Grafting Manual:
How to Produce Grafted Vegetable Plants

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Synopsis:
Grafting eggplant (*Solanum melongena*) to disease resistant rootstocks is commonly used for disease and abiotic stress management in commercial production. Grafting methods can be adapted to various systems of plant production.

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USDA United States Department of Agriculture National Institute of Food and Agriculture

Eggplant

Splice grafting is the most common method used to graft eggplant (*Solanum melongena*) because it has a high success rate (≥85%), is relatively simple, and can be used to graft a large number of plants in a short amount of time. For larger plants, the cleft grafting technique is commonly used.

Common rootstocks

Eggplant is commonly grafted onto either eggplant rootstocks or tomato rootstocks (Bletos and Olympios, 2008). When soil conditions are disease-free, eggplant rootstocks provide more consistent plant growth and yield (King et al., 2010), while tomato rootstocks generally have been more developed for disease resistance. Growers typically have more experience with tomato rootstocks, thus, tomato rootstocks are most commonly used for grafting eggplant in North America. Table 1 is a list of commercial eggplant rootstocks, and tomato rootstocks that have been investigated by university researchers for eggplant grafting. For a more complete list of tomato rootstocks, see the chapter on tomato grafting (NA, 2015). Local tomato cultivars are also commonly used as rootstock for eggplant; however, only commercial rootstocks are included here.

In addition to rootstocks that have been bred for eggplant grafting, there are several closely related wild species that are commonly used or marketed as rootstocks for eggplant. Most common of these is *Solanum torvum*. However, *S. torvum* seeds tend to have poor shelf-life and uneven germination, seedlings can be slow growing, and in the U.S. it is listed as a noxious weed (USDA-NRCS, 2016). *Solanum aethiopicum*, formerly called *Solanum integrifolium* Poir, is another wild species that was first used for grafting eggplant in the 1950s. Seed of these and other *Solanum* wild species are available through seed catalogs and through seed banks. They can be crossed with closely related species, including eggplant (*S. melongena*), to create interspecific hybrid rootstocks. Wild species that have been used in eggplant rootstock breeding programs include S. *sisymbriifolium*, S. *aculeatissumum*, S. *capsicoides*, S. *incanum*, S. *linnaeanum*, and S. *viarum* in addition to those mentioned above (Bletos and Olympios, 2008).

Advantages of rootstocks

Rootstocks can provide added vigor under favorable growing conditions, while under unfavorable conditions they may provide a level of resistance to abiotic stress, insect pests or disease. The common insect pests and diseases impacting eggplant production are root-knot nematode, bacterial wilt, Fusarium wilt and Verticillium wilt. While seed companies may state a particular rootstock may be resistant to a particular insect pest or disease, research studies have shown variable results (Bletos, et al, 2003; Johnson et al, 2011). Table 2 is a summary of research studies and findings for eggplant grafted onto various rootstocks.

Preparing for splice grafting

Graft plants when they have 2–3 true leaves, which typically takes 3–5 weeks from seeding. For a successful graft union to form, the cambium must be aligned when the cut stem surfaces of the scion and rootstock are placed together. To accomplish this, the scion and rootstock plants must have similar stem diameters at the time of grafting. However, the scion and rootstock may not germinate or grow at the same rate, and eggplant typically grows slower than tomato.

Both eggplant and tomato germinate best when soil temperature is 85°F (29°C), but will germinate well when soil temperature is in the range of 75–90°F (24–32°C) (Dupont 2012; Kemble et al, 1998). Conduct a preliminary trial to determine the growth rates of scion and rootstock plants in your growing environment in order to

Table 1. Rootstocks for eggplant grafting and disease resistance for each rootstock cultivar.

