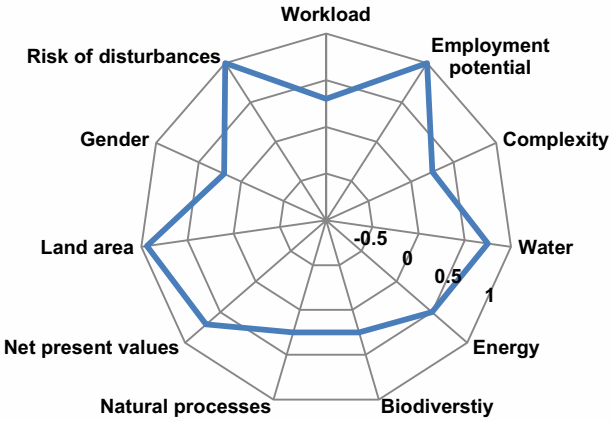
SATNET ASIA
Innovation network for food security and poverty reduction

Tomato Grafting

Technology fact sheet | 18 / April 2015

Key facts

- Helps overcome constraints to growth caused by stress such as flooding or soil-borne diseases.
- Grafting can make yield more stable under different stress conditions.
- Farmers can grow tomato in the hot-wet season (off-season) when prices are high.
- Best suited for commercial seedling production by nurseries.
- Effective when high-value tomato varieties are extremely vulnerable to soil-borne diseases and other stress, regardless of the season.
- Enables farmers to grow tomato varieties popular with consumers even though these may be vulnerable to soil-borne disease and floods.
- Can help reduce use of agrochemicals and contamination of soil and water bodies.



This graph summarizes the results of a sustainability assessment conducted for this technology. The closer the line is to the outer edge of the diagram, the better the technology performs in terms of the particular criterion.

What is tomato grafting?

- Grafting involves the attachment of an above-ground portion of a plant (scion) chosen for high fruit quality or high yield, to the root system (rootstock) of a seedling that is tolerant or resistant to stress caused by disease, nematodes, drought, flooding, heat or salinity.
- Grafting tomato scions onto flood-tolerant and/or soil-borne disease-resistant eggplant rootstocks can increase tomato yields whenever these constraints are present.
- Grafting tomato scions onto soil-borne disease-resistant tomato rootstocks reduces the impact of soil-borne disease in the plant and may provide higher yields than eggplant rootstocks, due to higher scion-rootstock compatibility.
- As grafting is time-consuming and somewhat expensive, many farmers prefer to buy grafted plants from nurseries.
- The grafting technology is best suited for commercial production of grafted tomato seedling in nurseries.
- The necessary components are rootstock seedlings, scion seedlings, pots and/or flats filled with planting medium (soil mix) for growing seedlings, simple grafting tools (razor blades and latex tubes[1]), a grafting healing chamber and adequate water supply. A separate screen house for hardening of grafted plants is useful but not mandatory.
- It is recommended to use a rotating system in the healing chamber with seedlings of different ages, for example, grafting once every three days. This ensures that grafted seedlings are available for sale throughout the planting period. Therefore, new seedlings for scions and rootstocks need to be sown frequently.
- The technology described here can also be used to graft chilli and sweet pepper seedlings for planting in areas where soil-borne diseases and flooding hamper production.
- Outside the grafting season, the grafting chamber can be used as a nursery for non-grafted seedlings of other crops such as chilli, papaya and cabbage.

History

- Bacterial wilt is a major problem in Lam Dong province in Viet Nam and can result in a 100-per cent loss of the tomato crop.
- Grafting and growing tomato from grafted seedlings was introduced in Lam Dong province in August 2003.
- Since the introduction of the technology, the demand for grafted plants has increased, leading many nursery operators to focus on growing grafted tomato.
- Adoption levels have now reached 100 per cent.

[1] If latex tubes are not available, soft plastic tubes or plastic straws having the same inner diameter can be used. However, these have the following disadvantages: 1) cannot expand while the grafted seedling stem grows thicker and, therefore, have to be cut open longitudinally; 2) once the plastic tube is cut open, it may not be able to hold the grafted stem together sufficiently. Grafting tweezers are also needed when fungicide treatment is used to prevent fungal infection at the graft junction.

Where it works

- This technology is especially effective in the hot-wet season of tropical countries where production constraints due to soil-borne disease, waterlogging and flooding are high.
- Typical successful adopters are tomato farmers and nursery operators in areas vulnerable to soil-borne diseases and flooding.
- A higher market price for tomato from a grafted plant can only be obtained if a lower-priced alternative is not available, for example, from other regions without the above-mentioned problems.

