AN INTRODUCTION TO TOMATO GRAFTING

A How-To Guide for Propagating Your Own Grafted Transplants

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Introduction

Vegetable growers around the world have been using grafted plants since the early 1920's. Initially this was to manage Fusarium wilt in melons, but by the 1930's tomatoes were being grafted onto Jimsonweed in the southern United States to control root knot nematodes. Though Jimsonweed fell out of favor as a rootstock, by the 1960's, interspecific hybrid rootstocks (crosses between cultivated tomato varieties and their wild relatives) were introduced and grafted tomatoes began to be produced on a commercial level. While this trend first took hold in Japan and Korea, where well over half of the vegetable production makes use of grafted plant, it took longer to catch on in the United States. Vegetable grafting (and tomato grafting in particular) began to catch on in a significant way in the US beginning in the 1990's. The popularity of grafting in the United States continues to increase today, particularly as the use of high-tunnels spreads and soils are becoming more intensively cultivated. Additionally, with the phase-out of methyl bromide, many growers are searching for alternatives to soil fumigation, and see grafting as a part of the solution.

Reasons to Graft

There are three main reasons a grower may choose to use grafted (tomato) plants:
1) Disease Resistance (or tolerance)
2) Improved Vigor (enhanced plant growth and/or increased fruit production)
3) Abiotic Stress Tolerance (less than ideal temperature, moisture, salinity, etc.)

Verticillium wilt, Fusarium wilt, Bacterial wilt, Southern blight, Corky root rot, and Root-knot nematodes are all soil-borne diseases caused by root and stem-infecting pathogens. These persistent pathogens can be problematic, but are especially so for urban, high tunnel, and small growers with limited crop rotation space, or for those wishing to produce highly susceptible heirloom tomato varieties. For this reason, disease resistance is likely the most common reason given for grafting tomato plants. While tomatoes are susceptible to a variety of soil-borne diseases, certain rootstocks have been shown to be resistant or tolerant of many of these, and grafting may be a good option for growers looking to control a variety of soil-borne diseases.

Researchers have also found that selected rootstocks can aid with other abiotic stresses such as temperature and salinity as well as increase in the efficiency of water and nutrient uptake. Grafted tomatoes with vigorous rootstocks have shown to increase tomato yields even in the absence of soil diseases, or abiotic pressure and it seems likely that the full productive potential of such vigorous rootstocks may only be unlocked under the best conditions. Therefore, regardless of their pest, disease, or soil-quality status, a grower using the right rootstock/scion combination has the potential to improve their yield with fewer plants and less cultivated space.

Grafting Challenges

Although grafting is a promising solution for several production issues, it does pose a few (primarily logistical) challenges. For about two weeks propagators must produce two plants, which adds costs, space, and time. Besides additional overhead expenses, the annual cost of rootstock seed and skilled grafting labor can be most distressing. For this reason, grafted plants will typically cost at least three times that of their non-grafted counterparts. However, with an increase in yield, especially when combating otherwise devastating disease issues, grafting can still be very profitable.

Unfortunately, the availability of grafted tomatoes for growers in the mid-west to purchase is currently very limited, therefore the following publication is intended to help interested growers successfully propagate their own grafted tomatoes.

Scion Selection

Scion Selection is much simpler than rootstock selection in some ways. Scions are chosen by looking for a cultivar with desirable fruit characteristics (e.g. appearance, size, flavor, shelf-life etc.) However, it should be noted that while the characteristics of a specific rootstock are typically fairly stable, specific rootstock-scion compatibility is somewhat variable (not all scions interact with the same rootstock in the same way). Your selection of scion should also help you determine whether you choose a generative or vegetative rootstock. If your scion is an indeterminant, and already produces large amounts of vegetation (like many heirloom varieties) you will likely want to choose a generative rootstock (generative rootstocks help to improve fruit production). However, if you are using a determinant scion variety (like many hybrid or commercial varieties) you will likely want to choose a vegetative rootstock, which will increase the size of the plant and give more room for additional fruit set.

Rootstock Selection

The first important step of successful grafting is selecting the right rootstock. You need to ask yourself "What are my reasons for grafting?". Being honest with yourself about the strengths and shortcomings of your production system will help significantly in making a wise rootstock choice.

If your goal is disease management, you'll want to correctly identify your specific soil-borne disease (Table 1) and select a rootstock that has corresponding resistance genes (more extensive lists of rootstocks and their genetic resistance to particular soil-borne diseases can be found at http://www.vegetablegrafting.org/resources/rootstock-tables/).

