Build a Simple, Low-Cost Greenhouse

How to Build a Small A-Frame Greenhouse with PVC Pipe & Plastic Sheeting for Less Than $50

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Part I: Introduction

The Problem - Short Growing Season & Low Overnight Temperatures

We needed some way to lengthen our short growing season and increase overnight temperatures for our garden plants, though we did not want to spend a lot of money on an expensive greenhouse. We wanted a simple, inexpensive solution and the PVC A-Frame Greenhouse described in this book has become our answer.

We live at about 41° North and 5,700 ft elevation. Minimum temperatures here average 40.9°F (4.9°C) in June, 47.1°F (8.4°C) in July and 45.8°F (7.7°C) in August. We have had at least 3 inches of snow after June 10th in 2 of the 6 years we have lived here and had a hard freeze during two growing seasons in late June. Data from the National Climatic Data Center gives my area a 50% chance of having a frost-free (36°F, 2.5°C) growing season of at least 63 days and a 50% chance of having a freeze-free (32°F, 0°C) growing season of at least 93 days (June 8th to Sept. 10).

Needless to say, we live in an area that makes it difficult to grow warm weather vegetables like tomatoes and peppers and few people here try to grow them. I guess everyone else is satisfied with the veggies sold at the grocery store.

My Grandfather was a life-long gardener in North Carolina and I remember him saying, "Tomatoes don't do well until the nighttime temperatures stay above 60° (F)." You can see my problem; a late spring, an early fall equals a short growing season and only a few nights in six years that actually stayed above 60° F (15.6°C). In fact, between June 1 and Aug 31, only 23 nights in one year and 32 nights in the following year were above 50° F. But one of the biggest obstacles to growing tomatoes is usually the last killing frost in the spring and the first killing frost in the Fall. One year, we saw the first red tomato on the very same day of the first killing frost. It got too cold for a tarp to save the situation. What a letdown. Most years, we can grow buckets of green tomatoes, but only get a handful of ripe ones.

Prior to building the greenhouse, we also tried to grow bell peppers on two separate years and harvested only a few bell peppers, We also tried growing cantaloupe and watermelon, but none ever ripened. The funniest experiment was trying to grow okra. Okra plants grow 6-8 feet tall in warm climates, but the few okra plants that survived here were barely more than one foot tall and produced only a few tiny pods. After trying to grow warm weather vegetables for several years, it was obvious we needed some kind of "greenhouse" to increase the soil and daytime temperatures earlier in the spring, raise the night-time temperatures during the summer and to allow the plants to survive those late spring and early fall frosts to extend the growing season.

The Solution - A Simple, Low-Cost "Greenhouse"

I wanted a simple and inexpensive "greenhouse" to cover my existing 5 x 10 foot raised beds. After looking at what was available, I was not interested in spending thousands of dollars on a real greenhouse or spending $400 or $500 on a flimsy looking piece of plastic with a zipper that someone calls a cold frame. This was going to have to be a DIY project.

Greenhouse Terminology

There are several types of Greenhouses and much of the terminology seems to be interchangeable. A Hoop House or Low Tunnel sold at one place looks an awful lot like a Cold Frame that is sold at another place.

- **Row Cover** - is a very low, covered tunnel made from metal or plastic hoops that support a plastic cover. A row cover is only high enough to cover the plants in one or two rows. Except for an irrigation system, row covers, would usually not include any additional technology.
- **Cold Frame, Low Tunnel or Hoop House** - are apparently different names to describe a design that is similar to a row cover, except that the hoops span a larger height and width. Low Cold Frames, tunnels or hoop houses also would not include much technology except for irrigation.
- **High Tunnel -** refers to a design similar to a Low Tunnel, except the walls are built higher to provide more height inside for moving equipment and for better air circulation. High Tunnels usually begin to incorporate more technology into the system.
- **Greenhouse** - What we typically think of as a greenhouse is usually a rectangular shaped house (Gable) with glass or other rigid panels on the walls and the roof. A true greenhouse is tall enough to move around easily and allow for good air circulation. Greenhouses usually include a high degree of automated technology. Greenhouses can also be skillion shaped design (Roof high on one end to provide for ventilation). A row of connected skillion greenhouses are referred to as a Saw-tooth greenhouse design.

Greenhouse Building Material

For the DIY guy building a greenhouse, the most common building materials would be wood, rebar or PVC pipe. Sure, there are others, but most people don't have welding materials or pipe benders. I quickly settled on PVC pipe, because I wanted to be able to move the greenhouse from one raised bed to another between seasons, so my tomatoes and peppers wouldn't be growing in the same soil every season. I concluded that it would be much easier to move PVC pipe than a wooden frame that was nailed or bolted together or a rebar frame that was "tied" together. I also have concerns about how well untreated wood or rebar would hold up under the high humidity/dripping water environment inside the greenhouse.

The PVC A-frame Hoop House

What I first decided to build was a simple PVC pipe frame "Hoop House". My original plan was to cut the spine (top rail) and permanently attach it to the ribs (side supports)

with 2 and 3-way connectors. I realized that this would create a very strong structure, but it would also be hard to move to a different bed every year to rotate crops and it would be hard to store the greenhouse frame if it were all cemented together.

So, instead of a hoop house, I modified the plans to become an A-frame instead of a true hoop house. This modification made the greenhouse 4.3 feet tall instead of just under 3.75 feet tall. Instead of permanently attaching the spine to the ribs, I temporarily attached them with zip-ties (cable ties). The cable ties have proven to be plenty strong, and now I can completely dismantle and re-assemble the greenhouse in less than 5 minutes. I can also easily store all the PVC pipe over the winter, because PVC pipes are not attached to each other and lay flat on the ground. In addition, cable ties are faster to assemble and cheaper to use than than 2 and 3-way connectors and PVC cement and primer. The 2, 3-way fittings cost about $1.20 each and the 3, 4-way fittings cost about $1.80 each, count on another $8 more for primer and cement, for a total savings of over $17 after tax).

Figure 1. PVC A-Frame Greenhouse. Ventilation can be controlled by adjusting clamps on the door flaps. Notice the opposite end is completely open and the near end is partially open to control air exchange.

Pros of using PVC pipe

- Cheap
- Easy to find
- Light weight
- Easy to work with (cut, bend, drill, cement)
- Can also provide irrigation
- Connect permanently or temporarily
- Does not degrade significantly in sunlight

Cons of using PVC pipe

- A petrol-chemical product that produces hazardous waste by-products and pollutants; including PCBs, chlorinated dioxins and furans, hexachlorobenzene, octachlorostyrene and phthalates.
- Not bio-degradable or recyclable.

- There have been some concerns about PVC pipes manufactured prior to 1977 for drinking water - Make sure to use PVC pipe that is marked with NSF-PW or NSF-61 see TOC 4 below - PVC Safety Precautions.

A Note about Using Pressure Treated Wood in Your Garden

Chances are, you have seen this information before, if so, sorry for the inconvenience, but if you have not, take a minute to read.

Note that I suggest using untreated lumber for your raised bed frames. There have been concerns that the chemicals used to treat the wood may get into the vegetables. I read recently that Arsenic can be taken up by plants, but only if the soil is deficient with Phosphorus. One thing I have learned is that you can never say never for Biology. It appears that the EPA doesn't want us to even touch arsenate treated wood. Since the EPA banned the sale of lumber treated with chromated copper arsenate (CCA) for residential use in 2003 (12/31/2003), the EPA recognizes several alternatives:

- Alkaline Copper Quaternary (ACQ)
- Copper Azole (CA)
- Micronized Copper Quaternary (MCQ)

I have seen in some of the gardening forums that the new treated wood products are safe to use for raised garden bed frames, but needed to do the research for myself.

For Alkaline Copper Quaternary (ACQ), the Copper is the primary active ingredient and is described as being similar to chemicals used to keep swimming pools clean and primarily prevents fungal growth. The Quat formulation is similar to other bio-degradable cleaners and preservatives and is a back up for Copper resistant fungi and termites. There are no EPA listed carcinogens in ACQ. Research has not identified any direct threats to humans, but the products do leach copper, which is very toxic in aquatic systems. Brand Names include YellaWood, Preserve® and NatureWood®.

For Copper Azole (CA), as with ACQ, the Copper is the primary ingredient (98%) and the tebuconazole fungicide is the backup (<1%). Brand names are Wolmanized, Tanalith®, or Tanalised® and Residential Outdoor®.

Micronized Copper Quaternary (MCQ), is the same chemical formula as ACQ, but it is first ground into tiny particles (micron sized) then are injected into the cellular structure of the wood under high pressure. This process releases 90-99% less copper into the environment, which is good news for aquatic environments. MicroPro claims that the small amount of Copper that is released, binds quickly to organic compounds in the soil, making it biologically inactive. The MCQ treated wood does not show as much color change as the other treatment processes. It is also not as corrosive to fasteners as ACQ or CA treated wood, but you would still need to use approved fasteners. because less corrosive does not mean non-corrosive. Brand names for MCQ treated wood include Yellawood MCQ, MicroPro® and SmartSense®.

Since the new wood preservatives use Copper, treated wood is more likely to react and corrode standard nails, screws and other fasteners. Building codes have begun to require stainless steel, ceramic coated or hot dipped galvanized fasteners to prevent failures due to corrosion when using the ACQ, CA or MCQ treated wood products. Another consideration with treated wood is the fact that the treatment process also

pumps water back into the dry wood as it applies the chemical treatment. Since the wood may still have a high moisture content it may shrink, warp and split as it dries out.

We are always cautioned to wear gloves, dust masks and eye protection when handling and cutting both treated and un-treated wood. We are also advised to wash our hands after handling the new types of treated lumber, to wash clothes separately and are warned not to burn treated lumber or use it as mulch.

Another consideration with treated wood is the fact that the treatment process also pumps water back into the dry wood as it applies the chemical treatment. Since the wood may still have a high moisture content it may shrink, warp and split as it dries out.

Am I convinced that it is safe to use the new copper treated wood products for raised garden beds? Yes, it is safe for people, but it is not safe for aquatic systems. The new Micronized process is better and leaches 90% less copper back into the environment than the CA or ACQ methods.

Using Untreated Wood

My untreated wood frames have been in the soil for 3, 4 and 5 years now. Yes, they have weathered and yes, there are signs of decay to the wood that is underground, but they are still sound and solid and I expect to get another 4 or 5 years before I have to pull them up and replace them. Some of the same cold, dry climate that make it hard for me to grow vegetables also slows the decomposition rate of untreated wood. Un-treated wood may not last as long in your climate. If I had to choose, I would use the Micronized Copper Quaternary (MCQ) treated wood. While leaching any Copper into the soil is not good, leaching 90% less would be better.