Technological aspects

Constructing a grafting healing chamber[2]

- Select a flat site at an elevation that is not at risk of flooding. Building the chamber in a shaded area decreases the need (and costs) of additional shading.
- Different designs and shapes are possible for the grafting healing chamber (see Figure 1 and other examples in the online version of this fact sheet) but the chamber should meet the needs of newly grafted seedlings, namely low light, high humidity (>85 per cent relative humidity) and temperatures between 25° C and 32° C.
- The material for the chamber can be chosen from what is locally available. A combination of bamboo stakes, PVC pipes, bricks, 60-mesh nylon netting, wood planks and laths, black polyethylene film, transparent polyethylene sheets, silver/ black/ green shade netting and plastic clips, ropes, wire or nails can be used.
- The use of 60-mesh nylon netting is crucial to keep out virus-transmitting insects such as aphids and whiteflies (standard 32-mesh will not exclude whiteflies).
- Double doors reduce the chances for entry of insect pests with workers. However, in smaller and low-cost grafting chambers, double doors might not be feasible. In any case, pests should be eliminated immediately on detection inside the chamber.
- A 2 x 1.5 x 1.75 m grafting chamber with two to three racks can accommodate up to 3,000 seedlings.
- The grafting healing chamber is used for about one week, immediately after grafting.
- Optional: a screen house can be used to grow seedlings prior to grafting and to harden the grafted plants. The screen house excludes pests, enabling growth of healthier seedlings.

Figure 1. Example of a grafting healing chamber with two racks

Grafting tomato seedlings[3]

The entire grafting process consists of 1) growing seedlings for grafting, 2) the grafting procedure including healing and hardening of grafted seedlings and 3) special field management measures after transplanting. In Indonesia, the entire process lasts about 30-33 days from sowing and takes place between September and December, which corresponds to the onset of the rainy season .

1) Growing seedlings for grafting:

- Suitable rootstocks for the grafted seedlings should be selected depending on the situation (see also http://www.vegetablegrafting.org/rootstock-tables/):
  - Eggplant rootstocks should be used when flooding or waterlogging is expected. To maintain high yield and fruit quality of the scion varietal, it is recommended to use eggplant accessions EG 195 and EG 203[4].
  - Disease resistant tomato rootstocks should be used only if flooding and waterlogging is not expected. It is recommended to use tomato line Hawaii 7996[5].

[2] For instructions on constructing a screen house, please consult Black, L.L., and others (2003). *Grafting tomatoes for production in the hot-wet season. AVRDC – The World Vegetable Center International Cooperators' Guide*. Publication Number: 03-551. Shanhua, Taiwan: AVRDC. Available from: http://203.64.245.61/web_crops/tomato/Grafting%20tomatoes%20for%20production%20in%20the%20hot-wet%20season_w.pdf.

[3] The grafting method described here is the so-called splice or tube grafting. For other possible methods, see Lee J-M., and others (2010). Current status of vegetable grafting: Diffusion, grafting techniques, automation. *Scientia Horticulturae* 127:93–105.

[4] Recommended by AVRDC – The World Vegetable Center. In Indonesia, these were initially provided and are now multiplied by farmers. These are resistant to damage caused by flooding, bacterial wilt, root-knot nematode and tomato fusarium wilt. Field observations indicate tolerance to southern blight.

[5] Recommended by AVRDC – The World Vegetable Center, because it shows high resistance to bacterial wilt and fusarium wilt. In Indonesia, these were initially provided and are now multiplied by farmers.

- Since the scion and rootstock stems must have the same diameter for successful grafting (see below), sowing scion and rootstock seeds at the correct time is very important. Growers should take the germination period and the growth rates of the seedling varietals into account and adjust sowing times accordingly.
  - If grafting large-fruited tomato scions on to eggplant rootstocks, sow the eggplant approximately three days before the tomato.
  - If grafting cherry tomato scions on to eggplant rootstocks, sow eggplant and cherry tomato on the same day.
  - If grafting tomato scions on to tomato rootstocks, take into account the different growth rates of tomato varietals for proper timing of the sowing.
- It is recommended to grow seedlings in a light, well-drained and pasteurized (heat-treated) soil mix (such as a mix of field soil, well-decomposed compost, rice husk and river sand in a 2:3:1:1 ratio).
- If compost is not available, add 30 g of nitrogen per 100 l of soil mix for tomato or 50 g nitrogen per 100 l of soil mix for eggplant.
- If using a field soil mix, cover seeds with a fine compost to prevent crusting.
- Rootstock seedlings are grown in individual, 6-cm diameter pots or in a big seedling tray (see picture below).