If your goal is to combat specific abiotic stressors, you should look for rootstocks that have been shown to combat those distinct stressors. "Arnold" may be a good choice if soil salinity is your main problem, however, you may need to consider other solanaceous species as potential rootstocks. For example, eggplant rootstocks work well with tomatoes and are very tolerant of flooding or waterlogging.

(Table 1) genetic resistance of a few tomato rootstock varieties to various soil-borne diseases

Rootstocks	TMV	Corky Root	Fusarium Wilt		Verticillium Wilt (r1)	Root-knot Nematode	Bacterial Wilt	Southern Blight
			Race 1	Race 2				
Beaufort *	R	R	R	R	R	MR	S	HR
Maxifort *	R	R	R	R	R	MR	S	HR
(Unreleased) *	R	S	R	R	R	R	HR	MR
TMZQ702 **	R	S	R	R	R	R	MR	MR
Dai Honmei ***	R	R	R	S	R	R	HR	MR
RST-04-105 ****	R	R	R	R	R	R	HR	MR
Big Power *****	R	R	R	R	R	R	S	HR
Robusta ******	R	R	S	R	R	S	S	?

R=Resistant , **HR**=Highly Resistant, **MR**=Moderately Resistant, **S**=Susceptible

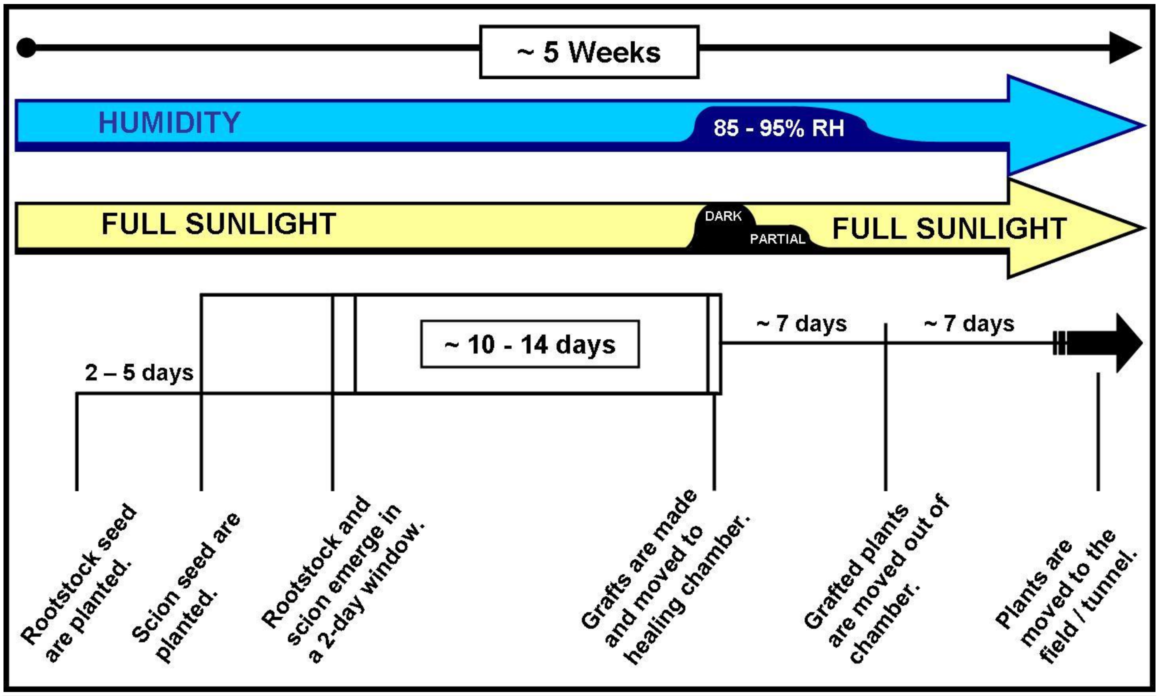
*** = De 'Ruiter Seed Co. ** = Sakata Seed Co. *** = Asahi Seed Co.**

****** = D Palmer Seed Co. ***** =Rijk Zwaan ****** = Bruinsma Seed Co.**

If your production system is fairly well established, you have little disease pressure, few abiotic stressors, and are getting good yields from your nongrafted plants, you may wish to graft purely to improve your yields. As such you should look for rootstocks that enhance a plants productive vigor. Often times these rootstocks will provide resistance or tolerance to one or more soil-borne diseases or abiotic stressors, so even if your primary reason for grafting is disease or stress management, you may be able to add extra productive vigor as well. A good example of such a rootstock is "Maxifort".

