurement is not the same on the opposite side. For the measurement on the opposite side of the structure, lift the final rib assembly from the top rail and slide the entire rib assembly so that the other end of the final rib assembly rests in the top rail/side rail of the opposite side, line up the 90 degree elbow with the outside edge face, measure the distance from the raised bench on the inside of the key rib to the raised bench on the inside of the "T" of the last rib assembly, cut the final 45 ½" spacer to match this measurement. Prime/clean one end of the spacer that has been cut to fit and cement into the "T" of the key rib. It is now time for the placement of the final rib assembly. Position and affix the final rib assembly using the steps previously described. The temporary2"X4" side rails can be removed once all carriage bolts, washers and nuts are in place.

Base plate

The base plate is used as an attachment point for the poly skin material. The base plate consists of two-10' and one-12' (= the structure length of 32-feet) painted 1"X4" lumber attached to the outside face of the 4"X4" ground posts. Attach the base plate to the base posts using 2" screws, start at one end, position the boards of the base plate adjacent to the next (butt joint) and secure the butt joint with an 18" long 1"x4" painted scab using 1 ½" screws. Place the scab section on the inside of the structure. The base plates can be positioned any time after the base posts have been set. Once the base plate is attached, use a hand saw to remove the outside corner of both ends. Cut this portion of the base plate at an angle of approximately 45 degrees. Removing this corner will help reduce wear on the poly skin.

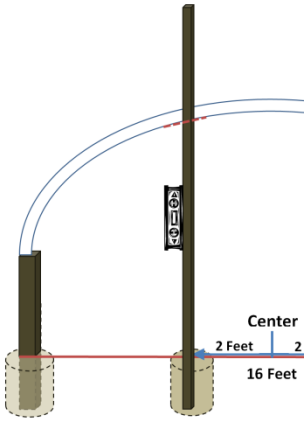
End-Wall Framing

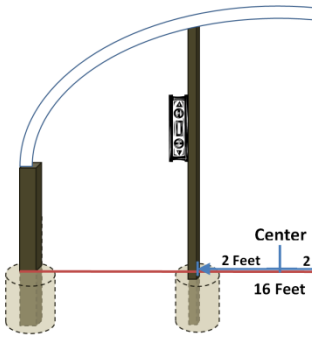
The desired door size will dictate slightly how the end walls are framed, but the framing is similar regardless of design and has several functions: provides rigidity to the structure; provides attachment points for the poly skin material; and provides access to the interior. You may choose to incorporate a door in both ends or in a single end. To establish the framing, lay a tape measure across the face of an end of the structure. Place a marker at the center point (for this structure it is at 8-feet). Most wheel barrows and small implements will easily fit through a 48-inch wide opening, so place markers 2-feet on either side of center along the tape measure (example at 6 and 10-feet, respectively). At the 6 and 10-foot markers, dig a 6 to 8-inch diameter hole approximately 2-feet deep.

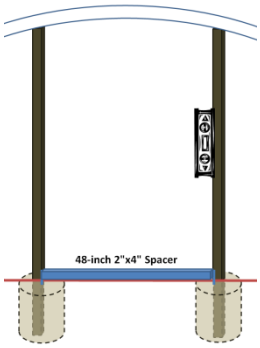


Door Frame

The center height of this high tunnel is between 9 and 10-feet, select a painted 2'X4'X16' and place vertically into the hole dug at 6-feet. Place the 2"X4" post into the hole and position so that the post is