Figure 2. Seedlings in a tray

- Scion seedlings are raised in individual pots or in open flats. If using open flats, space seedlings at least 4 cm apart (to prevent seedlings from becoming tall and spindly).
- If seedlings are becoming tall and spindly, this is due to inadequate light and you should place the grafting chamber in a place with better lighting or reduce the shade.
- Seedlings may be grafted after developing two to three true leaves. The stem diameter should be 1.6–1.8 mm at the cutting point. Typically, this requires 14 to 16 days after sowing.

2) The grafting procedure:

- The scion and rootstock stems must have the same diameter (1.6-1.8 mm).
- Cut the rootstock stem above the cotyledons at a 30º angle. Start the cut as high on the stem as possible.
- Cut the tomato scion stem at a 30º angle, slightly above the cotyledons or first true leaf. It is crucial that the scion's stem diameter matches the rootstock's stem diameter. Select a place on the scion stem to achieve the proper diameter.
- Slide a 10-mm-long latex tube (2.0-mm inner diameter and cut at a 30º angle) over the scion stem. Make sure that the cut angles of the tube and scion are parallel. Push the scion about halfway into the tube (you must leave room in the tube for the rootstock stem).

Figure 3. Adding latex tube to scion

Figure 4. Joining scion and root stock

- Slide the scion (now fitted with the latex tube) over the rootstock seedling stem. Make sure that the cut angles of the tube and rootstock stem are parallel.
- Gently push the scion and rootstock together. If you have kept all the cuts parallel, the scion and rootstock will be in complete contact with one another. The tube will stay on the seedling until it hardens naturally, splits and falls off in the field.

Figure 5. Pushing the scion and rootstock together

- Move the grafted seedlings immediately into the shaded chamber (recommended temperature: 25ºC-32ºC). Keep a shallow layer of water in the polyethylene floor liner or in water trays and keep the grafting chamber closed to maintain high humidity (>85 per cent RH). The grafted seedlings may wilt initially but will become upright within three days.
- Four to five days after grafting, begin the hardening process. Depending on the design of the chamber, you can do the following: (i) peel away the outer (silver) layer of shade net material; (ii) drain the water out of the floor pan or the plastic trays; (iii) open the chamber's plastic-covered door, but keep the screen door closed to prevent insect infestation; (iv) remove the plants from the grafting chamber but keep in the shade, protected against insect pests. Maintain these conditions for two to three days.
- If a screen house is available, move the grafted plants out of the chamber and into the screen house.
- Nine days after grafting, apply a foliar application of 0.3-0.4 per cent urea solution, or 1 g per litre of BASF foliar Nitrophoska (20N–19P_2O_5–19K_2O), or the equivalent of a similar soluble fertilizer.
- Hold the plants in the uncovered grafting chamber (or the screen house) for seven to eight days for further development and hardening.

3) Field management after transplanting:

- As the grafting of plants is recommended only during the hot-wet season, raised beds are strongly recommended to minimize flooding.
- Clear polyethylene rain shelters can be used to shield plants from the direct impact of heavy rainfall[6] and may reduce splashing which could infect the scion with soil-borne diseases.

Figure 6. Tomato crop grown under a rain shelter in Bangladesh

- When transplanting, the graft union must be kept above the soil line. Otherwise, new roots could develop from the scion and grow into the soil, allowing diseases to bypass the resistant rootstock.

Figure 7. Transplanted tomatoes with graft union above soil

- Remove any new roots still developing from the scion. Also remove shoots that develop on rootstocks near the cotyledons.
- The rootstock vigour may need to be adjusted to fit with the scion; for example, cherry tomato requires lower vigour to prevent the fruit from cracking.
- Indeterminate tomato plants should be pruned to allow two main stems to develop.
- Stake the grafted plants securely, two to three weeks after transplanting. This prevents vines from sliding down and the scion stem from making contact with the soil.
- Plants with eggplant rootstocks require higher soil moisture than non-grafted tomato plants. Adjust irrigation accordingly.
- High temperatures during the off-season can reduce yield.