Seeding

The entire grafting process from seeding to field-ready transplant takes approximately 5 weeks (Table 2). It is therefore important to keep in mind that the propagation process for grafted tomatoes should start about two weeks earlier than for standard, non-grafted plants. The biggest challenge in producing seedlings for grafting is keeping the scion and rootstock growth uniform. Maintaining uniformity will not only make grafting easier, it will also help to improve your success rate. If the germination time or growth rate is significantly different from rootstock to scion, a propagator can stagger seeding dates to keep seedling size similar. It can be advantageous for a grower to test the germination rate and time of seeds by trialing a set number of seeds before starting a larger batch.



(Table 2) Approximate timeline of tomato grafting process

Seeds should be obtained from reputable utilize a protocol for treating seed if not purchasing from a certified source, this will reduce the potential for diseases like bacterial canker. Seed should be sown in a fine seeding mix about 1/8-inch-deep and kept in a warm moist environment. For more consistent germination, a heating pad controlled by a thermostat with a soil probe may be used to keep the soil at approximately 78°F. Plastic domes can also be used to keep the soil moist during germination. However, such domes may retain too much heat, especially in a greenhouse, so unless you germinate your seeds under artificial light, covering the domes with a reflective or shading material may be necessary . As soon as seeds start to sprout, shade and domes should be removed in order to give the plant full light. If using artificial light be sure to position lights directly above the seedlings to avoid stretching. Seeds should be finely misted about twice a day to maintain consistent soil moisture while the root systems develop.

Transplant Management

Approximately 10-14 days after seeding, seedlings can be transplanted into seedling trays using clean soilless media. The use of soil or compost-based planting media can be risky as such media may harbor fungus or bacteria, increasing the risk of infection throughout the grafting process.

Though your growing medium may have an incorporated starter fertilizer, a liquid complete (N-P-K) fertilizer should be used on a weekly basis to keep transplants healthy. After approximately 21-28 days post seeding, transplant stem diameter should be about 1.5- 2.5 mm, and plants should have 2-3 sets of visible adult leaves.

When transplanting, it can be advantageous to transplant seedlings of approximately the same size into the same tray in order to allow for more precise tray-by-tray temperature (growth rate) control. The ideal growing temperatures for tomato transplants range from 65^o to 85^oF, and this 20 degree range can be utilized to improve the uniformity of the seedlings at grafting. If the scion and rootstock seem to be growing at different rates, modifying the growing temperature can help to equalize the two. Cooling to 55^o - 65^oF can help to slow growth, growth may be accelerated by placing the plants on a heating pad (75^o - 85^oF). As a last resort, significant leaf removal in the final days prior to grafting may pause growth long enough to allow the graft partner to catch up. Placing plants in a lower light may also help to slow growth, but this should be done carefully, as low light may cause the plants to stretch.

How Grafting Works

Grafting takes advantage of a plants natural wounding response and healing process. Understanding this wounding response will help you understand the grafting process, and may help you diagnose any problems you may encounter.

The plant wound response takes place in a series of steps:

1) When a plant is damaged mechanically, the layer of damaged tissue typically dies. This is known as the "necrotic layer".
2) The plant now begins to generate a mass of callus tissue, Callus tissue is essentially an undifferentiated and disorganized cell mass that fills in behind and eventually replaces the necrotic layer, forming a scar.
3) If no other callus tissue is recognized the plant will seal off the wound to prevent infection. However, if this callus tissue encounters other callus tissue (i.e. the tissue from the rootstock encountering the tissue from the scion) the two sets of callus tissue begin to communicate and coordinate the healing process. This interconnected tissue mass formed of callus from both scion and rootstock is called the "Callus bridge".
4) Callus tissue in the bridge coordinates cell differentiation to reconnect the vascular cambium across the bridge, which then differentiates into phloem (3-4 days post-grafting*) and xylem (6-8 days post-grafting*).

* for tomatoes

Grafting Prep

Prior to grafting, a grafting kit must be assembled. For the most part this is made up of materials and tools that are easy to find at any dollar or big-box store if you do not already have them lying around your house. You should also construct your healing chamber prior to grafting.

You will need to assemble the following:

1) Sharp razor blade or hobby knife

   Sharpness is critical when grafting as this reduces the damage you are doing at the cellular level, and thus minimizes the resulting layer of dead tissue forming between the grafting partners.