I read recently that organic farmers could not declared their produce "Organic" if they had treated lumber that contacted their soils or animals. I did a little research and found the statues (see § 205.206 & § 205.602 below*) that regulate the use of treated wood under the Organic Food Production Act. The actual language in § 205.206 refers only to arsenate materials in new and replacement installations, not to existing installations. After further research, it appears that existing installations that use even arsenic based PT wood are "grandfathered". So it is still possible for certified Organic Vegetables to be produced in raised beds constructed from arsenate treated wood if they received their certification prior to the last day of 2003.

***§ 205.206:** Crop pest, weed, and disease management practice standard. (f) The producer must not use lumber treated with arsenate or other prohibited materials for new installations or replacement purposes in contact with soil or livestock.

***§ 205.602:** Nonsynthetic substances prohibited for use in organic crop production. The following nonsynthetic substances may not be used in organic crop production: (b) Arsenic.

PVC Safety Precautions

Precautions about Using PVC Pipe

As with other plastic products, there have been some questions raised recently about the safety of drinking water from PVC pipes, especially PVC pipes manufactured prior to 1977. We should probably be more concerned about drinking water from the garden hose than using PVC pipe for structural support for a greenhouse, but perhaps it is wise to err on the side of caution.

- We propose that PVC pipe be used only as structural support for the greenhouse and for watering plants, but not as a growing container.
- Use only PVC pipe that is marked with NSF-PW or NSF-61, which is safe to use for drinking water.
- Take precautions not to inhale the PVC dust when cutting PVC pipe. A PVC pipe cutter does not make dust, but sawing PVC pipe creates a lot of fine electrostatic dust (really more like tiny chips or granules). The PVC dust/chips/grains stick to everything. Be careful about taking the dust into the house or around children.

Other PVC Information

I have read claims that PVC pipe deteriorates in the sunlight. I have not found that to be the case. In fact, I found a study that tested PVC Pipe after 15 years exposed to sunlight. Sunlight will effect the PVC, but according to the study (see UNI-TR-5) by Unibell.org, only the outer 0.002 inches was visibly effected after 15 years and the pipe passed all standard requirement tests. All UV deterioration can be stopped if the PVC pipe is painted (acrylic or latex paint).

Part II: Building The Greenhouse

Materials List for 5 x 10 Foot Raised Garden Bed and A-frame Greenhouse

It is important to note that I already had raised beds in place before planning the greenhouse. Much of the strength and stability of the A-frame hoop house comes from the raised bed. My raised beds are 5 feet wide and 10 feet long and are constructed from untreated 2 x 12 lumber. I used the raised bed frame to level the garden plot. One of the raised bed sits nearly on top of the ground on one corner, but most of the other beds are buried about 6 inches into the ground, so the beds are heavy and are sunk into the soil, which makes a good foundation for the hoop house. If you do not have or do not build a raised bed frame, you should do something to provide a solid foundation before building the A-frame hoop house. I have included a materials list and instructions for building a raised bed.

Table 1 below is the list of building materials for a 5 x 10 foot raised bed and the A-frame PVC structure for the greenhouse. I included the price I paid for most items, instead of current prices, since they change too often to be kept current. I bought materials for the raised beds in Spring 2008 and the materials for A-frame hoop house in Spring 2010. I did not include the price of nails or screws, because I already had them, so add a few more dollars to the cost if you don't have nails or screws on hand. I also already had plastic sheeting, but did include that cost since it is a large portion of the total project cost.

Table 1. Materials List and My Cost for a 5 x 10 foot Raised Bed and an A-Frame Green House

N	Material List for Raised Bed	My Cost
3	2 x 12 x 10 feet Un-treated Lumber	$31.50
12	#10 x 3 1/2 inch Exterior Screws	$0.00
4	Framing Angles (optional)	$1.92
12	10d Nails (for optional framing angles)	$0.00
	Total Cost for Raised Bed	$33.42
N	**Material List for A-frame Hoop House**	**My Cost**
5	3/4 inch PVC pipe, 10 foot length for side supports (ribs)	$6.00
1	3/4 inch PVC pipe, 10 foot length for central spine support	$1.25
10	1 inch EMT Conduit Straps (2-hole, metal)	$4.05
1 Pack	Cable Ties (zip-ties) (3/8 inch wide, 8-inch long; pack of 100)	$3.99
1 Roll	4 or 6 mil Plastic Sheeting (10 x 25 feet)	$18.97
20	#10 x 1 1/2 inch Exterior Screws	$0.00
16	PVC Clamps (home made)	$0.00
	Total Cost for A-frame	$34.26
	Total Cost for Raised Bed Frame	$33.42
	Total Combined Cost	$67.68

Directions for Building a Raised Garden Bed Frame

Note: If you already have a bed frame or something similar to attach the greenhouse frame to, then skip to Building the PVC A-Frame.

Summary of steps, followed by detailed instructions:

1. Cut one board in half
2. Decide Frame Orientation
3. Mark and drill pilot holes
4. Attach frame with nails or screws
5. Attach angles or corner brackets for additional strength (Optional)

Step 1: Cut one board in half.

The first step is to cut one of the boards in half. If your board is exactly 10 feet long, cut your board into two 5 foot sections. Some boards may be an inch or so longer. You could trim them down to exactly 10 foot or leave them as they are and just make sure cut one exactly in half. Some building supply stores will make this cut for you.

Step 2: Decide Frame Orientation.

Now decide which way the frame will fit together. There are three different ways (see Fig. 2) to construct a frame with 2, 10 feet long and 2, 5 feet long boards. Decide if you want the bed to be slightly longer (example A - Nail or screw through the 5 foot end boards into the the ends of the 10 foot side boards), slightly wider (example B - Nail or screw through the 10 foot side boards into the the ends of the 5 foot end boards), or split the difference (example C - start at one corner and lap each board over the end of the next board). If you care about such things, Example A has a "cleaner" look when viewed toward the short ends. Example B has a cleaner look when viewing the long sides. Example C does not have a clean look from either direction.

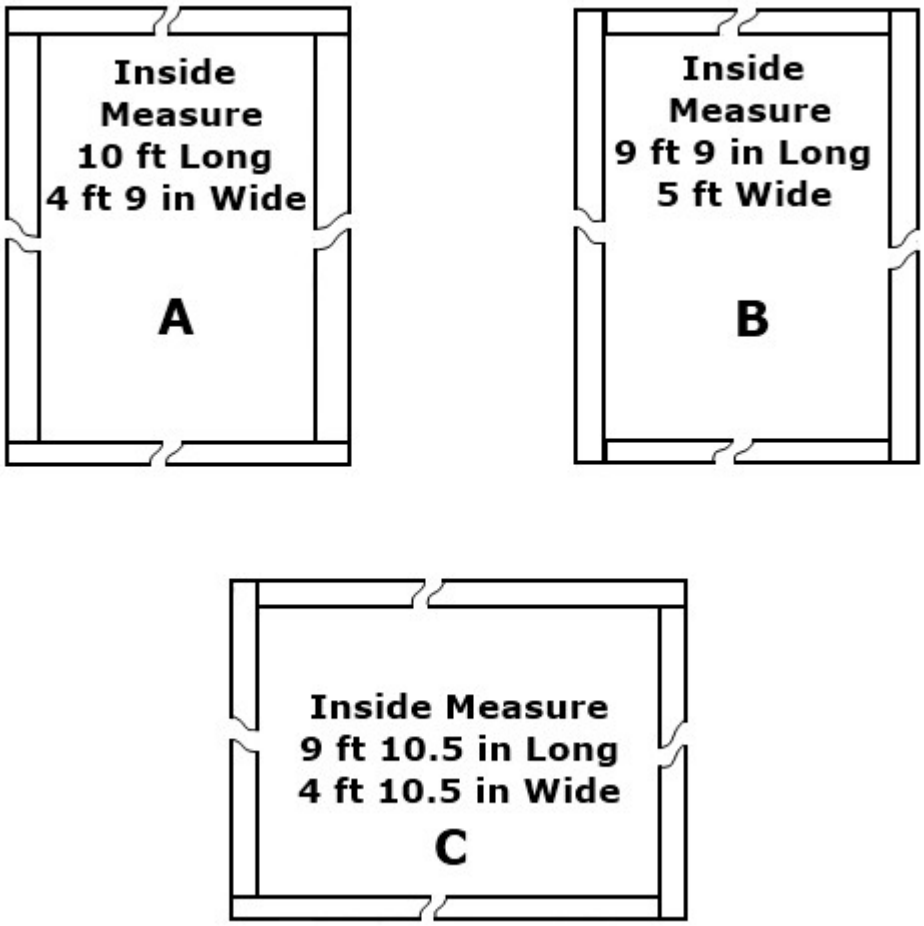

Figure 2. Diagram of Three Different Methods to Attach the Frame for a Raised Garden Bed. **(A)** To maximize length, **(B)** To maximize width and **(C)** To split the difference.

Step 3: Mark and Drill Pilot Holes

We all know that most lumber framing is done simply with hammer and nails, but if holes are pre-drilled and screws are used instead, the frame will fit tighter, last longer, warp less and the boards will not split. Start by marking the width of your board on each end that is to be drilled (Fig. 3 , next page), so you can drill holes close to the middle of the board. Use a drill bit that is slightly narrower than the screws you plan to use. A 1/8th inch drill bit is recommended for #10 screws in softwood.