Rootstock type	Variety	Bacterial Wilt	Fusarium Wilt Race 1	Fusarium Wilt Race 2	Verticillium Wilt
Eggplant	Java[1]		HR[2]	HR	HR
	Red Scorpion[1]	IR	HR	HR	
	Zippy[1]	HR	HR	HR	
Tomato	Meet				
	Estamino		HR	HR	HR
	Survivor	IR	HR	HR	HR
	Beaufort		R[3]	R	R
	Maxifort		R	R	R
	E16R.4040F1				
	Multifort		R	R	
	RST-04-106-T	HR			
Wild type	*Solanum aethiopicum*	IR	HR	HR	IR
	Solanum torvum	HR	HR	HR	HR

[1] Information provided by rootstock seed companies.
[2] HR represents high resistance, IR represents intermediate or partial resistance.
[3] R represents resistance in cases where seed companies or literature did not rate for partial resistance.

Table 2. Research studies that have investigated eggplant grafting in North America.

Rootstock type	Variety	Source	Research Location[1]	Focus of Research[2]	Year(s) Researched
Eggplant	Java	Takii	WSU	VW	2013, 2014, 2015, 2016
	Red Scorpion	Takii	WSU, UA	VW, cold tolerance	2013, 2014
	Zippy	Takii			
Tomato	Meet	Takii	WSU	VW	2013, 2014, 2015, 2016
	Estamino	Johnny's	WSU	VW	2014, 2015, 2016
	Survivor	Takii	WSU	VW	2016
	Beaufort	DeRuiter Seeds	WSU	VW	2011
	Maxifort	DeRuiter Seeds	WSU, Cornell, NCSU	VW, herbicdes	2010, 2011, 2012, 2016
	E16R.4040F1	Enza Zaden	WSU	VW	2015
	Multifort	DeRuiter Seeds	WSU	VW	2009
	RST-04-106-T	DP Seeds	NCSU	BW	2016
Wild Spp.	*Solanum aethiopicum*		WSU	VW	2010

[1]WSU=Washington State University; UA=University of Arizona; NCSU=North Carolina State University.

2VW=Verticillium wilt; BW= bacterial wilt.

determine proper seeding dates for both. Seed more plants than necessary to have a selection for matching stem diameters, and also to account for some graft failure. Overall, seed 15-20% more scion and rootstock plants than the final number needed.

The day before grafting, sort scion and rootstock plants into small, medium and large size categories based on stem diameter. Stem diameter range will be 1.5-3.0 mm overall. Water both scion and rootstock plants 12–24 hours before grafting. Unless absolutely necessary, do not water rootstock plants immediately before grafting, as this will cause the plants to exude water when they are cut, which will prevent the cut surfaces from being in tight contact. If reusing grafting clips, make sure they have been cleaned and sterilized. Use only clean, sharp razor blades, and sanitize hands with antibacterial soap or hand gel. Fill spray bottles with tap water to mist plants as needed during grafting.

Splice grafting

Graft during a time of day when plant transpiration is lowest, such as early morning, to minimize water stress in the newly grafted plants. If needed, shade the grafting area to reduce temperature and water stress of plants (Zhao, 2010). Graft plants in groups based on stem diameter category (small, medium, large). It is critical to match stem diameter so that the entire cut surface of both scion and rootstock stems are in close contact, with no air between them. If the cut surface of the scion or the rootstock dries out, the graft will fail.

1. Cut the rootstock stem at a 45° angle below the cotyledons to prevent the rootstock from producing new shoot growth; immediately discard the rootstock tops.

2. Place a grafting clip over the cut rootstock stem.
3. Cut the scion at a matching 45° angle and slip the plant into the grafting clip (Fig. 1).
4. Cut rootstock and scion seedlings one flat (72-cell trays) at a time to attain more rapid grafting time.
5. If needed, place a small plastic stick into the potting media to hold plant straight and upright.
6. Lightly mist plant leaves with water as needed to reduce water stress, but do apply too much water

Place each flat of grafted plants into the healing chamber as soon as the flat is grafted.

Cleft grafting

The cleft graft technique is a good choice for grafting larger plants (5-6 true leaves), and is also known as apical grafting and wedge grafting. The cleft cut holds the scion more tightly than splice grafting. However, cleft grafting takes more time than splice grafting, and the rootstock stem may split if the scion wedge is too large.

