GRAFTING GUIDE
A Pictorial Guide to the Cleft and Splice Graft Methods as Applied to Tomato and Pepper

Compiled by
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Acknowledgments

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# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A Quick Guide to Cleft and Splice Grafting</td>
<td>4</td>
</tr>
<tr>
<td>2. Planning to Graft</td>
<td>7</td>
</tr>
<tr>
<td>A. Rootstock Selection</td>
<td>8</td>
</tr>
<tr>
<td>B. USDA-SCRI Grafting Project Rootstock Table</td>
<td>9</td>
</tr>
<tr>
<td>C. Seed-to-Grafted Plant Calculation</td>
<td>14</td>
</tr>
<tr>
<td>D. Example Age Progression and Growth of Selected Scions and Rootstocks</td>
<td>15</td>
</tr>
<tr>
<td>E. Variation in Stem Development and Growth during Seedling Growth</td>
<td>16</td>
</tr>
<tr>
<td>F. Seed Sanitation (Fact Sheet HYG-3085-05)</td>
<td>21</td>
</tr>
<tr>
<td>3. Preparing to Graft</td>
<td>25</td>
</tr>
<tr>
<td>A. Sanitation</td>
<td>26</td>
</tr>
<tr>
<td>B. Prepare Your Space</td>
<td>27</td>
</tr>
<tr>
<td>C. Grafting Supplies</td>
<td>30</td>
</tr>
<tr>
<td>D. Labor</td>
<td>31</td>
</tr>
<tr>
<td>E. Hand Sanitation</td>
<td>32</td>
</tr>
<tr>
<td>4. Selecting Plants</td>
<td>33</td>
</tr>
<tr>
<td>5. Grafting Process</td>
<td>35</td>
</tr>
<tr>
<td>A. Types of Grafts</td>
<td>36</td>
</tr>
<tr>
<td>B. Cleft Grafting Overview—Tomato</td>
<td>38</td>
</tr>
<tr>
<td>C. Splice Grafting Overview—Tomato</td>
<td>48</td>
</tr>
<tr>
<td>D. Splice Grafting Overview—Pepper</td>
<td>55</td>
</tr>
<tr>
<td>E. Securing Graft Union</td>
<td>61</td>
</tr>
<tr>
<td>6. Healing and Acclimation</td>
<td>63</td>
</tr>
<tr>
<td>A. Reasons for Graft Failure</td>
<td>65</td>
</tr>
<tr>
<td>B. Establishing in the Field</td>
<td>69</td>
</tr>
<tr>
<td>7. Issues to Avoid</td>
<td>72</td>
</tr>
<tr>
<td>A. Reasons for Graft Failure</td>
<td>71</td>
</tr>
<tr>
<td>B. Examples of Undesirable Grafting Outcomes</td>
<td>69</td>
</tr>
<tr>
<td>8. Image Credits and Citations</td>
<td>77</td>
</tr>
</tbody>
</table>
A Quick Guide to Cleft and Splice Grafting

I. Preparation

A. Rootstock and scion varieties must be genetically compatible. Therefore, select varieties proven to be compatible through experience or research.

B. Note that all the seed sown will not result in a grafted plant suitable for field use. Account for four types of loss when sowing seed:

1. Lack of emergence
2. Seedling quality and survival: some seedlings may perish before grafting or be unsuitable for the process
3. Graft survival: some grafts will be unsuccessful (some grafts may perish before grafting or be unsuitable for the process)
4. Low graft quality: although some grafts “take,” the union is weak or deformed, rending the plant unfit for use in production.

C. Therefore, multiple sowings are recommended. Anticipate these losses and adjust seed sowing rates or the number of plants purchased.

II. Sanitation

A. Minimize the transmission of disease by keeping work spaces clean and free of debris. Always keep work spaces clean with washed hands before and after touching seedlings to prevent the mechanical spread of pathogens.

B. Minimize the transmission of disease: keep seedlings in a properly sanitized space and always involve hot water and/or chlorine.

C. Minimize the onset of seed-borne disease: use clean, high quality, and possibly treated seed, and avoid tobacco use. Seed suppliers and farmers can treat seed using recommended methods.