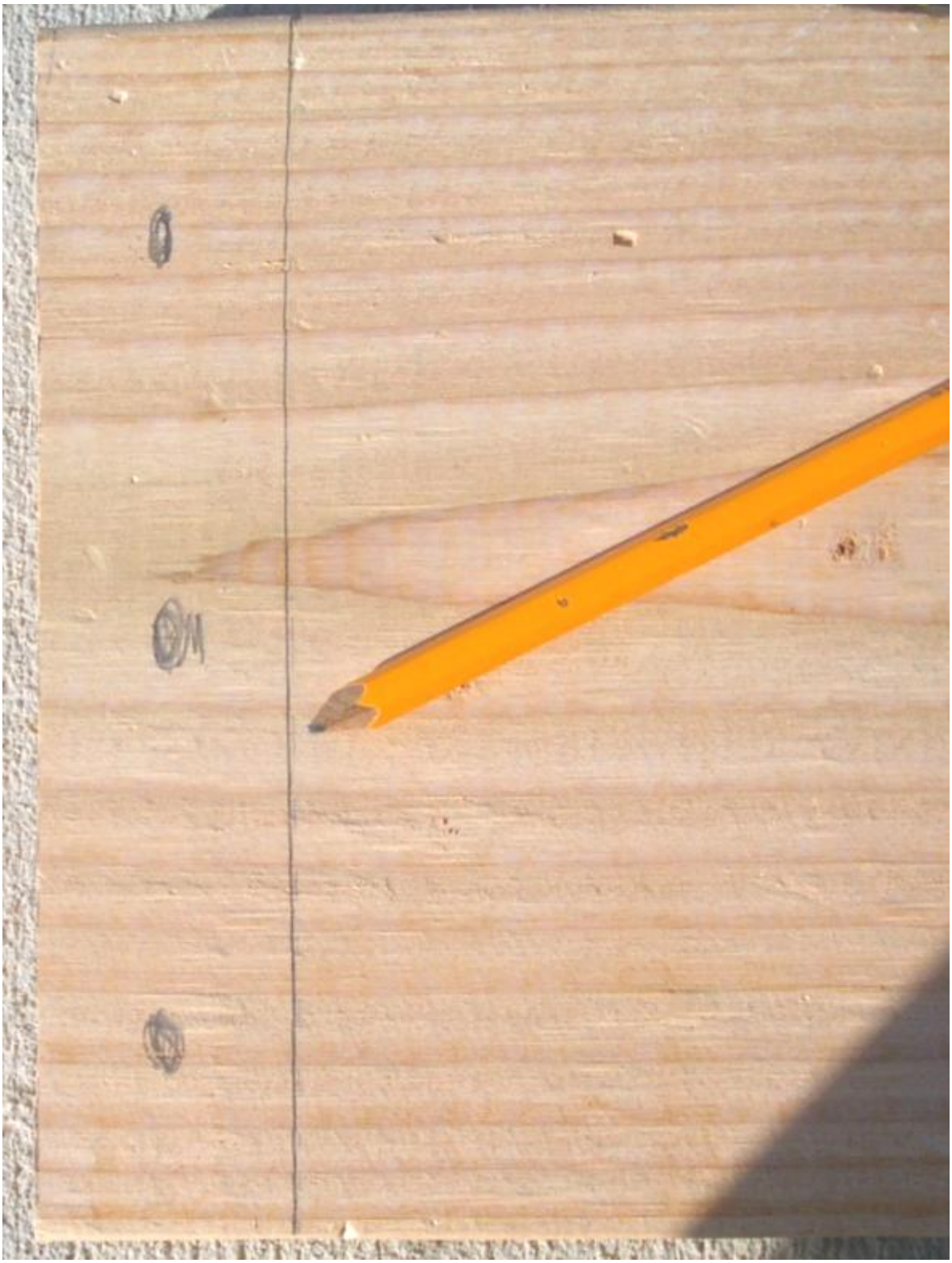

Figure 3. Mark holes to be pre-drilled.

Drill the pilot hole through both the face of one board and through the end of the other board (Fig. 4, next page). Make sure to use screws that are long enough to hold the

boards together for many years. A 2 inch screw might hold a 2x4 board for a very short time, but the screw in Figure 6, is #10 screw that is 3.5 inches long and should hold for many years.

Figure 4. Drill the pilot hole through both the face of one board & through the end of the other board.

Step 4: Attach Frame with Nails or Screws

After drilling the pilot holes, start the screws and let them extend about quarter inch out of each hole on the other side of the board so you will be able to feel when the screws fit into the holes on the other board (Fig. 5).

Figure 5. Use screws long enough for a strong hold. This is a #10 exterior screw, 3.5 inches long.

Hold the two boards tightly together and while each screw is tightened (Fig. 6).

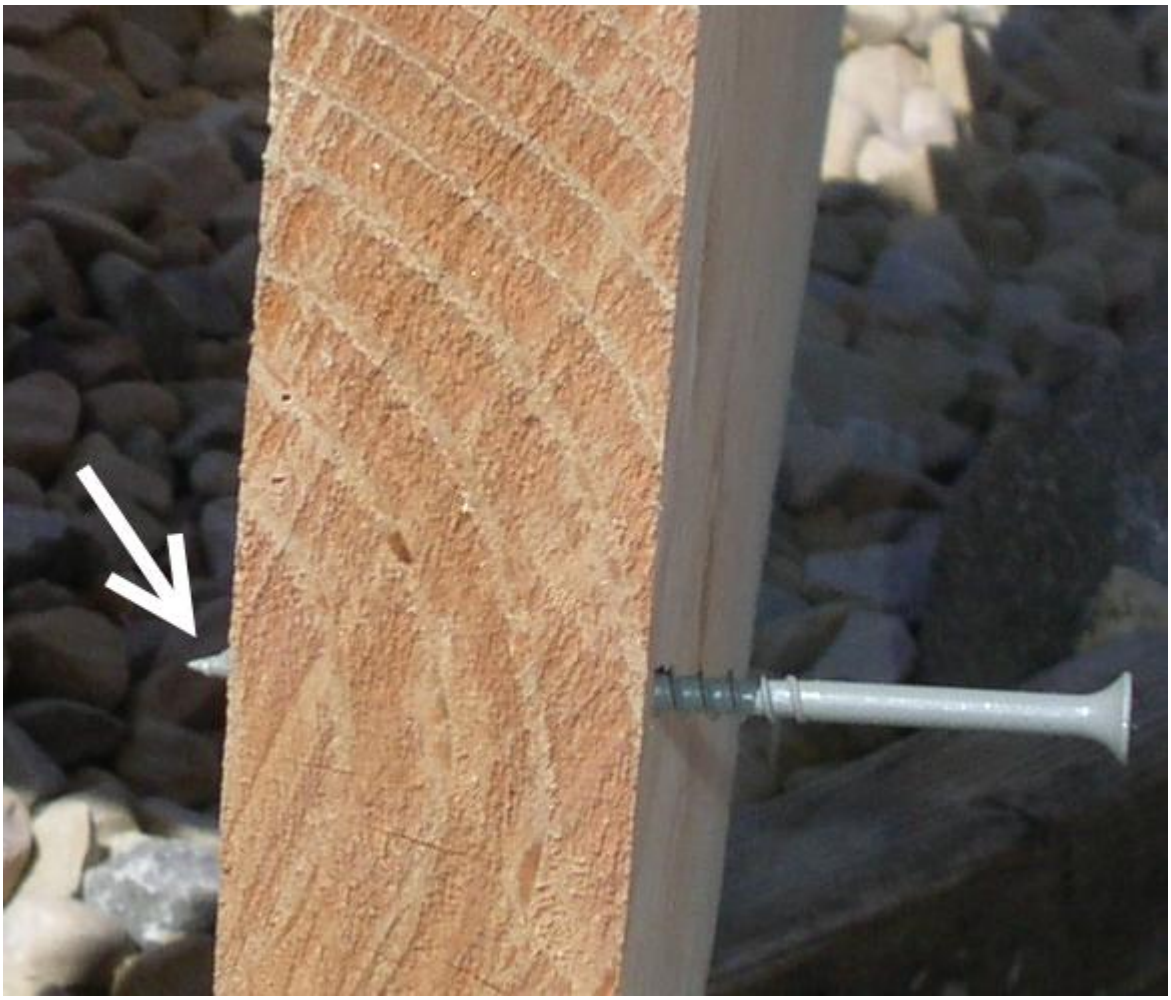

Figure 6. Start Screws, let them extend about quarter inch so you can feel them fit into the holes on the other board.

Figure 7. Finished corner of frame.

Step 5: (Optional) - Attach angles or corner brackets for additional strength

To prevent wood from splitting, pre-drill holes for nails or screws with a small bit (like 1/8th inch). You want to create a pilot hole, but you still want the nail or screw to fit tightly. It also helps to use angles or corner brackets for strength and to help line the corners up properly, but the angles or brackets are optional. For the 12" boards, I used 3 screws per corner. If using a narrower board, like a 2 X 6, 2 nails or screws per corner are probably enough. But if you want the raised bed to last, screws will hold better over time than nails and three screws will hold better than two screws.

Directions for Leveling and Squaring the Garden Bed Frame

After the frame is nailed or screwed together, move it into position and begin to level and square the box a little at a time. The site needs to be fairly flat. If using dimensional lumber (2x6, 2x8, 2x10 or 2x12s), the total rise or drop across the length

or width of the site cannot be more than the width of the board. From Table 2 below, you can see that the real width of a 2 x 12 is 1.5 inches x 11.25 inches, so the slope of your proposed site can only rise or drop 11.25 inches in either the length (10 feet) or width (5 feet) of your raised bed.

Table 2. Nominal and Actual Dimensions of Lumber and Maximum Rise or Run for Constructing a Level Raised Bed.

Lumber Dimension Nominal	Actual Dimension	Actual Dimension Metric	Maximum Rise or Run for Raised Bed	
inches	inches	mm	inches	mm
2 x 4	1.5 x 3.5	38.1 x 88.9	3.5	88.9
2 x 6	1.5 x 5.5	38.1 x 139.7	5.5	139.7
2 x 8	1.5 x 7.25	38.1 x 184.15	7.25	184.2
2 x 10	1.5 x 9.25	38.1 x 234.95	9.25	235.0
2 x 12	1.5 x 11.25	38.1 x 287.75	11.25	287.8

If the rise or drop of your site is only 8 inches over a 10 foot length, 2 x 10 boards would be wide enough to create a level raised bed and if the rise or drop of your site is only 6 inches over the 10 foot length, 2 x 8 boards would be wide enough to create a level bed.

If the rise or drop is greater than the width of a 2 x 12 (11.25 inches), you will have to move some dirt, or build shorter raised beds (See Figures 8-10 below).

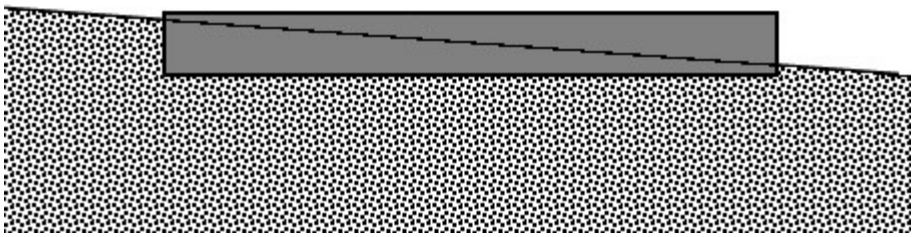

Figure 8. Diagram of a Site with a Mild Slope for a Raised Garden Bed. The slope is not more than width of board over the 10 foot length of the board. This site is suitable to build a 10 foot long raised bed with minimal effort.