2) Scissors
3) latex gloves

   Important for maintaining sanitary working conditions and preventing infection (absolutely necessary if you are a tobacco user, as tomatoes are highly susceptible to tobacco mosaic virus)

4) paper towels
5) Isopropyl alcohol

   It is a good idea to get a small container that the isopropyl alcohol may be poured into, so tools can be dipped and sanitized

6) Compost bin or plastic bucket

   Any kind of container that you can use to dispose of the unused portions of the rootstock and scion after grafting

7) Clean grafting clips in at least two contiguous sizes to account for variation in transplant size (sizes 1.5 mm and 2.0 mm are recommended)

   Grafting clips are one of the few items you will likely not be able to obtain locally. While you may be able to make your own from short lengths of silicon tubing, grafting clips are easy to order online, will be more user-friendly, and are relatively inexpensive.

<u>See the following websites for grafting clips</u>

http://www.graftingclips.com/products/clips-for-tomatoes/tubes/
http://www.johnnyseeds.com/tools-supplies/seed-starting- supplies/silicone-top-grafting-clip-2.0-mm-9847.html
http://www.tomatogrowers.com/GRAFTING-CLIPS/productinfo/6936/
https://www.harrisseeds.com/products/40862-grafting-clips-2-mm

The healing chamber provides nearly ideal (warm, humid, and dark) conditions for bacterial and fungal proliferation. As such, sanitation, both of the chamber and throughout all steps of the grafting process is essential. This means cleaning the work area prior to grafting, washing your hands, wearing gloves, sanitizing your tools frequently, and using paper towels to keep your work area clean (and as a clean surface on which to set sanitized tools

How to Graft

There are several different methods of grafting tomatoes, but the splice-grafting method (also known as "tube grafting" or "Japanese top-grafting") described below is relatively simple and has a high rate of success. For this reason, it is probably the most popular method for grafting tomatoes.

The evening before grafting, water plants well so that the soil will be wet but the foliage will be dry for grafting. If watering the day of, consider bottom watering to avoid wetting the foliage. If desired, scions may also be placed in lower light to help acclimate them to low light and decrease transpiration.

While grafting, remember to sanitize your blade and scissors with alcohol and wipe clean. Repeat after about 10-20 cuts.

Grafting Steps

1. Trim 80-90% of the leaves off of the scion with sharp clean scissors or blade taking care not to disturb apical meristem (growing point)
2. Using your razor blade or hobby knife, cut the rootstock just below the cotyledons at ~70-degree angle (Figure 1).
3. Pinch to open clip and place half way on rootstock facing perpendicular to the cut. Make sure to use an appropriately sized clip (Figure 1).
4. Select a scion with the same diameter stem* and cut at the same 70-degree angle (Figure 1). Note that well-matched stem diameters are one of the most important factors to ensure physical compatibility between the rootstock and scion. For tomatoes, this cut may be made above or below the cotyledons, and since the stem tapers to some degree the cut should be made where the stem diameter best matches the rootstock (this is very important as the vascular bundles in tomato plants are arranged in a ring and need to line up in order to reconnect properly across the callus bridge).
5. Slide scion into clip making sure there is even surface contact with the rootstock (Figure 1). Contact should be firm to ensure minimal space is created between grafting partners as the necrotic layer forms. Minimizing this space will improve the likelihood of successful callus bridge formation.
6. Place finished trays immediately into the low light and high humidity healing chamber.