D. Assemble the following:

1. Labor
2. Scion and rootstock plants
3. New razor blades or cutting tools
4. Clips
5. Sanitation supplies (e.g., alcohol, Physan 20, detergent, all purpose, sterilized, gloves, gloves, bench paper, Green Shield)

E. Set aside special clean, climate controlled spaces to:

1. Produce seedlings
2. Assemble grafts
3. Heal and acclimate grafted plants
4. Store seedlings

Therefore, multiple sowings are recommended.
Splice Graft Method

B.1. Using a new, clean razor blade or cutting tool, decapitate rootstock seedling using an angled cut approximately 45 degrees and a horizontal cut approximately 5 mm below cotyledons.

B.2. Cut scion with a razor blade above or below cotyledons at a similar angle to the rootstock cut and where stem is of similar size to rootstock.

B.3. Place scion on cut end of rootstock to allow the angles of the two cut edges to match as closely as possible.

Cleft Graft Method

B.1. Using a new, clean razor blade, decapitate rootstock seedling using an angled cut approximately 45 degrees and a horizontal cut approximately 5 mm below cotyledons.

B.2. Place the rootstock and scion seedlings of a similar stem diameter in an area with humidity, light and temperature ranges recommended for acclimating tomato seedlings prior to planting.

B.3. Place two-week-old grafted plants in a climate-controlled chamber with humidity at 90% (a humidifier may be needed), light reduced by 50%, and temperature range of 70–80°F for at least 5–7 days.

B.4. Trim the cut surface of the scion seedling to the shape of a wedge containing sides approximately 4 mm long and an angle of the two cut edges to match as closely as possible.

B.5. Insert the trimmed scion into the vertical slit of the rootstock.

III. Grafting Process

A. Select healthy rootstock and scion seedlings of a similar stem diameter.

B. Cut the rootstock and scion seedlings into sections approximately 4 mm long.

C. Place the rootstock and scion seedlings into sections approximately 5 mm above or below the cotyledons. Make sure to keep the sections in a horizontal orientation.

IV. Healing and Acclimation

A. Place new grafted plants in a climate-controlled chamber with humidity at 90%, light reduced by 50%, and temperature range of 70–80°F for at least 5–7 days.

B. Place grafted plants in a second post-graft chamber to begin transitioning into ambient greenhouse conditions. Bottom watering is still important to reduce stress on the graft union.

C. Place grafted plants in a climate-controlled chamber with humidity at 90%, light reduced by 50%, and temperature range of 70–80°F for at least 5–7 days.

V. Planting

A. Plant the grafted plant so that the graft union remains at least 2.5 cm (1 inch) above the soil line. Proper placement of the plant limits root formation from the rootstock and/or roots from the scion. Observe plants closely as needed.

B. Grafted plants may develop shoots from the rootstock and/or roots from the scion. Proper placement of the plant limits root formation from the scion. Do not bury the clip, if it remains. Proper placement of the plant limits root formation from the scion.

C. Secure graft with a clip, tube, or glue.

The same chamber can be modified to accommodate all post-graft healing and acclimation environments.

VII. Grafting Process

A. Select healthy rootstock and scion seedlings of a similar stem diameter.

B. Cut the rootstock and scion seedlings into sections approximately 4 mm long.

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Planning to Graft
Variety Selection, Seed Number, Seed Treatment and Sanitation

Planning

Preparing

Selecting plants

Cleft graft

Securing graft union—clips or glue

Splice graft

Healing / Acclimating

Establishing in field
Rootstock Selection

Grafted tomato plants have long been a staple in greenhouse production systems; now, their use in soil-based outdoor and high-tunnel ones is rising, too. Moreover, the number of commercially available tomato and pepper rootstocks (RSs) is increasing, perhaps faster than users are becoming familiar with their compatibility and performance when paired with various fruiting, scion varieties.

A snapshot survey of the list of commercially available tomato RSs in the U.S. may reveal that most were developed for greenhouse systems or that their parents were. However, that balance is changing. Each year, more open field and high tunnel acres are established with grafted plants. From breeders to farmers, all recognize that RSs must be developed and selected for specific conditions. Greenhouse, high tunnel and field production environments vary—so it is reasonable to conclude that RSs ideal for each will also.

Grafting is a type of organ transplantation. Currently, protocols and parameters for assessing the viability, strength and performance of rootstock-scion combinations are inadequate but improving. Regardless, for growers to succeed, it is clear that: (a) the rootstock and scion must be fully compatible; (b) the “operating room” where grafting occurs and all other materials used in the process must be clean; (c) newly grafted plants must have an opportunity to heal; (d) plants of the new, “hybrid” rootstock-scion combination must out-yield, on average, ungrafted plants of their parents; and (e) fruit taken from grafted plants must be at least equal in quality to fruit taken from ungrafted scion plants. In this section, we will focus on rootstock selection.