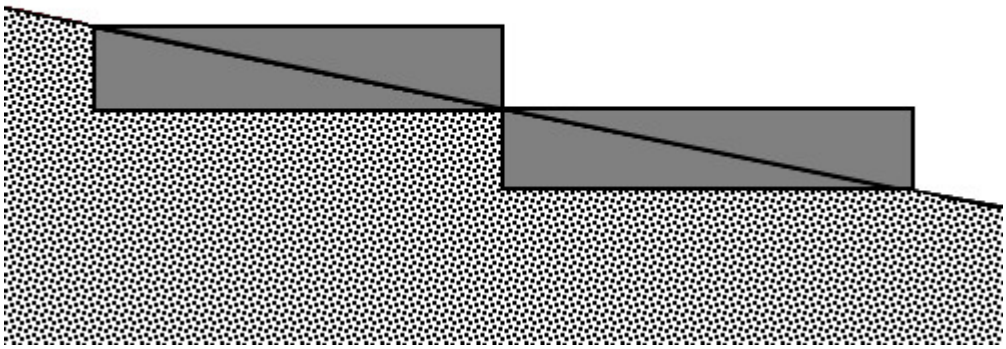

Figure 9. Example of a Site with a Steep Slope for Raised Garden Bed. Slope is twice the width of board over the 10 foot length of the board. In this example, the beds can only be 5 feet long unless soil is excavated.

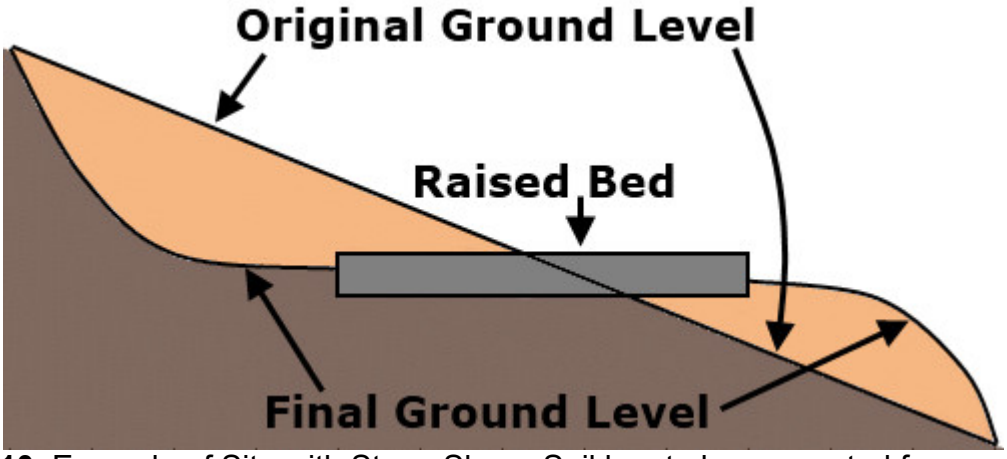

Figure 10. Example of Site with Steep Slope. Soil has to be excavated from up slope and deposited down slope to create a level site for the raised garden bed.

Depending upon how much of a perfectionist you are determines how close to square you make your frame. The best way to make sure it is square is to make sure the measurement across the outside diagonals are the same. For example, the outside diagonal measurements (Fig. 11) should be close to 136 and a fat 13/16 inches long. If they are within a quarter of an inch, bump it one time and measure again. That's probably close enough for a garden frame.

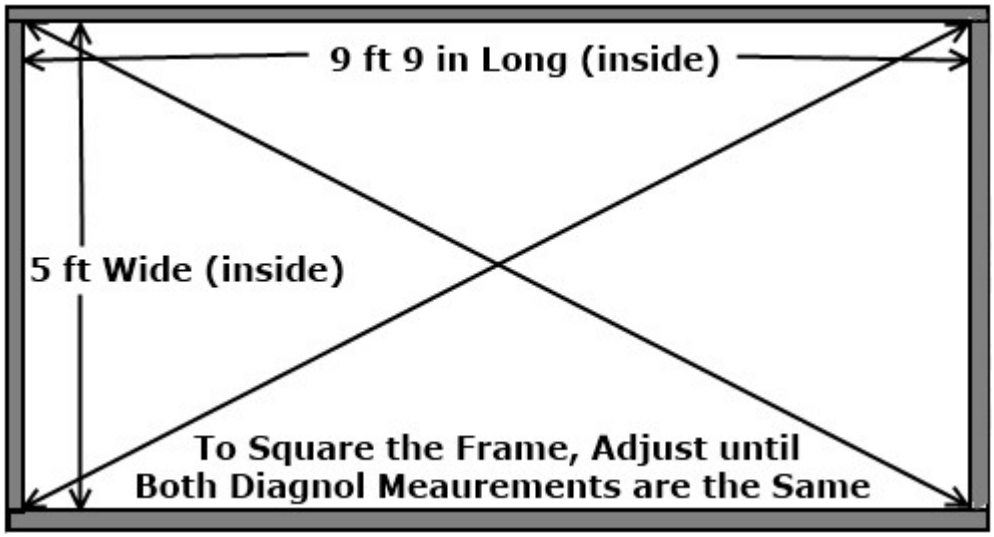

Figure 11. Scale Drawing of 10 ft X 5 ft Raised Bed Frame. Frame is connected as Example B from Fig 2 (inside measure 9 ft 9 in long, 5 ft wide). The actual inside measure is 9 feet 9 inches long and is exactly 5 feet wide. Diagram shows where to measure diagonals to square the frame. It is easiest to measure outside to outside.

To level the frame, use a carpenters level. If you have high spots, you will have to prop up the frame and remove dirt from under the high spots. If there are low spots, you will need to add soil and compact it. Below is a picture (Fig. 12) of my neighbor's unlevel raised beds. I don't want to give my neighbor a hard time, because I am happy they are attempting to grow a few of their own vegetables, but trust me, you will appreciate a level raised bed in the long run, especially if you are building a

greenhouse on top of it, so make sure it is level on all 4 sides and across all 4 corners.

Figure 12. Example of Unlevel Raised Garden Beds.

Fig. 13 and 14 on the next pages are pictures of my raised beds with the A-frame PVC greenhouse structure assembled. The untreated lumber of the raised beds are starting to show a little weathering, but the beds are level even though my yard has a fair amount of slope. The untreated wood had been exposed to the weather for four full years when these pictures were taken, but they are still square and very sturdy. Based on that fact, I expect they will last at least another 4 or 5 years.

Figure 13. Overhead of Our Raised Garden Bed on June 3rd. Notice the A-frame has been assembled and peas have come up in another raised bed.

Figure 14. Ground-level Photo of Same Raised Beds on June 3rd. Peppers are ready to transplant and after transplanting, plastic sheeting was attached to the PVC frame with homemade PVC clamps.

Directions For A-Frame PVC Greenhouse Construction

Note: The following directions assumes you ***already*** have a 5 x 10 foot raised garden bed made from lumber to attach the greenhouse to. If not, follow previous instructions for **building a raised bed**.

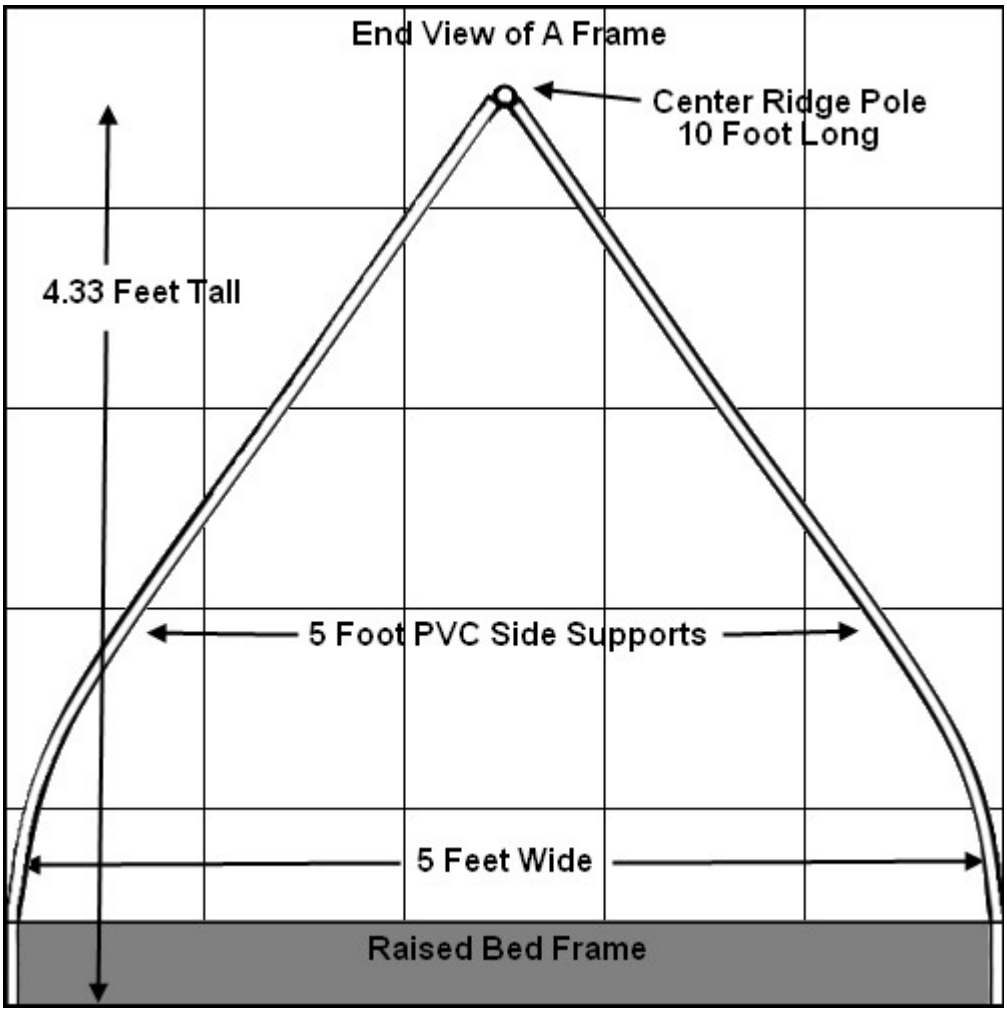

Figure 15. Scale Drawing of the End View of the A-frame PVC Greenhouse.

Steps For Building the Greenhouse:

Step 1. Cut 5 of the 10 ft PVC pipes in half (this will create 10 side supports, 5 foot each).

Step 2. Before marking the raised bed frame for where the ribs will attach, first attach the Conduit straps on each end (Fig.16) and attach them as close to the edge as possible. You can attach the frame either inside or outside of the raised bed frame. Inside is best if you want to attach the sheeting to the raised bed frame. Outside provides a little more room inside, for the plants, but much of the condensation will drip outside of the raised bed, but you will have to attach the plastic sheeting by weighing it down with gravel or rocks. I would also suggest using two conduit straps for each side support if they are attached to the outside.