(Figure 1) splice-grafting procedure

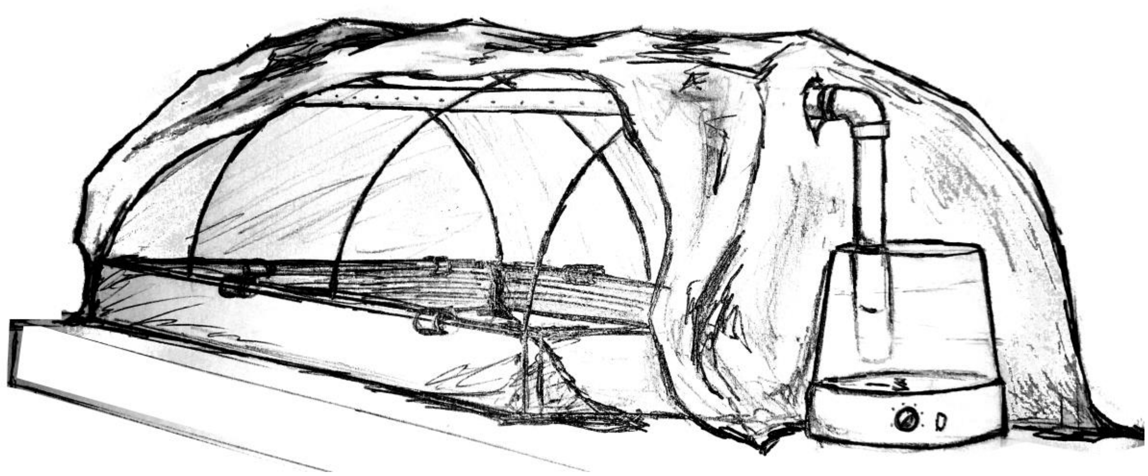
Healing Chambers

The most challenging part of the grafting process is post-grafting healing chamber management. A healing chamber is a small-enclosed area designed to promote graft formation by providing the newly grafted plants with the ideal conditions for rapid recovery. Healing chambers may take a variety of forms, but all must allow the propagator to control humidity, light, and temperature.

Healing Chamber Construction

As mentioned previously, the healing chamber should be constructed well in advance of grafting. Any materials used in the construction or management of a chamber should be easily cleaned with sanitizing solution. Typically, a sodium hypochlorite (bleach) solution is used. Such a solution is not only an effective sanitizer, but is also allowed by organic certification standards provided the manufacturer's instructions are followed regarding solution concentrations. Bacteria and fungi are well suited to the environment found within the healing chamber, so organic or porous materials that hold moisture (such as wood) should be avoided.

When learning, or for smaller batches of plants, plastic domes, upside-down aquariums, or even clear plastic totes placed over individual trays may be used as a miniature healing chambers (Figure 3), though for a grower producing multiple trays of grafted plants, a large purpose-built chamber is ideal for ease of management (Figure 2). Whatever the situation, locate your chamber in a draft-free room where the ambient temperature is consistently around 78°F.



(Figure 2) completed healing chamber showing humidifier as described herein

Before you begin construction, keep in mind that there are many ways to fulfil the functional requirements of a healing chamber, and there are many different designs out there (Figure 4). If your situation does not permit the precise application of the plans given here, do not be afraid to modify or innovate. Keep in mind that materials used for chamber construction should be kept as clean as possible, and especially those coming into direct contact with moisture or plants should be sanitized (at a minimum) at the beginning of each grafting season.

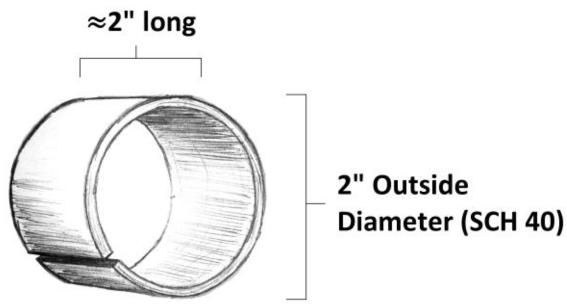
(Figure 3) alternative small batch healing chambers showing extra foam-board shade

Our healing chamber design begins with a composite lumber frame (Figure 7). The frame is constructed to accommodate two seedling trays end-to-end across the beam, and can be made as long as necessary (within reason) to accommodate the desired number of plants, though it should be noted that maintaining a consistent microclimate from end to end becomes more challenging with a drastic increase in length.

(Figure 4) alternative healing chamber design using PVC framework

Clean clear 6mm plastic film is used to line the bottom of the chamber (Figure 7), and is clipped into place with PVC "clips" (Figure 5). Such clamps are simple and inexpensive to make, as they are fashioned from 2" lengths of 2" outside diameter (SCH 40) PVC pipe. These short lengths of PVC are placed into a vice and one side is cut length-wise, they can then be pried open by hand and hold the plastic securely to the composite lumber frame.

Wire arches are then fitted into



(Figure 5) PVC "clip"