First, we recommend that the grafter-user of grafted tomato and pepper plants consider their production goals, cultivation history, growing conditions and resources. Ask key questions. For example, why do I intend to prepare and use grafted plants? What benefits will grafted plants offer to me? How much time, money, effort and space can I devote to preparing and using grafted plants? And, how much time, money, effort and space can I devote to preparing and using ungrafted plants? For example, why do I intend to grow lesser-of-granted tomato and pepper plants consider heirloom production?

Second, we encourage the grafter-user to track the success of their grafting operation and the performance of the grafted plants. Again, rootstock numbers and diversity are increasing and the number of scion varieties is large. Therefore, many rootstock-scion combinations are possible. Unless industry-university consortia form investments, grafting tomato plants may significantly out-perform and using grafted plants? What is my expected return on selling and growing grafted plants? What benefits will grafted plants offer to me? How much time, money, effort and space can I devote to preparing and using ungrafted plants? For example, why do I intend to grow lesser-of-granted tomato and pepper plants consider heirloom production?

Third, we recommend that the grafter-user of grafted tomato and pepper plants consider heirloom production environments vary—so it is reasonable to conclude that RSs ideal for each will also.

Compatibility and performance when paired with various fruiting, scion varieties.

Grafted tomato plants have long been a staple in greenhouse production systems; now, their use in soil-based outdoor and high tunnel ones is rising. Moreover, the number of commercially available tomato RSs in the U.S. may reveal that most were...
### Description of Commercial Tomato Rootstocks as of September 17, 2013

**Common Tomato Diseases and Pests and Susceptibility Characteristics**

Rating rootstock characteristics is complex. For example, strains of pathogens differ and plant responses to them are rarely “yes” or “no.” Therefore, many approaches are used to rate rootstock characteristics. This table is a compilation of publicly available information provided by seed companies in catalogs and at websites. Additional information from peer-reviewed technical and scientific reports is available in the table Addendum. The table is to be updated often.

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<th>Fusarium Crown and Root Rot</th>
<th>Southern Blight</th>
<th>Verticillium Wilt</th>
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Notes: N/A – Information is not available  
R – Resistant  
S – Susceptible  
For additional information on rootstock descriptions please contact developer directly.
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Seed-to-Grafted Plant Calculation

The number of high-quality grafted plants needed to produce fruit does not equal the number of seeds that are initially sown. In fact, the number of seeds sown must exceed the number of plants to go to the field or high tunnel.

So, how many seeds must be sown?

The calculator at http://hcs.osu.edu/vpslab/seed-grafted-plant-calculator can be used to assist in this determination.

The calculator is based on the below equations. These equations can be used to calculate seed requirements manually.

Step 1.

\[
\frac{\text{# of grafted plants desired for planting in field or high tunnel (A)}}{\text{% of grafted plants of high quality (suitable for fruit production))(B)}} = \text{# of surviving grafted plants available after 14 days}
\]

Step 2.

\[
\frac{\text{# of surviving grafted plants available after 14 days}}{\text{% of grafted plants surviving after 14 days (C)}} = \text{# of grafted plants to attempt}
\]

Step 3.

\[
\frac{\text{# of grafted plants to attempt}}{\text{% seedlings suitable to graft (D)}} = \text{# of seedlings suitable to graft}
\]

Step 4.

\[
\frac{\text{# of seedlings suitable to graft}}{\text{% emergence after 21 days (E)}} = \text{# of seeds to sow}
\]
Example Age Progression and Growth of Selected Scions and Rootstocks

Seedling growth rates—including stem expansion—differ among varieties. Differences in growth rates (and, therefore, stem diameters) between scion (SC) and rootstock (RS) varieties can be large. If sown on the same day, RS and SC seedling size and stem diameter may be different. This is a problem since successful grafts tend to be produced more efficiently when RS and SC seedling stem diameters are similar and because seedlings should be neither too young nor too woody when grafted. Avoid mismatches between RS and SC seedling stem diameters by choosing seeding dates carefully. Also, consider multiple, staggered sowings.

<table>
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<th># Days after Seeding</th>
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<td>14</td>
<td>BHN-589 Moskvich Celebrity</td>
<td>Maxifort DP-106 Emperador</td>
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<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
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In our experience, seeding RSs and SCs multiple times increases the number of seedlings available to graft on any one day. In this approach, the potential for mismatched stem diameters and plant waste is reduced and small teams of grafters can keep pace with the process. A drawback is that grafted plants may differ in age when set into the field or high tunnel.
Variation in Stem Development and Growth during Seedling Growth

The seedlings at right are of the same variety (Maxifort) and have been removed at the soil level. Note how seedling size, appearance and other characteristics have changed over 14 days.