Figure 16. Photo of 1 inch conduit strapping attached to inside of raised bed frame to hold 3/4 inch PVC Pipe from Steps 3 and 5. Note that the PVC pipe has been pushed down into the soil for stability.

Step 3. After attaching the Conduit straps on the ends, measure 2.5 ft from the center of each of the conduit strap on the ends and mark them. Attach conduit straps on each side, then find and mark the center conduit straps and attach them to the raised bed frame with screws. There should be Five conduit straps on each side to hold the five side supports (each side).

Step 4. Drill holes in one end of each of the PVC ribs; Drill at an angle (Fig.17).

Figure 17. Step 4, drill holes at an angle in the top of each PVC rib. The hole needs to be large enough to allow the electrical zip-ties to thread through. My zip-ties are about 3/8th inches wide. I used a 3/8th drill bit and "wallowed" it around a bit to make the hole slightly larger.

Step 5. Slide the un-drilled end of PVC into each conduit strap and press down into soil for several inches (see Fig.17 and 18). If using two conduit straps, slide each side support into both straps.

Figure 18. Step 5 - Insert all 10 pf the pre-drilled PVC Pipes into the Conduit Straps.

Step 6. Loosely attach zip-ties between opposing ribs, make sure to leave room to slide spine into place (Fig. 19). Zip-ties should be at least 8 inches long to be able to connect through both ends and still leave space to slide the center spine. Zip-ties should also be at least x thick for strength and to survive at least one growing season in the sunlight.

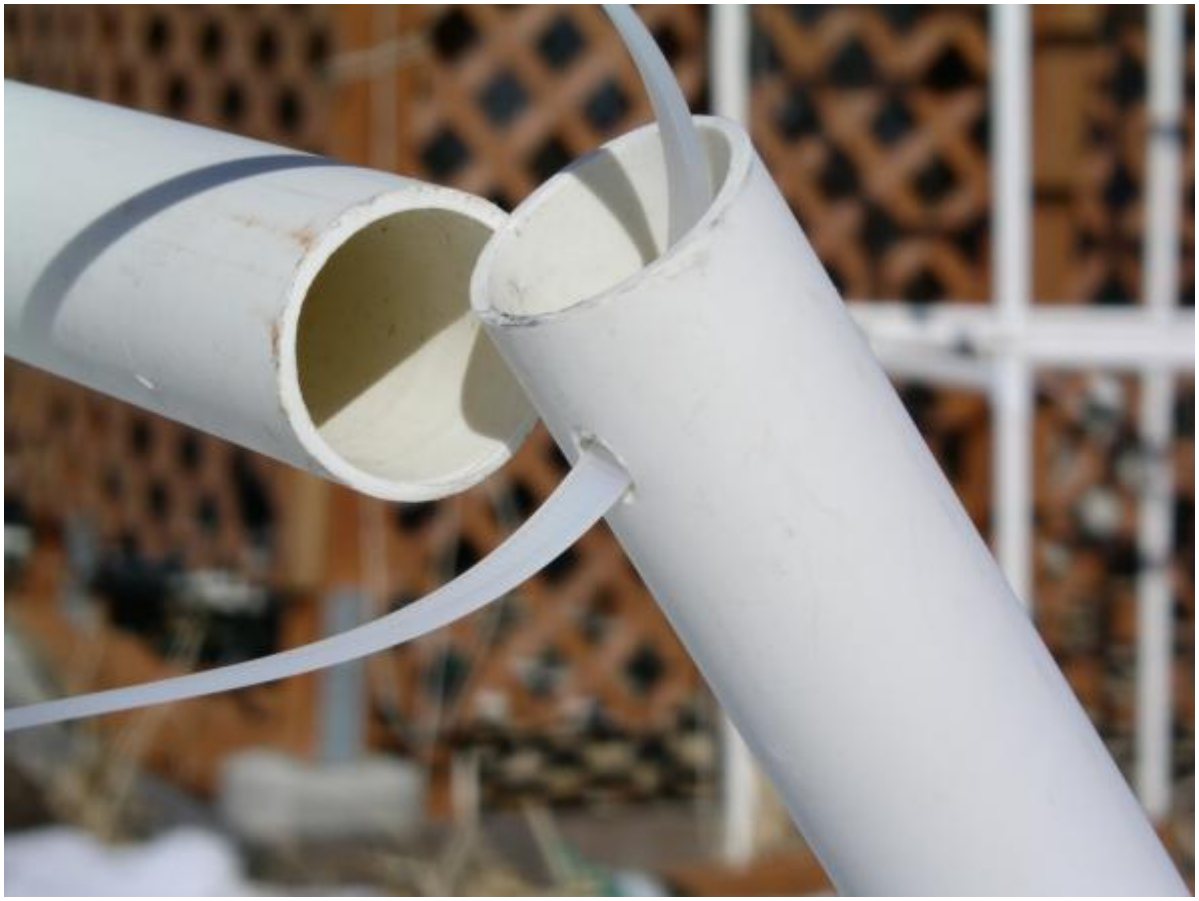

Figure 19. Step 6 - Loosely attach zip-ties between opposing ribs, make sure to leave room to slide the spine into place.

Step 7. Slide the single uncut 10 foot PVC pipe that will act as the spine in between all the zip-ties (Fig. 20).

Figure 20. Step 7- Slide the single uncut 10 foot PVC pipe that will act as the spine in between all the zip-ties.

Step 8. Begin to tighten all the zip-ties a little at a time (Fig. 21). Make sure the spine is on top to provide smooth surface for plastic sheeting.

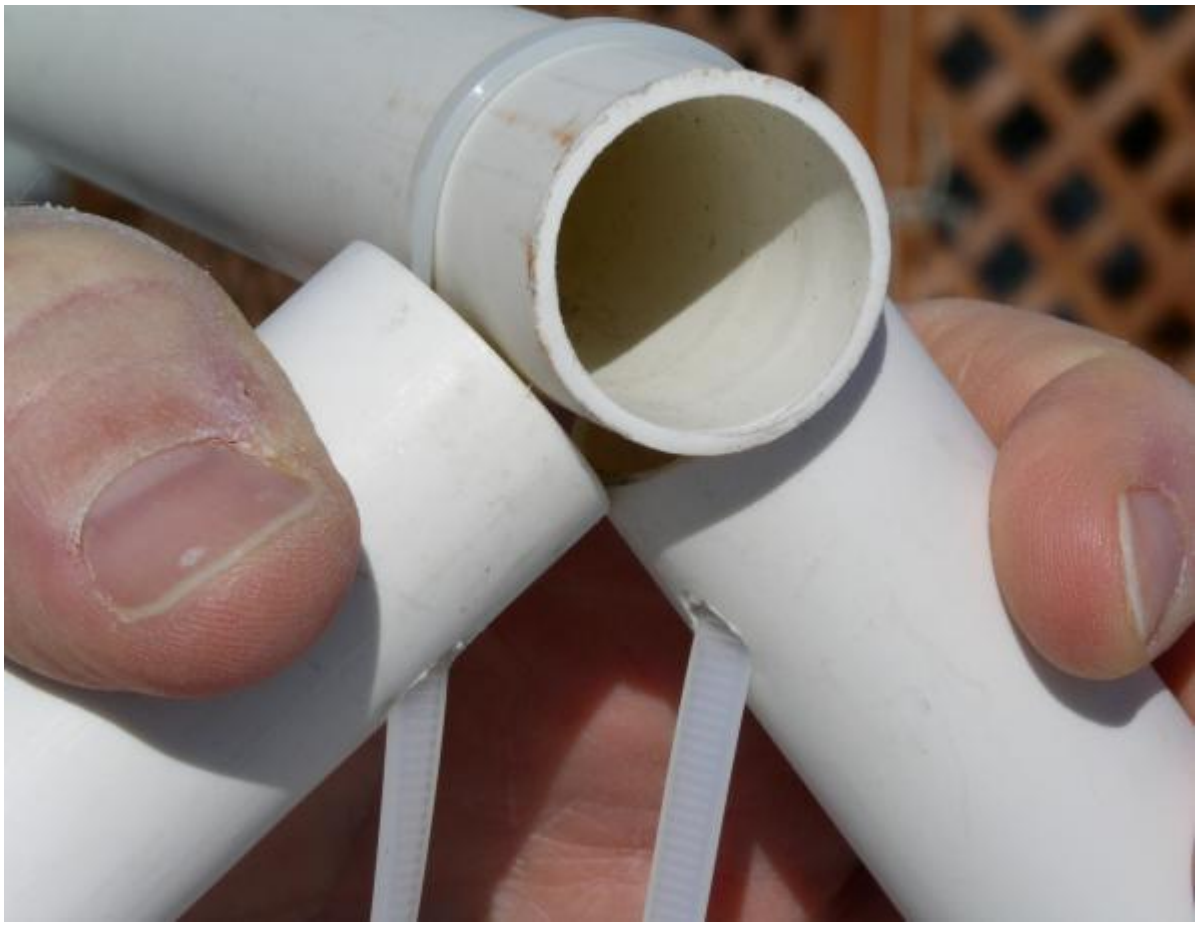

Figure 21. Step 8-Begin to tighten all the zip-ties a little at a time. Make sure the spine (top support) is on top and not trapped between the ribs.

Step 9. Completely tighten all the zip-ties until the spine is held firmly in place (Fig. 22 and 23). If they bind too much, you may need to drill the holes slightly larger. Sometimes it helps to grab the zip-ties with a pair of pliers for a better grip.

Figure 22. Step 9 - Completely tighten all the zip-ties until the spine is held firmly in place.

Figure 23. Step 9-All zip-ties completely tighten and holding spine firmly in place. Use pliers for a good grip on the zip-tie.

Step 10. The next step is to cut and attach the plastic sheeting to the PVC frame. See sections 9, 10 and 11 below for making homemade PVC clips, information about different types of plastic sheeting and different ways to attach the plastic sheeting.

Notes about the Plastic Sheeting that Covers the Greenhouse

Plastic Coverings - Choosing the Right Greenhouse film AKA agricultural plastic, poly-film and greenhouse plastic.

As I have learned, all Plastic Coverings are not created equal. There are several options for buying plastic sheeting to cover the greenhouse:

- **Utility Grade** (4 and 6 mil) polyethylene plastic (PE)
- **UV protection** - Protects plastic film from Sunlight - should last 4 years
- **Thermal protection** - Reflects IR back into greenhouse - claims to cut heating costs 15-30% and to maintain higher temperatures at night if you don't heat the greenhouse
- **Anti condensation** - condensation attached to film can reduce sunlight and reduces dripping onto plants.