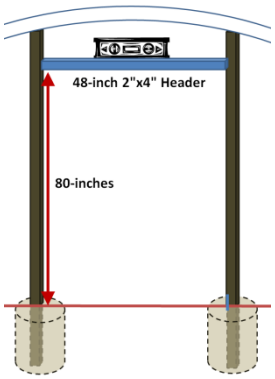






2-feet out from the center marker. Turn the 2”X4” so that the 2-inch wide side is facing the PVC rib. Push the top of the 2”X4” towards the PVC rib, so that it is just touching, place a 4-foot level on the 4-inch wide side of the 2”X4”, adjust **this** side of the 2”X4” for level. Mark the 2-inch face of the 2”X4” just under the PVC rib, and vertically mark the PVC rib where the 2”X4” intersects (these marks on the PVC are approximate sight markers for aligning the 2”X4” post when positioning for attachment to the PVC rib). Remove the 2”X4” from the hole and cut to size on the mark either with a hand saw or chop saw (the angle on the 2”X4” to match the arc of the PVC rib is about 22 degrees). Return the 2”X4” back to the hole, slide the cut end under the PVC rib (match the angle and align the 2”X4” with the vertical marks on the PVC rib) and be certain that the outside face of the 2”X4” is flush with the outside face of the PVC Rib and the structure base. Using a 7/32” drill bit pre-drill two holes through the back/top of the PVC in line and angling toward the 2”X4”. Attach the PVC rib to the 2”X4” using 4-inch screws through the pre-drilled holes; tighten to the point of being snug. Do not over tighten the screws and distort the PVC pipe. Level this 2”X4” post on both the 2-inch and 4-inch faces, backfill the hole with soil and fines, tamping and jiggling the post in the same manner as when setting the base posts. Be sure to keep the post vertically level and flush with the outer edge of the structure base.

Cut a 48-inch long 2”X4” spacer. Place this spacer on the ground between the 2”X4” post of the door frame and the second hole. Using the spacer as a guide for distance, place a painted 2”X4”X16’ post into the second hole. Repeat steps outlined above to size and set the second door post.

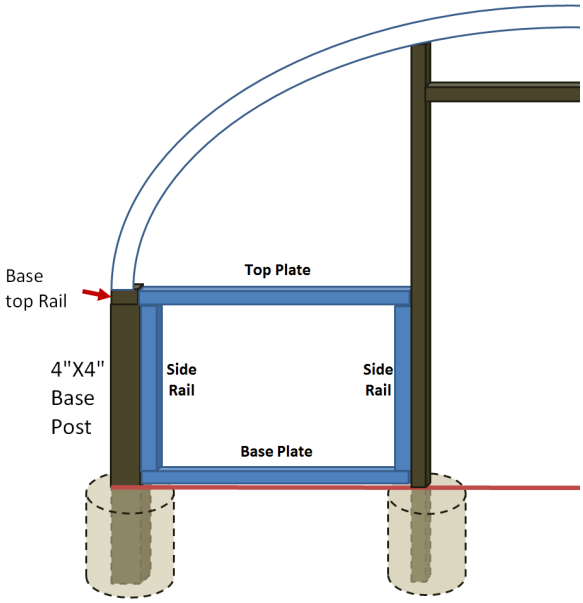


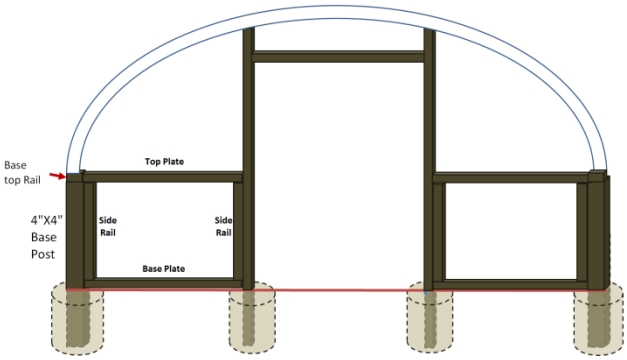
Once both door frame posts have been set, measure up 80-inches from the ground, mark this point on one side of the door frame, use the 48-inch spacer as the header for the door frame and attach to the inside of the door frame post (the 4-inch wide face) using two 3-inch screws at the 80-inch mark (through the

door frame post into the header), place a 2-foot level on the horizontal surface of the header, fit for level and drive two 3-inch screws through the second door frame post into the header 2”X4”.

Completing the end frame

The next process is to build rectangular frames that consist of a base plate, two side rails and a top plate that fits between the door frame and the corner posts of the structure base. At ground level, measure the distance between the inside 4”X4” base post and the outside of the 2”X4” door frame post. Cut the 2”X4” base plate to fit this measurement. Place (do not attach) the base plate into the measured opening at the soil surface and fit for level. Measure the distance from the top of the 4”X4” base post (just under the base top rail) to the top of the base plate, and cut two 2”X4” pieces (side rails) to match this measurement. Remove the base plate and attach the side rails to the base plate with two 3-inch screws per side rail. Attach the side rails by driving the screws through what will be the bottom (soil side) of the base plate (avoid “toe nailing”). Slide this “U” shaped assembly back into position between the 4”X4” base post and the door frame. Fit the base plate level so that the side rail is just under the base top rail. Attach the side rails to the 4”X4” corner post and the door frame with 3-inch screws. Measure and cut to fit the top plate and attach to the structure using 3-inch screws. Drive the screws through the top plate into the side rails. Follow these steps and build another rectangular frame to fit the other side of the door frame to complete the end framing.