Days after Seeding

<table>
<thead>
<tr>
<th>Days after Seeding</th>
<th>14</th>
<th>21</th>
<th>28</th>
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<tbody>
<tr>
<td>Cotyledon</td>
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Seedling stem diameters should be at least 1.5 mm for the splice method (0.06 in.) when grafted. Ideally, stems will be larger (e.g. 2.0 to 2.5 mm or 0.08 to 0.1 in.) for the cleft method. Stem diameters optimal for grafting can differ with the skill and experience of the grafter and the method they employ. Make sure to measure stem diameters at the point on the stem in which you plan to cut.

Use of calipers can provide accurate measures of stem diameter.
Grafting methods can be chosen based on the stem diameters of scion and rootstock seedlings. Splice grafting requires RS and SC stem diameters to be nearly identical. Cleft grafting tends to allow slightly greater variance in RS and SC stem diameters. Therefore, cleft grafting may be ideal for new grafters or when RS and SC seedling size differences are intolerably high for splice grafting. Also, the location of the graft on the stem of the scion can be adjusted to obtain the closest match with the rootstock stem diameter below the cotyledons.

<table>
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<table>
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<th>28</th>
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<td>8x10</td>
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<tr>
<td>13x18</td>
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Some stems far exceed a useable size for grafting.
Water and other materials move in preset pathways (vasculature) within plant leaves, stems and roots. These pathways are depicted in red in the figures here and they must align, at least to a minimal extent, for a graft to be successful.
The use of red stain highlights the anatomical differences in the vasculature above and below the cotyledons.
Hot Water Treatment

Thermotherapy is the process of heating seeds with a hot water bath to kill certain disease-causing organisms on the seed. Water temperatures of 130°F to 160°F for 10 to 30 minutes are effective for killing fungi and some bacterial pathogens. The length of time varies depending on the temperature of the water. The shorter the time, the lower the temperature. Seeds should be soaked for 24 hours in water at room temperature before heating to allow seed germination to occur. Seeds should be removed from the hot water bath as soon as they float to the surface to prevent scorching.

Bacterial Plant Pathogens

Hot Water and Chlorine Treatments

Extension

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For more information, visit the Ohio State University Extension website at extension.osu.edu.
Step 1. After heating, place bags in cold tap water for 5 minutes to stop heating action.

Step 2. Place pre-warmed seed in a water bath that will continuously hold the water at the recommended temperature (see Table 1).

Step 3. Pre-warm seed for 10 minutes in 100°F (37°C) water.

Step 4. Wrap seeds loosely in a woven cotton bag (such as cheese cloth) or nylon bag.

B. How to Hot Water Treat Seed.
A. The following equipment and supplies are needed to cultivate your vegetable seed.

**Contracts**

- Screen for seed debris
- Staining sheet
- Glass pellets or jars
- Substrate (e.g., vermiculite or peat)
- Colonies (e.g., hyphae)

**Instructions**

is not a concern if the seeds have not been treated by any other method and the possibility of pathogens being carried inside the seeds is minimal. Treatments within the seed, Colonization treatment is recommended for both large- and small-seeded vegetables. Chlorine treatment effectively removes bacterial pathogens on the seed surface. Unlike hot water treatment, it does not

### Chlorine Treatment

<table>
<thead>
<tr>
<th>Seed Type</th>
<th>Treatment</th>
<th>Temperature</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lettuce, celery, cole</td>
<td>4%</td>
<td>1:1</td>
<td>15</td>
</tr>
<tr>
<td>Pepper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brussels sprouts, cauliflower, cabbage</td>
<td>1:22</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Broccoli, cabbage</td>
<td>1:122</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Brussels sprouts, cauliflower, cabbage, cole</td>
<td>1:122</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Brussels sprouts, cauliflower, broccoli</td>
<td>1:122</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

**Step 6:** Dust seed with TYPHN (1 gbp) (1 tsp. to 1 lb. seed) once the seeds are completely dry.

**Step 5:** Spread seed in a single uniform layer on screen to dry. Do not dry seed in areas prone to insects.
2. Compare % germination in each group; they should be within 5% of each other.

\[
\frac{\text{seeds planted}}{\text{seeds counted}} \times 100
\]

6. Determine the % germination in each group.

5. Count seeds in each group separately.

4. Allow the seeds to germinate and grow until the growth stage appears to allow for differences in germination rates.

3. After germination, proceed with the two groups of seeds separately in each container, planting mix according to the seed packet.