I have used the 4 mil and 6 mil (utility grade) polyethylene plastic (PE) (Fig. 24) readily available at most home improvement and hardware stores, but can only use them for one season. They were still good at the end of the fist season, but I tried to reuse some of the plastic for a second season and it became very brittle and began to disintegrate. After it disintegrated, it was nearly impossible to pick up. So if using plastic sheeting without UV protection, only use it for one growing season.

Plastic sheeting specifically designed for use on greenhouses are also available that have UV protection which allows them to last 4 years or more. It is actually cheaper in the long run to buy UV protected plastic sheeting (12 x 25 ft $38;12 x 55 ft $76). I may even try using a thermal greenhouse film to help keep temperatures up a night (12 x 55 ft $92).

Cutting the Plastic Sheeting

Cut the plastic sheeting to desired length and width, making sure there is at least 6 inches of overlap on all four sides, but 1 foot of overlap on would be better. If you plan to weigh the plastic sheeting down instead of attaching it to the raised bed, 2 extra feet may be better on each side. Remember, you can always cut away more excess, but you can't put back what you already cut. Also leave at least 6 inches (1 foot is better) overlap for the two door flaps. After you trim them, the door flaps will be triangular in shaped.

Figure 24. Example of utility grade plastic sheeting that can be used to cover the greenhouse for a single season.

Save $ & Make Your Own Clamps to Fasten Plastic Sheeting to PVC Pipe

Specialty PVC clamps can be purchased for about 50 - 60 cents each for a 4 inch clamp that clamps onto a 3/4 inch PVC pipe. The look like they should work well and should be easy to put on and to take off. But clamps can also be easily made from scrap sections of the same size PVC pipe you are already using (Fig 25). The clamps are made by basically splitting and then removing a small section (1/4-1/2 inch) of material along the entire length from a short section of PVC pipe. If making your own clamps, cut sections of PVC pipe into various lengths from 3-6 inches long. Longer pieces are very strong and hold well, but they are also very hard to put on and to take off. Long pieces also do not work well on the curved lower surface of the A-frame, so you will want to make several short pieces. You will want at least 12 clamps; 6 clamps to hold the plastic film onto the frame at each end and another 6 to attach each end or door flap onto the frame at each end.

Once you have the pieces cut, secure them in a vise or jig so you can cut out the middle section without cutting yourself. I found it easiest to secure the pieces in a vise and score them deeply with a hack saw or key-hole saw. Because the pipe is rounded, it is easiest to make cuts with the saw on the inside of the pipe and cut toward the outside. I complete the cuts with a sharp pocket knife. It may seem like entire cut could be made with a good utility knife, but I personally can't make the cuts straight enough. I strongly advise against splitting PVC pipe with utility knife because it seems too dangerous to me. It would also be simple and safe to split the PVC pipe with a table saw using a guide and a push stick. Be advised that if you saw PVC pipe, you will create volumes of electrostatic PVC granules that will stick to everything.

My wife developed a simple method to attach the homemade clips that prevents getting your fingers pinched. "Real men" can attach and remove the clamps without the "finger savers", but I also use them because they also also help to protect the plastic sheeting. To make the "finger savers", cut two short sections, about 3 inches long from on old garden hose and split them as shown in Figure 26. See Figures 27-30 below for directions of using the "finger savers" to attach the plastic sheeting to the PVC frame.

Figure 25. Homemade PVC Clamps for attaching plastic sheeting to PVC frame.

Figure 26. Homemade "finger savers" cut from on old garden hose for attaching PVC clamps to PVC frame.

Figure 27. Step 11 - Attach plastic sheeting to PVC frame with PVC clamps. Position the home made clamp and "finger savers" as shown in picture above. Begin spreading the clamp with the finger savers and push the plastic sheeting onto the PVC frame.

Figure 28. Step 11 - Attaching plastic sheeting with PVC Clamp; half-way there, continue spreading and pressing toward the PVC frame.

Figure 29. Step 11 - Attaching plastic sheeting with PVC Clamp; The clamp has been pushed onto the frame, now just pull out the finger savers.

Figure 30. Home made PVC clamp holding plastic sheeting onto PVC pipe.

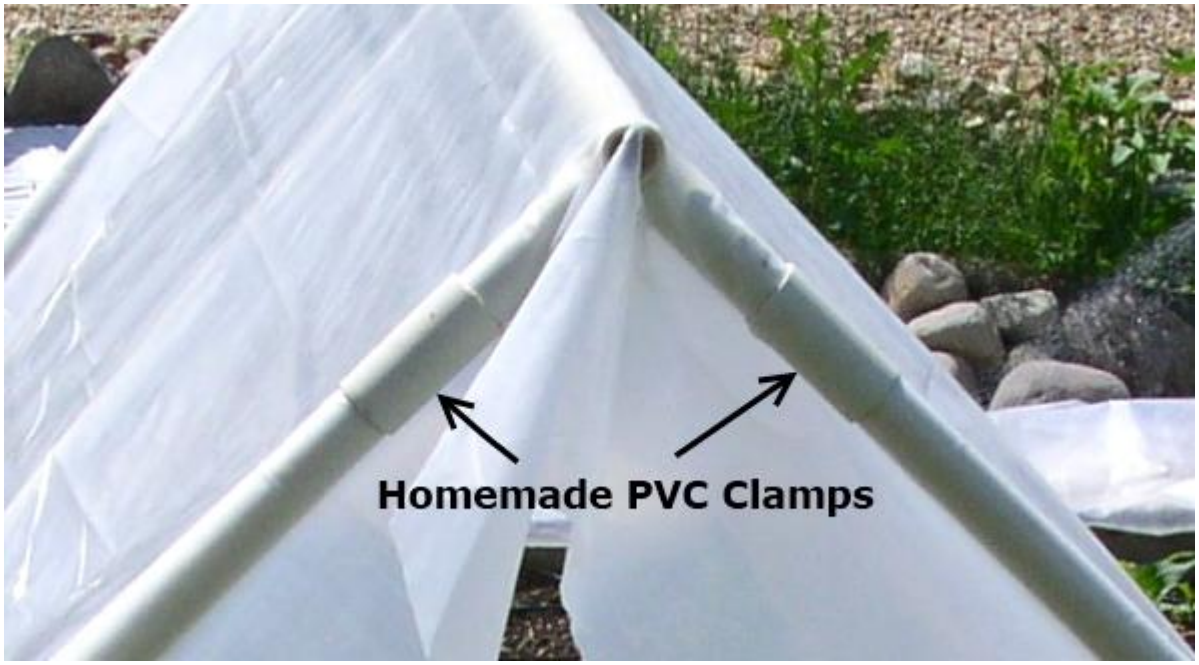

Figure 31. Another angle of home made PVC clamp holding plastic sheeting onto PVC pipe.

Attaching Plastic Sheeting to the Raised Bed Frame; Sides and Door Flaps

Semi-Permanent or Temporary Attachment

I have secured the plastic sheeting to the wooden frame of the greenhouse in several ways and have learned of and included additional methods below. You have to decide if you plan to attach the sheeting semi-permanently (not permanent, because screws can always be removed) for the entire growing season, or if you want to be able to easily remove and re-attach one side for quick removal of the sheeting. Remember, this is a small greenhouse, and it helps to be able to remove the plastic to water, weed and check and treat for pests or just to remove the plastic on a hot day so the plants don't over heat and can also be exposed to full sunshine.

Methods for attaching plastic sheeting to the wood raised bed frame.

1. Weight down plastic sheeting with lumber, cinder blocks, rocks, gravel or soil
2. Attach plastic sheeting to bed frame with spring clamps
3. Screw plastic sheeting to bed frame with wooden furring strips (wrap plastic around one furring strip several times and use a washer on each screw)
4. Screw plastic sheeting to bed frame by wrapping plastic around one furring strip and sandwich between 2nd furring strip and the raised bed frame
5. Make a loop from the plastic sheeting by sandwiching plastic between wooden furring strips and insert wood or rebar for weight
6. Commercially available channel and "wiggle wire"
7. Screw home-made PVC channel to frame, snap into place with PVC Pipe
8. Reinforce plastic sheeting with Mesh tape and attach with zip-ties
9. Staple plastic sheeting with batten material (strong flexible rubber-like material like agricultural drip-line)

I have used the first three methods above. The first year, I used Methods 1 and 2 for attaching the sides of the plastic and I used Method 3 to attach the door flaps. The second season, I used Method 4 for attaching both the sides and the end flaps.

For attachment Method 1, I left two extra feet of plastic to overhang each side. I placed 2 x 6 boards on the plastic and weighed it down with large rocks (softball - soccer ball sized) This was very simple and except for several very windy days, held the greenhouse in place. It was also very easy to remove the plastic from one side on days that were too hot for the greenhouse and also very simple to replace the sides before the temperature cooled too much in the evening. Sometimes, If not too windy, I would all the clamps still attached to the one side and simply flip the plastic sheeting over to that side and weight it so it would blow around. I don't have a picture of this, but the greenhouse was completely closed on one side and completely open on the other. Remember that any plastic that is still attached will act like a sail if the wind picks up. If windy, it is best for the plastic sheeting to be either completely attached to the frame or completely removed and weighted down. It is o.k. to leave the sides up, but have both ends open so the wind can blow through. It is also o.k. to leave one door open and the other closed if the one closed is toward the wind. If not, the greenhouse will fill up with air and something (usually the closed door flaps) will be blown open. Any loose plastic can beat around in the wind and damage the plants.

Method 2, semi-permanently attaches the plastic sheeting to the raised bed by wrapping the plastic sheeting several times around a 1/2 inch by 2 inch wood furring strip and attaching it to the raised bed with screws. Use washers to help the screws hold the plastic and prevent the plastic from tearing. Be very careful when screwing the screws in tight so the washers don't cut through the plastic (Figure 32). Screws need to be at least 1 inch long.