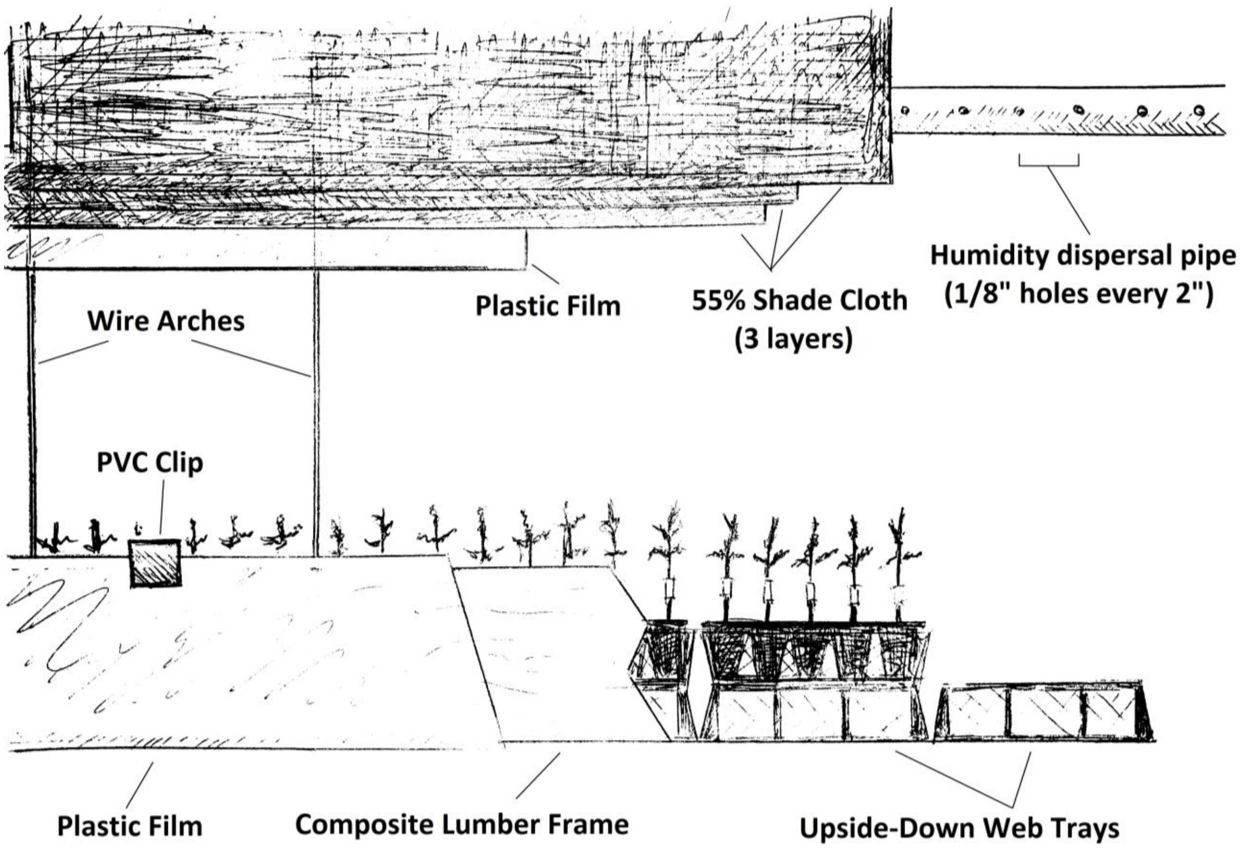
holes drilled into the frame, and a second, larger sheet of clear 6mm plastic is tucked under the back and then draped over the front and sides of the chamber (Figure 7). You will need easy access to the chamber, though the front and sides should be fastened down securely using a few bricks or spring clamps most of the time. This will prevent drafts and allow for effective control of the humidity within the chamber. Additionally, you should cut several (number depending on the size of your chamber) ~3" square holes (not merely slits or "Xs"), about 1 to1.5 ft apart on top of the plastic to release heat and allow for some air circulation.

Next add three layers of 55% shade cloth to the top of the chamber (Figure 7). If your chamber is located somewhere such as a greenhouse where sunlight may heat up your chamber excessively, you may consider covering the top of the chamber with a couple of pieces of foam-board to further shade the chamber (Figure 3).

Adding upside-down web trays to the bottom of the chamber (Figure 7) will prevent your plants from sitting in any water that may condense and accumulate on the bottom of the chamber.

(Figure 6) humidity dispersal pipe

Finally add your humidifier (Figure 2) and a humidity dispersal pipe (Figures 6 & 7). The humidifier should be a cool-water vaporizer or "Sonic" humidifier. For smaller setups, passive humidification (i.e. a pan filled with warm water) may be sufficient. Warm water vaporizers and misters are discouraged as the may raise the temperature or damage the graft? The humidity dispersal pipe is more necessary for longer healing chambers than shorter ones, and is simply a length of PVC pipe with 1/8" holes drilled approximately every 2". This pipe is hung from the wire arches, is capped at one end and connected to the humidifier at the other end. This piece is designed to equally disperse the humidity throughout the length of the chamber, helping the propagator maintain a consistent microclimate within.



(Figure 7) healing chamber assembly (cut away view)

Healing Chamber Management Protocol

After you have placed your plants in the healing chamber, you will need to give them special care for the next 10-12 days. The following protocol is intended as a guide to help you manage the healing chamber and encourage the graft healing process.