2. Treat 30 of the seeds exactly as described in the first section.

1. Mix seeds in each seed lot and count out 100 seeds for each lot.

How to Test for Seed Germination After Hot Water or Chlorine Treatment
Preparring to Graft
Space, Supplies, Labor

Planning

Preparing

Selecting plants

Cleft graft

Securing graft union—clips or glue

Splice graft

Healing / Acclimating

Establishing in field
Proper sanitation will greatly improve your success with grafting. Use a clean work space, cleaned cutting tools, and detergent and alcohol to kill and limit the spread of pathogens. Those who use tobacco should be excluded from participation in the grafting process because tobacco is a source of tomato disease inoculum. In addition to the sanitation methods in the chart below, tools may be sanitized by flaming. Dip the tool (e.g. blade) in alcohol, expose to flame, and allow to cool in air before using. Take proper steps to limit fire and fume hazards.

Options for sanitizing grafting tools—Dr. S.A. Miller, The Ohio State University, OARDC

<table>
<thead>
<tr>
<th>Options</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dip tool in 33% bleach</td>
<td>Rinse tool in clean water</td>
<td>Soak tool in 70% ethanol for 15 minutes</td>
<td>Allow tool to dry on a clean surface</td>
</tr>
<tr>
<td>2</td>
<td>Soak tool in 10% bleach for 30 minutes</td>
<td>Rinse tool in clean water</td>
<td>Soak tool in 70% ethanol for 15 minutes</td>
<td>Allow tool to dry on a clean surface</td>
</tr>
<tr>
<td>3</td>
<td>Soak tool in Physan 20 or similar disinfectant for 10 minutes</td>
<td>Rinse tool in clean water</td>
<td>Soak tool in 70% ethanol for 15 minutes</td>
<td>Allow tool to dry on a clean surface</td>
</tr>
</tbody>
</table>
The work space for grafting should be clean, well-lit and temperature-controlled. Chairs, tables and clean water should also be available.
Prepare adequate space for rootstock and scion seedling production, i.e. roughly double the space needed to produce standard transplants.

Prepare space to accommodate, heal and acclimate grafted plants. The post-grafting environment is important and can be set up in a number of ways. Three types of post-grafting environments are recommended: (1) high relative humidity (e.g. 80–90%), low light (e.g. less than 50% of normal maximum); (2) medium relative humidity (e.g. 50–60%), moderate light (e.g. 70% of normal maximum); and (3) conditions typical for tomato seedling acclimation (Johnson et al., 2011).
Immediately after grafting, the SC portion of the grafted plant has little access to water and the RS portion cannot photosynthesize. Therefore, the newly grafted plant’s biochemical activity and water loss must be minimized.

Post-grafting environments can be constructed on benches. A PVC frame covered with plastic and shade cloth is adequate although cool-mist foggers/humidifiers may also be used. Capillary mats with drip irrigation under plant trays moisten the rooting medium and humidify the chamber, and shade cloth reduces incoming light levels at least 50%. A plastic covering helps stabilize humidity levels. Because the plant becomes more self-sufficient and tolerant of normal growing conditions as the graft union heals and vascular connections re-establish, light and humidity levels differ among post-grafting environments.

Continuing research will provide improved designs of healing chambers.
Commercial clips to hold newly grafted plants intact are available. Plastic tubing (available in various diameters) can also be purchased wholesale or through a vendor, cut to length and opened lengthwise. These “self-made” tube clips are shown in the table at left and featured throughout this guide. A unit that assists in their preparation is also shown at left. Recall that the type of clip used may relate to the grafting method used; we have found self-made tube clips to be most appropriate for cleft-grafted plants.

<table>
<thead>
<tr>
<th>Fastener</th>
<th>Type</th>
<th>Quantity</th>
<th>Approximate Price (December 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Silicone Grafting Clip (1.5 or 2.0 mm)</td>
<td>200</td>
<td>$14.95, $15.95</td>
</tr>
<tr>
<td></td>
<td>Spring Loaded Grafting Clip (1.5–4 mm)</td>
<td>200</td>
<td>$44.50</td>
</tr>
<tr>
<td></td>
<td>Self Made Grafting Clip</td>
<td>200</td>
<td>&gt; $0.90*</td>
</tr>
<tr>
<td></td>
<td>Glue, brush on .18 oz</td>
<td></td>
<td>$4.00</td>
</tr>
</tbody>
</table>

*Note that the price of self-made clips varies with material and labor costs.
Grafting is easy to learn, but experienced grafters are often more efficient.