1. Cut the rootstock stem horizontally to remove the top of the plant and discard the top.
2. Cut a ~¼ inch (0.5 cm) long vertical incision into the center of the rootstock stem.
3. Where the scion stem is the same diameter or slightly smaller than the rootstock stem diameter, cut into a ~¼ inch long wedge.
4. Insert the scion stem into the vertical incision in the rootstock. (Fig. 2).
5. Place a plastic clip around the graft union to hold the plant tightly together.
6. Place small plastic stick through the clip into the potting media to hold plant straight and upright.

For graft survival, it is more essential to maintain a high humidity for eggplant than for tomato (Johnson and Miles, 2001).

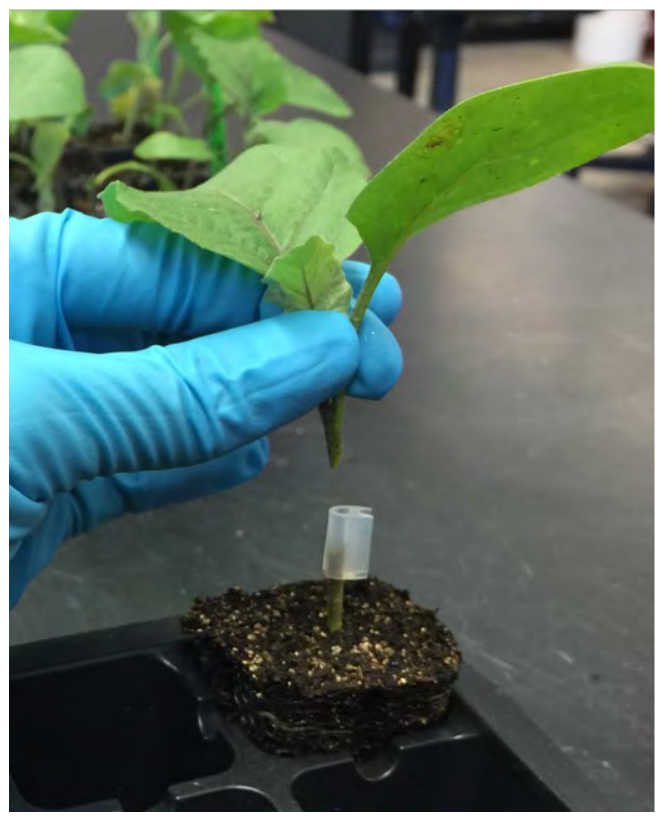

Figure 1. Splice Grafting: Cut the rootstock and scion stems at a 45° angle below the cotyledons (L) and slip the scion into the grafting clip on the rootstock. (*Photos by Ed Scheenstra and Patti Kreider*)

Figure 2. Cleft Grafting: Cut the rootstock horizontally below the cotyledons and make an incision in the stem, cut the scion into a wedge below the cotyledons and insert into the rootstock; attach with a grafting clip, and add a plastic stick to keep the plant upright. (*Photos by Ed Scheenstra and Patti Kreider*)

Depending on the greenhouse and healing chamber temperature, humidity, and solar radiation, this healing schedule may need to be adjusted so that plants are not stressed. For example, decrease the number of hours each day that plants are exposed to the greenhouse environment so they are not too wilted. The key is to slowly acclimate the grafted plants without causing permanent wilting, which will lead to plant death. Refer to Chapter 4, "Healing and acclimatization methods and design principles," for a more detailed description on plant healing.

Although the scion and rootstock establish vascular connection at approximately 4-7 days, it takes at least 10-14 days from grafting for the graft union to fully heal. After removing plants from the healing chamber, leave plants in the greenhouse for an additional 4 days. Then, move plants outside to the hardening off area for 3 days before transplanting them into the field. Adjust this schedule if needed so plants are not stressed when they are placed in the field (Spalholz, 2013).

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