Day-to-Day Management – Plants should be checked often (every 1-2 h) to 1-2 times daily depending on where they are on the healing chamber timeline. Keep in mind that the chamber will respond to the environment, and to sun light in particular. On sunny days, the chamber will need to be watched closely so that it does not heat up too much. Similarly, the chamber will not need to be monitored very closely (if at all) once the sun is down.

Chamber Management Tasks – Refill the humidifier as needed. Check the temperature on a regular basis, but especially between 11:00 AM and 3:00 PM. after the first day or two vent the chamber daily by billowing the chamber roof to bring in fresh air. Check soil moisture and (bottom) water <u>carefully</u> as needed. Check the temperature within the chamber.

Note that anytime an "action" is taken (e.g. shade cloth removed, humidifier turned down, etc.), the plants should be checked again within 60-90 minutes, particularly in the first 4 days of the healing process.

Chamber Management Timeline

This timeline has been designed to assist in the management of grafted plants in the healing chamber. It represents a *sequence* of actions taken to manage the microclimate within the healing chamber and day-to-day variances may occur depending on the batch, environmental conditions (e.g. greenhouse temp) and other factors like day length. Also note that scion leaf removal prior to grafting may affect the length of time required for recovery. Some plants may require longer than 10 days in the chamber. If the plants are wilted or look stressed, do not proceed to the next step unless otherwise indicated.

(F = film chamber, H = humidifier, S = 55% shade cloth)

Day	Chamber	Notes
1	All layers shade, humidifier turned up to visible "fog" in chamber. (F, H, 3*S)	Day of grafting. **Check often (every 1-2 h)** for wilting
2	Remove 1 layer shade cloth. Turn down humidifier to reduce visible fog. (F, H, 2*S)	**Check often (every 1-2 h)** for wilting
3	Shade cloth stays the same. Humidifier output should be minimized. (F, H, 2*S)	**Check 2-3 times daily.** Can turn humidifier back up if wilting occurs or add shade cloth layer
4	Shade cloth stays the same. Humidifier minimal or turned off. Check for watering. (F, H, 2*S)	**Check 2-3 times daily.** Same as Day 3
5	No change. Keep humidifier use minimal. Check for watering (F, 2*S)	Wilting day(s). Plants may wilt some as they reconnect their tissues. **Check 2 times daily**
6	No change. Keep humidifier use minimal. Check for watering (F, 1*S)	Wilting day(s). Plants may wilt some as they reconnect their tissues. **Check 2 times daily**
7	If plants have recovered from wilting days, remove shade cloth. (F)	Plants should be recovering from wilting day(s) now. Will most likely need to be watered by now. **Check 2 times daily**
8	Allow a small amount of ventilation around edges or ends reduce relative humidity. (F – with ventilation)	Watch closely for watering. **Check 1-2 times daily**

9	Increase ventilation or clip poly film ½ way up to keep a "pocket" with increased relative humidity. (F – with ventilation)	Watch closely for watering. **Check 1-2 times daily**
10	Remove film. Keep under shade cloth area in warm (east) greenhouse.	Watch closely for watering. **Check 1-2 times daily**

Manage Soil Moisture – During the first few days, the plants will not need any water. However, once the graft unions start to form and as RH goes down, they will start to dry. Oftentimes, this happens sporadically as individual plants heal, they will suddenly start using more water. You will need to watch for watering needs after days 3-4. Be very careful when watering so as to not damage the developing graft unions. Bottom-watering is best, but some careful overhead watering can be done.

Manage Humidity – Relative humidity levels need to be kept above 65-70% through the first 7-8 days in order to keep scion tissue turgid. However, excessive moisture for an extended period of time will lead to disease and/or adventitious roots from the scion. Ideally, we like the humidity to be very high (>90%) for the first 48 hours and then reduced as much as possible without causing wilting after that and returned to ambient levels by day 10. The required RH to keep the plants from wilting will change through the timeline.

Managing Light and Temperature – Balancing light requirements and reducing the transpiration stream of the scion is a difficult task. The plants benefit from some light throughout the process and light should be re-introduced as quickly as possible. However, too much light may heat up the chamber, and will stress the scion and lead to wilting. On very cloudy (snowy/rainy) days, hardly any shade cloth is really needed and it is a good idea to remove a layer (or two) even early in the timeline. However, be sure to re-cover if ANY periods of sun or part-sun occur. If the chamber heats up too much (>90^{O}F), especially during the hottest (sunniest) part of the day, water the plants and add fresh (cool) water to the bottom of the chamber to cool down the chamber. You may also add layers of shade cloth or foam board for several hours to shade the chamber. If the plants are further along (day 8-9 or further) the chamber may be vented (plastic pulled back, shade cloth left on) for longer periods as well, though care should be taken not to dry the plants out too much.