Some people are more adept at certain stages of grafting. A team approach can speed the process and increase success.
Grafting requires clean hands and surroundings and, for tomato, no tobacco use. Disposable gloves help maintain a sanitary work space. Now you are ready to graft!
Selecting Plants

Planning

Preparing

Selecting plants

Cleft graft

Splice graft

Securing graft union—clips or glue

Healing / Acclimating

Establishing in field
When producing seedlings, follow standard, reliable irrigation regimens. However, we have found that reducing the amount of water given to RS seedlings approximately 20–25% at 12 hours prior to grafting reduces root pressure and may improve graft take. (See page 15, Example Age Progression and Growth of Selected Scions and Rootstocks.)

Healthy, uniform RS seedlings with 2–4 true leaves and a minimum stem diameter of about 1.5 mm (0.06 in.) to 2.5 mm (0.1 in) are best for grafting. Some grafters prefer to sort their RS and SC stock by size before grafting. Choose RS and SC seedlings whose stem diameters are similar. Using RS and SC seedlings with a similar stem diameter will help align the pathways (vasculature) within them at the graft union.
Grafting Process

Planning

Preparing

Selecting plants

Cleft graft

Splice graft

Securing graft union—clips or glue

Healing / Acclimating

Establishing in field
Types of Grafts for Solanaceous Crops (tomato, pepper, eggplant)

Drawings after Lee (2003).
Where to cut the rootstock and scion on the stem is a matter of choice and experience. We suggest cutting the rootstock and scion 5 mm (0.2 in.) below and above the cotyledons, respectively.
For all but pin grafts, a clip is needed.
While not considered in this guide, other techniques are used to graft other fruiting vegetables (e.g., Cucurbits). Overall, grafting is similar in Cucurbit and Solanaceous crops and requires attention to detail throughout.
Cleft Grafting Overview—Tomato

1) Remove shoot of RS below cotyledons.
2) If using a self-made plastic tube clip, place it on and around the RS stump.
3) Create a cut in the RS stump that bisects it.
4) Remove above or below the cotyledons and trim SC stem into a wedge shape as shown with two diagonal cuts.
5) Place the prepared SC shoot into the bisected RS stump.
6) Pull the self-made clip upward to secure graft union or attach a commercial clip.

All steps are done carefully and quickly. Clean tools or change to a clean, new razor blade frequently. Once plants and other materials are in place, preparing a grafted plant requires approximately 1 minute or less.
Decapitate the RS seedling with one horizontal cut 5 mm below the cotyledons.

The top of the RS has been removed and only the stem remains.
Clips are used to secure grafts. If using a self-made plastic tube clip, place it on the remaining portion of the RS stem immediately after decapitation and slide it down to the soil line. Commercial clips are often positioned after graft assembly. Self-made and commercial silicon clips are removed naturally by plant growth. Commercial clips, if spring-loaded, may need to be removed manually.
Bisect the RS stem with a single cut approximately 4 mm deep.
In the three-cut process, de-root the SC with a single cut. The cut can be made within 5 mm either above or below the cotyledons; regardless of its position relative to the cotyledons, the cut should be at a point where the SC stem diameter matches the RS stem diameter. In the two-cut process, make two diagonal (65 degree) cuts to de-root the SC, creating the wedge to be placed in the bisected RS. A two-cut process can save time. Trial and error will help determine which process is best for you.

Successful grafts have been achieved by cutting the SC either above or below the cotyledons. With regard to grafted plants we prepare, our current preference is to cut below the cotyledons.
Until the vasculature of the RS and SC seedlings connect, water loss from the SC must be minimized. We have found that removing the largest leaves can help in this regard. You may wish to experiment on your own to determine if trimming works for you. If you trim, do NOT remove the growing tip/point (meristem) of the SC. Regardless, balance the benefit of reducing water loss against problems that may be created by more wounding through trimming.
In the three-cut process, trim the lower section of the SC seedling stem to form a blunt wedge.
The edges of the wedge should be approximately 4 mm long.
A SC is ready for insertion into the RS. The SC in this example was created using a three-cut process (a horizontal cut followed by two diagonal cuts). As mentioned, it is also possible to prepare the SC using only two diagonal cuts, simultaneously separating the SC from its roots and forming the wedge shown above.
Insert the wedge end of the SC into the bisected RS.