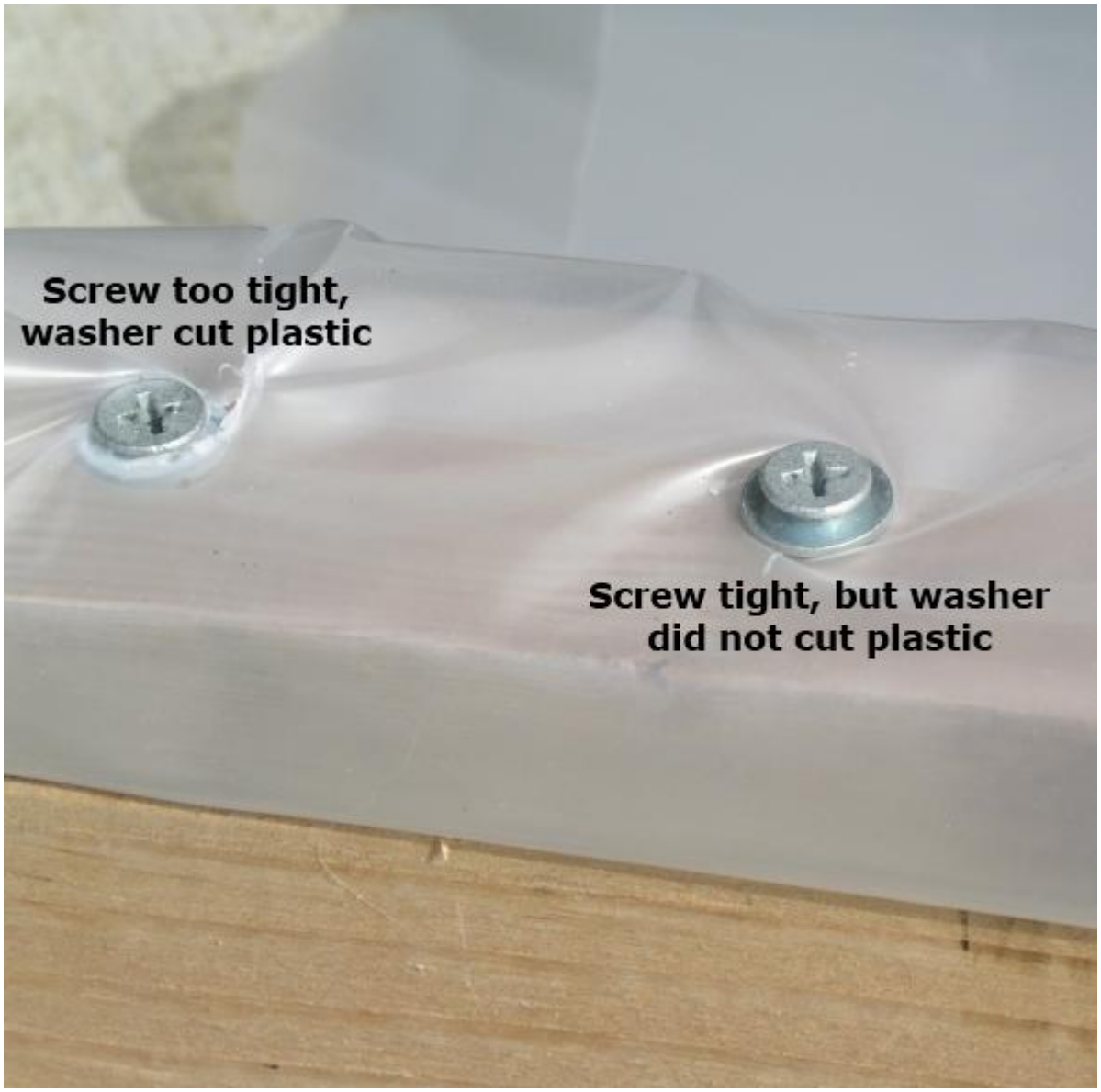

Figure 32. Plastic Sheeting attached to raised bed frame with single wood furring strip, screws and washers. Wrap the plastic several times around the furring strip and be careful not to cut the plastic. This method will still hold for the entire season even if the plastic is cut.

The second Year, I permanently attached the plastic sheeting to the raised bed frame with Method 3 above. As with Method 2 above, wrap the plastic around a furring strip several times, and attached it to the raised bed with screws. But instead of a single furring strip, screw the entire assemble to the wooden frame with a second furring

strip (Figure 33 and 34). The screw needs to be at least 2 inches long, but does not need to be longer than 3 inches.

Figure 33. Plastic Sheeting attached to raised bed frame with two wood furring strips and screws. Wrap the plastic several times around the first furring strip and screw through both furring strips into the edge of the raised bed frame. Use screws at least 2 inches long.

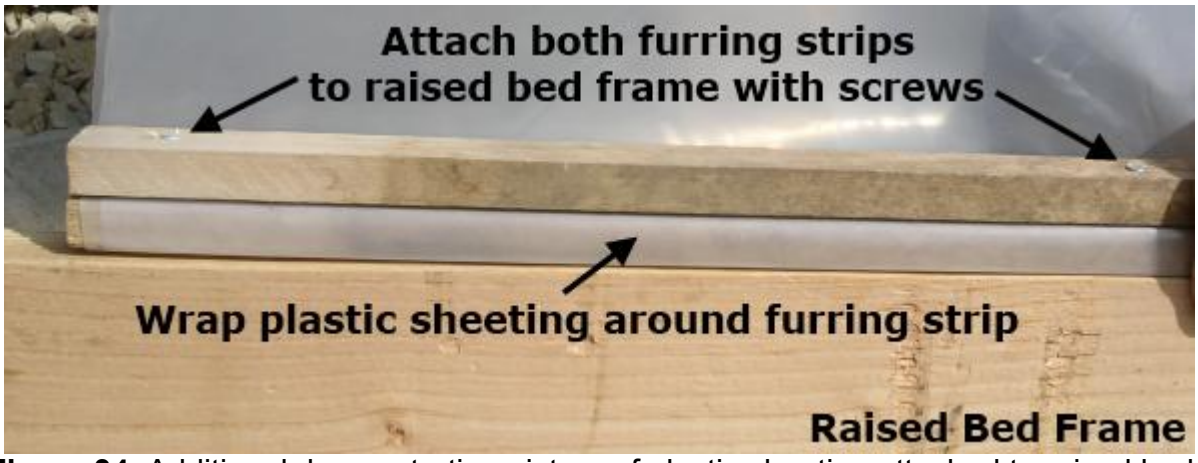

Figure 34. Additional demonstration picture of plastic sheeting attached to raised bed frame with two wood furring strips and screws. This picture showing the plastic sheeting oriented toward the frame side, so screws can be attached and removed from the outside of the green house.

The 10 ft edge pieces should be screwed at each end and at least every 2.5 feet, for at least 5 screws on each side. The 5 foot end pieces that hold the door flaps should be attached with screws on each edge and at least once in the center. I never had any trouble with the plastic coming off even in severe winds (70 mph gusts), but I only removed the plastic cover several times all season, because it took more effort to remove and to re-attach. It is nice to be able to remove the plastic sheeting to weed, fertilize or just check the plants since the roof is so low, especially after the plants begin to fill the area up.

So decide if you plan to attach the plastic sheeting to raised bed frame permanently for the season with wooden furring strips or to temporarily by covering the bottom edge of sheeting with boards weighted down with rocks and/or gravel or by clamping to the plastic to the wooden edge of the raised bed. If using furring strips, wrap plastic sheeting around wooden furring strips several times and screw into the bed frame, using washers to help protect the plastic and to help the screws to hold better.

Making and Attaching Door Flaps

You can attach the door flaps to the bed frame with the same method you used to attach the main piece of plastic, but I think the door flaps will work best if attached semi-permanently as opposed to simply being weighted down. Since the door flaps have to cover the ends, they will need to be trimmed to triangular shapes. It is still important to leave at least a foot of extra plastic. The extra plastic gives you room to work and also creates a good seal when there is extra plastic at the edge of the green house and at the door flap. Then close the door flap with additional home made clamps. The clamps can be removed at the top for ventilation (Figure 35, next page).

Figure 35. Attach plastic sheeting for the door flaps semi-permanently at bottom of each end. Then also attach the door flaps to the frame with PVC clamps. Trim the excess plastic sheeting from the door flaps so they are triangular shaped.

Part III Results, FAQs, Resources

A Work in Progress; Results

After using the the A-frame greenhouse for two seasons, we have had two very good crops of peppers (Figs. 36 - 38).

Figure 36. Anaheim peppers growing in the greenhouse.

Figure 37. Jalapeno peppers growing in the greenhouse.

Figure 38. Example of a few peppers harvested. This harvest completely filled the crisper draw of the refrigerator.

FAQs and Additional Notes

Q: Your plan has 5 Ribs for 10 ft length. One on each end, one every 2.5 feet. Would It be better to add an additional rib, so there is a rib every 2.0 feet?

A: It obviously would not hurt to have an extra rib, but I haven't needed it. If you add the extra rib it will only cost an additional PVC pipe and two conduit straps or rebar stakes and an extra zip-tie. If I were to build a true hoop house, I would probably use the extra rib because snow would pile up on the flatter top. Snow does not accumulate on the A-frame.

Q: How does the A-frame hold up to the wind?

A: My A-frame and home made clamps have withstood a storm with 70 mph wind gusts. On an other occasion, the wind did blow the ends open. I think I left the end fastened a little loose. The wind was blowing straight from the North into the loose plastic. Instead of slipping off the sides, the loose plastic created a pocket just like a sail and caused the plastic to slip from the clamps. Once that end blew out, I suspect it quickly blew the other end out. The loose plastic door flapped around and destroyed one pepper plant. So, keep the doors (end flaps) tightly attached to the frame. If you have the door partially open to let heat out of the greenhouse and a storm rolls in, it is best to either completely close the greenhouse up tight or completely open it up and let the wind blow through.

Q: Why did you build your raised beds 5 feet wide? Don't you have to step into them to reach the middle?

A: As you say, If I were using the raised beds without the greenhouse, I would build them to be only 4 feet wide, so I could reach the middle of the beds without having to step into them. But, after covering the raised beds with the greenhouse, I have decided the 5 ft width is actually better because it provides extra space for plants to grow without being crowded into the plastic sheeting on the sides. We have planted 4 rows of peppers in the greenhouse with the 5 foot width. If the greenhouse was only 4 feet wide, I would only plant 3 rows. Since we do have to step into the greenhouse to weed, fertilize or harvest, we have strategically placed stepping stones or boards to reduce soil compaction and help keep our shoes clean.

Q: How many peppers do you plant in the greenhouse?

A: We plant 32 peppers in 50 square feet. See the example in Figure 39. This is planting closer than most recommend, but small plots can plant closer with good results because we small plots can be intensively managed by making sure the soil is a deep good quality soil. We can water and fertilize as needed.

Q: Can tomatoes be grown in this greenhouse?

A: Of course. We are working on a design that will be a better size for tomatoes, but tomatoes can be grown in this greenhouse. Since tomatoes grow taller than peppers, I would plant the tomatoes down the center of the greenhouse (see Fig. 40 and 41) or stagger them off the center and let them lean the direction they want.