Repeat all steps as outlined above and complete the frame on the opposite end of the structure.

Door Construction
Structural Purlins
Purlins for Irrigation

Attaching Poly Skin
Roll-up sides

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Appendix

I. Suggested Tools List

Battery Powered drill(s)	(2) 50 ft tape measure(s)	Tamping Bar
Ladder	(2) String Lines	Shovel
Table Saw	Line level(s)	Markers
Chop Saw	Strap on post levels	Paint Pans
Saw horses	25 ft tape measure	Paint Rollers
Post hole digger	7/32 drill bits	Duct Tape
4 ft level	Screw Driving Bits	50 poly Rope
2 ft level	Hand Saw	*Generator
*depending on availability of electricity at build site.		

II. Materials list for Hard Sided High Tunnel (HSHT)

Hard Sided High Tunnel

Material List

Item	Qty	Description
1	17	Plastic PVC Pipes 2 in. x 20 ft. / Schedule 40
2	5	Plastic PVC Pipe (100 feet total) $^{3}/4$ in. x 20 ft/ Schedule 40
3	18	Plastic 2 in. PVC Tees
4	4	Plastic 2 in. PVC end caps
5	27	2 Hole Conduit Straps 3/4 Pipe Straps
6	1	PVC Qt Primer
7	1	PVC Qt Glue
8	2	Screws (Deck Screws) 1 in. Box 150 Screws (1 lb.)
9	1	2 in. Box 150 Screws (1 lb.)
10	1	3 in. Box 150 Screws (1 lb.)
11	1	4 in. Box 150 Screws (1 lb.)
12	32	Carrage Bolts & Nuts / 1/4 inch x 5 inch
13	64	washers 1/4 inch
14	14	Wood Boards (perlins) 1 in. x 4 in. x 10 ft. (#2)
15	2	1 in. x 4 in. x 12 ft. (#2)
16	1	Plastic Cover (6 mil skin) 24X50 feet
17	1	Plastic Cover (4 mil skin) (2 each @) 4X96 feet
		Lumber
18	7	2 in. x 4in. x 8ft. (Doors)
19	10	2 in. x 4in. x 10ft.
20	8	2 in. x 4in. x 16ft.
21	7	2 in. x 4in. x 10ft. (Ferring Strips)
		Lumber
22	5	4 in. x 4 in. 10 ft.
23	4	Hinges
24	2	Latch
25	2	Gallons Paint

Materials For Roll Up Sides

Item	Qty	Description
26	4	Plastic PVC Pipes 2 in. x 20 ft. / Schedule 40
27	4	Plastic 2 in. PVC 90's
28	3	2 in. x 4in. x 10ft. (Ferring Strips)
29	90	Feet of Wiggle wire/U-chanel

For Irrigation System

Item	Qty	Description
30	12	Plastic Tee Joints 3/4 Slip Tee X 1/2 threaded / Schedule 40
31	12	Threaded Nipple *1/2 X 1/2*
32	1	*Plastic PVC Pipe* 3/4 in. x 10ft. /Schedule 40
33	6	PVC Spray Nozzles 360° (adjustable) *1/2* inch Threaded
34	3	PVC Ball Valve 3/4 inch
35	1	PVC Hose Connector $^{3}/4$ inch
36	5	End Cap 3/4 inch
37	1	Plastic 3/4 in. 90° Elbow
38	2	Plastic $^{3}/4$ in. 45° Elbow

III. Suppliers (Listing is neither exclusive nor extensive)

Woven Poly Skin Material

J&M Industries, Inc.
300 Ponchatoula Parkway
Ponchatoula, LA 70454
985-386-6000
www.jm-ind.com

Peaceful Valley Farm Supply, Inc.
PO Box 2209
125 Clydesdale Court
Grass Valley, CA 95945
(888) 784-1722
http://www.groworganic.com/growing-supplies/greenhouses.html

Woven Poly Skin Material & Wiggle Wire

Northern Greenhouse Sales
Box 42
Neche, ND 58265
1-204-327-5540
http://www.northerngreenhouse.com/products/polys/wovenpolys.htm

FarmTek
1440 Field of Dreams Way
Dyersville, IA 52040
1.800.327.6835
http://www.farmtek.com/farm/supplies/home