Position the clip around the graft union. A self-made tube clip is shown.
Splice Grafting Overview—Tomato

1) Remove the shoot of the RS below the cotyledons.
2) Cut the SC seedling above or below the cotyledons where the stem is similar in diameter to that of the RS seedling stump.
3) Place SC on cut end of RS to allow the two cut edges to match as closely as possible.
4) Place a clip around both the SC and RS or use glue to secure the graft union.

All steps are done carefully and quickly. Clean tools or change to a clean, new razor blade frequently. Once plants and other materials are in place, preparing a grafted plant requires approximately 1 minute or less.
Assemble needed materials including plants, clips and razor blades. A variety of clips are available that are appropriate for splice grafting. Decisions will likely be based on cost, size of plants that are being grafted, and personal preference.

Some grafters chose to trim some of the older true leaves prior to grafting. This reduced leaf area can lower transpiration (water loss through leaf stomates) and water demand on the plant vasculature that was severed in the grafting process. However, leaf removal can also reduce the photosynthetic potential of the plant when returning to greenhouse conditions after healing and it creates additional wounds. Therefore, balance the benefits and drawbacks of trimming the scion.
Remove the shoot of the RS seedling with one cut approximately 5 mm below the cotyledons. The angle of the cut can vary according to your preference and experience, but it is important for the angle of cut on the RS and SC to be similar.
Prepare the SC by trimming a portion of the plant stem. The cut can be made within 5 mm either above or below the cotyledons making sure to match the correct stem diameter to the RS, removing all root and excess stem material from the SC seedling. For optimum graft union connection and healing, it is best to make the scion cut at a similar angle that the rootstock cut was made.

Japanese-made grafting clippers can aid in making cuts at a consistent angle.
Carefully place the cut edge of the SC on the cut edge of the RS in a manner that allows the angles of the cut to match as closely as possible.
Position the clip around the graft union in a manner that securely connects the SC and RS. A spring-loaded clip with two possible diameter positions (1.5 and 4 mm) is shown here. The clip as shown is used on the 1.5 mm diameter position on the clip.
Splice Grafting Overview—Pepper

1) Remove the shoot of the RS below the cotyledons.
2) Cut the SC seedling above or below the cotyledons where the stem is similar in diameter to that of the RS seedling stump.
3) Place SC on cut end of RS to allow the two cut edges to match as closely as possible.
4) Place a clip around both the SC and RS or use glue to secure the graft union.

All steps are done carefully and quickly. Clean tools or change to a clean, new razor blade frequently. Once plants and other materials are in place, preparing a grafted plant requires approximately 1 minute or less.
Remove the shoot of the RS seedling with one cut approximately 5 mm below the cotyledons. The angle of the cut can vary according to your preference and experience, but it is important for the angle of cut on the RS and SC to be similar. A Japanese-made grafting clipper is used here to make the angled cut.
Prepare the SC by trimming a portion of the plant stem with a single cut above or below the cotyledons. For optimum graft union connection and healing, it is best to make the scion cut at a similar angle that the rootstock cut was made.
Carefully place the cut edge of the SC on the cut edge of the RS in a manner that allows the angles of the cut to match as closely as possible. Pepper splice grafts may require very careful clip selection. Self-made clips are used here; however, commercial clips may be preferable.
Position the clip around the graft union in a manner that securely connects the SC and RS.
Newly splice grafted and clipped pepper plants
Self-made (left) and commercial (center) clips are not the only devices that can be used to secure new grafts, particularly of the splice type. “Instant bond” glue is also being studied (right). Using glue, grafting proceeds as described in terms of preparing the RS and SC sections. However, to secure the graft, cyanoacrylate (“super” glue) is brushed around the exterior of the graft union while the grafter holds the union in place for 3–4 seconds until the glue sets.
Healing and Acclimating

- Planning
- Preparing
- Selecting plants
- Cleft graft
- Securing graft union—clips or glue
- Splice graft
- Healing / Acclimating
- Establishing in field
More time is required to produce grafted plants ready for transplanting than to produce field ready ungrafted seedlings. For example, a 1–2 week post-grafting healing period is required. Therefore, consider adjusting typical seeding schedules and other practices to offset the greater amount of time required to prepare field ready grafted plants. Otherwise, field planting may be delayed.
Place newly grafted plants into tent-like healing chambers. The first type of chamber, described earlier, has the highest humidity but lowest light levels and is maintained at approximately 21–27/29 degrees C/70–80/84 degrees F night and day. Plants remain in this chamber for approximately 1 week.