Additional Notes:

1. We didn't ventilate the greenhouse soon enough on several occasions, allowing the temperature inside the greenhouse to get too hot (>130 degrees F). This did not kill any of the plants, but we must assume that plants were stressed. We also know that when temperatures climb above 85°F, blossoms can drop off.
2. We also don't always close the greenhouse early enough on some evenings and loose the opportunity to keep temperatures high during the evening and through the night (decreasing GDD).
3. The ends of the plastic sheeting was attachment with screws to the raised bed frame in 2011 (as opposed to being weighted down with board and rocks in 2010). This made it more difficult (time consuming) to completely remove the plastic on warm days. As a result, it was difficult to remove weeds and we allowed them to grow larger than we should have.

Some Sample Planting Configurations:

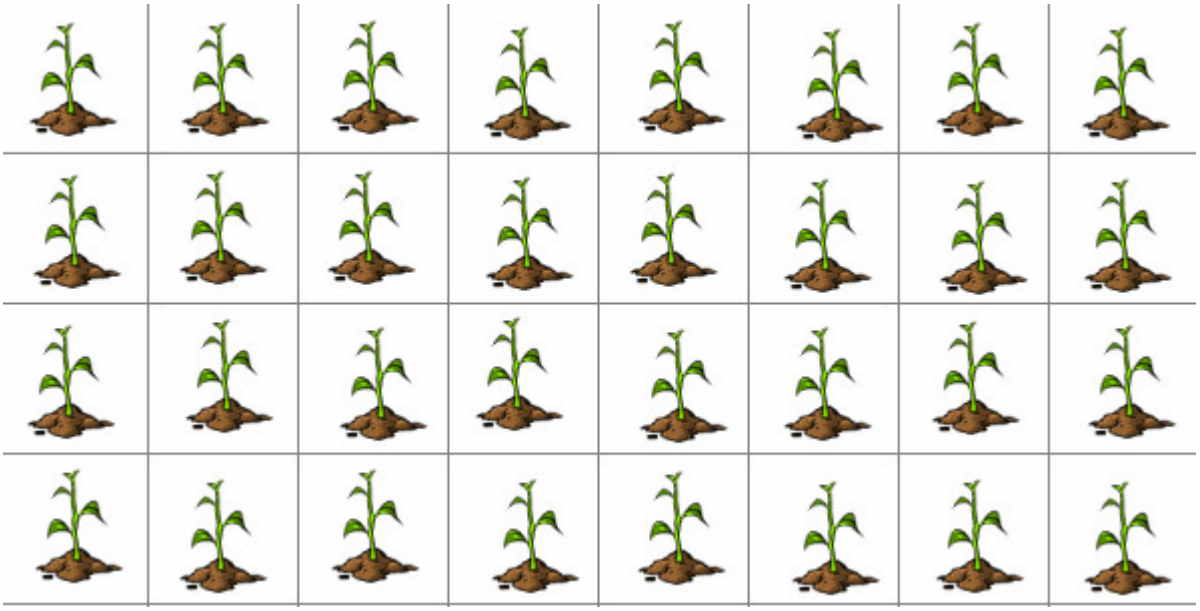

Figure 39. We planted 32 pepper plants in the 50 square feet of the greenhouse.

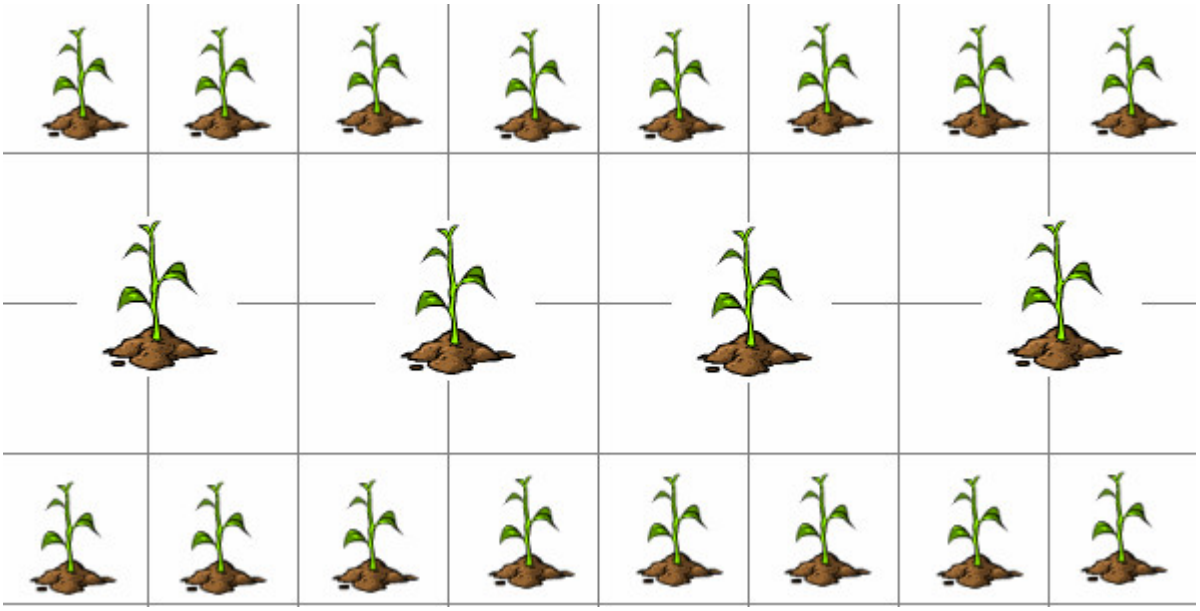

Figure 40. Space accordingly when planting taller and larger growing plants like tomatoes.

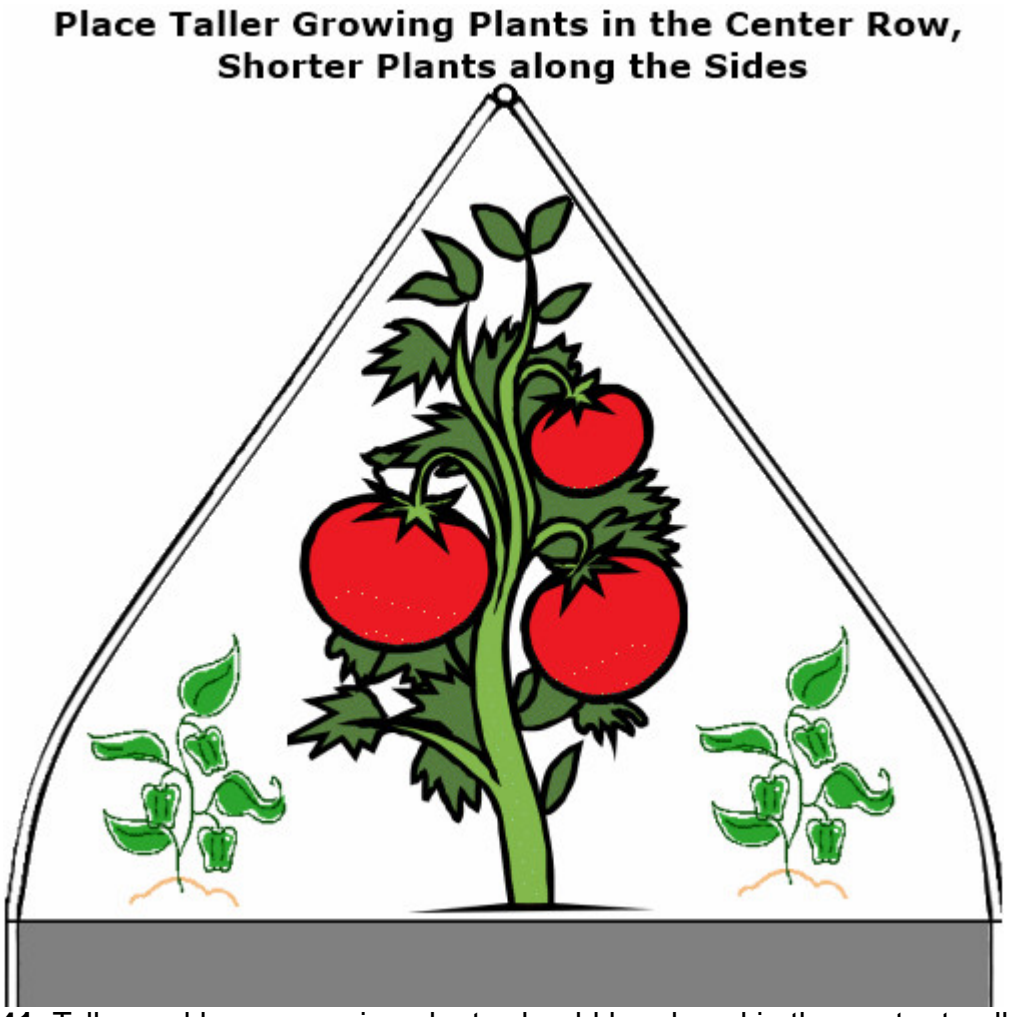

Figure 41. Taller and larger growing plants should be placed in the center to allow for more growing room.

Resources:

Click on links for additional information.

USDA Plant Hardiness Zone Map - Determine which plants are most likely to thrive at a location

NOAA Regional Climate Centers - For frost-free dates by region: Western, High Plains, Souther, Midwestern, Northeast & Southeast.

NOAA Freeze/Frost Maps - Spring & Fall Freeze Occurrence Maps (10% Probability), Freeze Free Period Map (90% Probability)

Greenhouse Tips - Additional information and tips about building greenhouses and gardening from the author's blog, HomemadeHints.com.

Contact Us - We truly value reader feedback. If you have comments, questions or see errors in this book, please feel free to contact us. Unfortunately, every device displays a little differently (optimally viewed on a larger computer screen with free Kindle reading apps) so it is difficult to make everything perfect for every device, but if you see sections or photos not displaying correctly, please let us know.

You can also Find Us on Facebook and ask your questions on our wall.

I hope you enjoyed this book and I would love to hear what you thought of it. You can leave your comments here" (and have a link to your Amazon page)

Gardening Quotes:

"Gardens are not made by sitting in the shade." -Rudyard Kipling

"Anyone who thinks that gardening begins in the spring and ends in the fall is missing the best part of the whole year. For gardening begins in January with the dream." -Josephine Nuese

"Gardening is a labour full of tranquility and satisfaction; natural and instructive, and as such contributes to the most serious contemplation, experience, health and longevity."-John Evelyn, 1666

"I've learned everything about gardening by trowel and error." -unknown

"An optimistic gardener is one who believes that whatever goes down must come up." -Leslie Hall

Happy Gardening & May Your Fresh Fruits & Vegetables be Plenty!

I hope you enjoyed this book and I would love to hear what you thought of it. You can leave your review at Amazon by clicking the link below:

http://www.Amazon.com/gp/customer-reviews/write-a-review.html?asin=B007VG91H4

Thank you, Taylor Birch

http://www.HomemadeHints.com/

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