Post-Grafting Care

After about seven days healing in the chamber, plants can be removed and place in full sun and low humidity. Take care not to disturb graft unions especially with overhead watering. Consider using bottom watering or small spouted water can for a few days. Plants should continue weekly liquid fertilizing schedule and slowly acclimated to lower night temperatures. Allow plants at least 7-14 days of acclimation before planting in field or high tunnels. Typically, the grafting clips will fall off on their own, however you will likely have to remove a few to prevent girdling the plant. When planting in the ground, make sure graft union is above the soil line. Throughout the season check and prune any adventitious roots from the scion and sucker shoots from the rootstock.

Troubleshooting

Incompatibility - Incompatibility often results in graft failure and may be an immediate failure to heal during grafting, or delayed. Delayed incompatibility is often indicated by stunted plant growth and scion over or undergrowth (Figure 8). Typically graft failure caused by incompatibility results from a poor or non-existent reconnection of the vascular bundles (which restricts the flow of water and nutrients). Because there is very little you can do after the fact, grafting incompatibility must be resolved before you graft by selecting compatible grafting partners. However, it should be noted that not all graft failure is a result of incompatibility, often grafts fail due to infection, physical damage, or poor grafting technique.

(Figure 8) Scion overgrowth (above) and undergrowth (below) in grafted bell pepper

Stretching of Stems or Folding of Leaves - If the healing chamber is kept too dark for too long, the plants may begin to stretch, searching for light, or the leaves begin to curl, this can lead to plants with weak stems that are prone to lodging and breakage before making it to the field, if you notice these symptoms, remove as much shade cloth from the chamber as possible, or remove the plants from the chamber entirely if they are far enough along.

Wilting – Wilting of the scion is common, and typically occurs on days 4-5 when the vascular tissue is reconnecting within the graft union, however, if the plants do not come out of this within a day or two, check for other possible causes such as overheating, drying, or media that is saturated, perhaps from sitting in a puddle within the chamber. If wilting occurs prior to days 4-5 the plants may also be receiving too much sunlight which can stress the scion. Rectify any of these issues quickly as severely wilted scions will often not survive.

Edema – Edema is another physiological disorder that is characterized by a swelling of the leaves. This can occur in the healing chamber if the relative humidity is too high. If you see edema, do not throw away the affected plants, instead begin by reducing the relative humidity, and if the edema does not resolve, remove the affected plants from healing chamber as soon as possible.

Adventitious Rooting – Perhaps the most common problem faced by those propagating grafted tomato plants is the formation of adventitious roots. If these roots are numerous enough and reach the soil they may cause total graft failure as the scion will abandon the rootstock in favor of its native roots. Even if the graft does not fail, adventitious roots may present a non-disease resistant route for soil-borne pathogens to enter the plant, reducing or eliminating the benefit from a disease-resistant rootstock. While minimal adventitious rooting is normal, and not often problematic, the development of adventitious roots may be stimulated by keeping the plants in a high humidity environment (>85%) for too long, and can occur both inside the chamber and after removal. Monitoring the humidity is an important way to reduce the formation of adventitious roots, but the removal of scion leaves prior to grafting (as outlined earlier) can also have a highly beneficial effect. Research with grafted tomatoes has shown that removing 80-95% of the scion leaves improves grafting success rates, reduces water stress and significantly reduces the formation of adventitious roots. Keep in mind that such leaf removal does increase the time in the healing chamber by a couple of days. Typically, untrimmed plants require only about 7 days in the chamber, while plants with trimmed leaves will often require 10 days before they can be removed. Leaf removal is performed pre-emptively. So to avoid adventitious rooting becoming a problem for you, such leaf removal should be a part of your standard grafting protocol as outlined above.

Pathogens (general) – As mentioned earlier, general sanitation of tools, work and growing spaces, and healing chamber materials, as well as the use of clean potting media and seed are important to reducing the risk of pathogen introduction or spread. It should also be noted that sickly plants should not be grafted, as they may become sources for infection once placed in the healing chamber. Since plant pathogens and newly-grafted plants flourish under similar environmental conditions (dark with high humidity), it is important to reduce the humidity to 55-60% as soon as possible after the first 24-72 hours and allow the plants as much light as possible without causing significant wilting.