Humidity and light levels are moderate in the second healing chamber where plants remain for week 2 after grafting. Temperatures remain at roughly 21–27/29 degrees C/70–80/84 degrees F night and day. Graft failure tends to become evident at this stage.
Misters or cool-air humidifiers can help maintain humidity levels in the first and second healing chambers and are recommended instead of overhead hand-watering. Regardless, do not saturate the rooting medium as doing so may increase “root pressure” (pressure exerted by the upward flow of water from root to growing tip) weakening the graft union.

Take care NOT to disrupt the graft union in any way, including by applying water. Monitor light, temperature and humidity levels in all healing and acclimation areas because these factors contribute greatly to the survival of grafted plants.
Healthy grafted plants 1 hour after grafting.

Healthy grafted plants 1 week after grafting. Note new growth on the SC, which usually becomes evident beginning about 1 week after grafting.
High-quality grafts after grafting and healing (splice on left and cleft above). Vascular connections appear to be strong. Callus formation on the graft above is associated with a healthy grafted plant suitable for field use. Plants are typically ready for transfer to the field 2–3 weeks after grafting. Some of the plants shown here were grafted 3+ weeks prior.
Establishing in the Field

Planning
Preparing
Selecting plants
Cleft graft
Splice graft
Securing graft union—clips or glue
Healing / Acclimating
Establishing in field
A healthy grafted plant in the field. The graft union remains 2.5 cm (1 in.) above the soil line to limit root establishment from the SC. As a rule of thumb, do not bury the tube clip if it remains attached at planting.

Grafted plants in the field supported by stakes and twine are common in fresh market tomato production.

Setting plants in field can be done by hand or by machine.
Issues to Avoid
Reasons for Graft Failure

1. Rootstock and scion varieties are genetically incompatible.

2. Insufficient sanitation at any stage from seed sowing through grafted plant healing can promote the onset of disease.

3. Selected seedlings are unhealthy or improperly matched in diameter.

4. Poor grafting technique.

5. Improper management of the post-grafting environment, including:
   a. Extreme temperatures that desiccate plants or slow graft union healing.
   b. Insufficient healing period.
   c. Direct overhead watering that saturates the rooting medium, raises "root pressure" (pressure exerted by the upward movement of water from root to growing tip) and weakens the graft union.
   d. Excessive light levels that force newly grafted plants to perform activities, such as photosynthesis, that are difficult or impossible until the graft union heals, and mechanical disruption of the new graft union through forceful overhead watering or physical contact.
   e. Insufficient light levels during the hardening-off stage that weaken the plant and graft union.

6. Mechanical disruption of the new graft union through forceful overhead watering or physical contact.

7. Insufficient healing period.

8. Some varieties tend to either produce shoots from the rootstock or roots from the scion. Neither are a form of graft failure, but both conditions are undesirable and should be monitored and corrected.

1. Rootstock and scion varieties are genetically incompatible.
Examples of Undesirable Grafting Outcomes

Poor sanitation at any stage from sowing through acclimation can lead to serious disease problems and reduce yield and quality.

Poor management of the conditions in the healing and acclimation areas can stress grafted plants, limit the number of successful grafts, increase costs, and decrease profit potential.
Inadequate, unhealthy grafted plants can occur for a number of reasons, including but not limited to:

1) Genetic incompatibility between RS and SC
2) Plant disease
3) Poor connection of the RS and SC vasculature
4) Poor grafting technique
5) Improper management of the healing and acclimation areas, including under- or over-watering or extreme temperature, light or humidity levels.
Adventitious roots forming on scions or shoots forming on rootstocks are undesirable and can be a result of RS or SC characteristics or grafting method (Bausher, 2011).

Grafting has been a tool for decades in fruit and ornamental plant production and is an emerging tool in field and high-tunnel vegetable production. Choosing compatible RS and SC varieties and using proper grafting technique (including sanitation) and recommended production practices can help increase profit potential.
For additional information, please visit the grafting information portal at http://www.vegetablegrafting.org.
Image Credits and Citations

The guide contains images credited to the sources listed below.

Images by Page

Source

Bausher, M. G. 2011. Grafting technique to eliminate rootstock suckering of grafted tomatoes.

Citations