[6] Aganon, C.P. and others (2002). Enhancing off-season production through grafted tomato technology. *Philippine Journal of Crop Science*, vol. 27, No. 2, pp. 3-9.

The use of heat-tolerant varieties, plus application of a commercial fruit-set hormone[7], is recommended. Vigorous rootstocks may also help in this situation.

Economic aspects

- Gross margin for the production of 2,400 grafted seedlings by a nursery in Indonesia. To produce 2,400 marketable pieces, 3,000 seedlings should be prepared of which 80 per cent can be marketed while the others are rejected.
- Initial investment includes the cost of the grafting healing chamber. Costs depend on design, material used and labour, for example:
  - Chamber (2.1 x 1.3 x 1.6 m) and shade 3 x 4 x 2.5 m) including labour costs: Rp 500,000 ($51.35) and Rp 5,000,000 ($513.50), respectively (for Indonesian chamber in Figure 1).
  - Chamber (2.5 x 4 x 1.25 m) and shade (4 x 6 m) based on bamboo frame including labour costs: $250 in 2008. (for Indian chamber in Figure D)

Table 1. Variable costs for 2,400 grafted seedlings

Necessary production of 3 000 seedlings	Unit	Unit costs Rp	Total Rp ($)
Six labourers[1]	Person-day	70 000	420 000 (43.13)
Seed for rootstock	seedling	75	225 000 (23.11)
Seed for scion	seedling	200	600 000 (61.62)
Other costs[2]	seedling	50	150 000 (15.41)
Total costs for 3000 seedlings			1 395 000 (143.27)
Total costs per marketable seedling[3]			581.25 (0.06)
Selling price	seed-ling	1 000	2 400 000 (246.48)
Gross margin			1 005 000 (103.21)

Note: [1] a person can graft 500 seedlings per day; [2] e.g. water, fertilizer, pesticide, heat-treated soil mix, latex tubes; [3] 80 per cent (2,400) of grafted seedlings are marketable, others are rejects.

Enviromental aspects

- Reduced application of chemical pesticide with use of disease-resistant rootstocks reducing contamination of soil and water bodies.
- Tomato scions grafted on to eggplant rootstocks require more irrigation than non-grafted tomato plants.
- With grafted plants, it is possible to reduce resource inputs and use marginal soils.

Social aspects

- During the seedling production period, a nursery operator in Indonesia creates employment of 36 person-days per month (six people working for six days a month). Hence, there is immediate creation of seasonal employment.
- Nursery workers earn Rp 50,000 ($5.14) plus a meal worth Rp 20,000 ($2.05) per day. This is comparable to income from other skilled work, for example in construction, but more than what agricultural labourers earn for unskilled work such as watering, weeding or harvesting.

Issues for replication

- Maintaining high humidity (>85 per cent relative humidity), constant temperature (25º C-32º C) and sanitary conditions in the healing chamber is essential to successful grafting. This can be a challenging task, requiring frequent monitoring and possible initial adjustment in the design of the grafting chamber.
- If the disease-resistance of tomato rootstocks is overcome, new varieties must be developed. However, this is not currently the case.
- If tomato from non-grafted plants reaches the target market at a lower price, the farmer will not be able to recover the higher cost of grafted tomato cultivation.

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Useful links

- Video: How to graft tomato and eggplant: tube splice method. Available from www.youtube.com/watch?v=m5PPsOrcFaY.
- Video: How to build a grafting chamber. Available from www.youtube.com/watch?v=8-ghBWKuII4.
- Video: Grafting Tomatoes: Healing chamber. Available from www.youtube.com/watch?v=9Mxy0HfgpKY.
- Video on vegetable grafting in Thai language. Available from www.youtube.com/watch?v=fw56k9rEVfQ.
- www.vegetablegrafting.org.

[7] Such as Tomatotone or Tomatolan

Recommended reading

- Martínez-Andújar, C., A. Albacete, and F. Pérez-Alfocea (2015). *Rootstocks for Increasing Yield Stability and Sustainability in Vegetable Crops.* Consejo Superior de Investigaciones Cientificas (CSIC). pp. 21.
- Rivard, C.L., and F.J. Louws (2011). *Tomato Grafting for Disease Resistance and Increased Productivity. Agricultural Innovations Fact Sheet.* Sustainable Agriculture Research & Education, p. 8. Available from www.sare.org/Learning-Center/Fact-Sheets/Tomato-Grafting-for-Disease-Resistance-and-Increased-Productivity.

Figure A. Technical drawing of grafting healing chamber

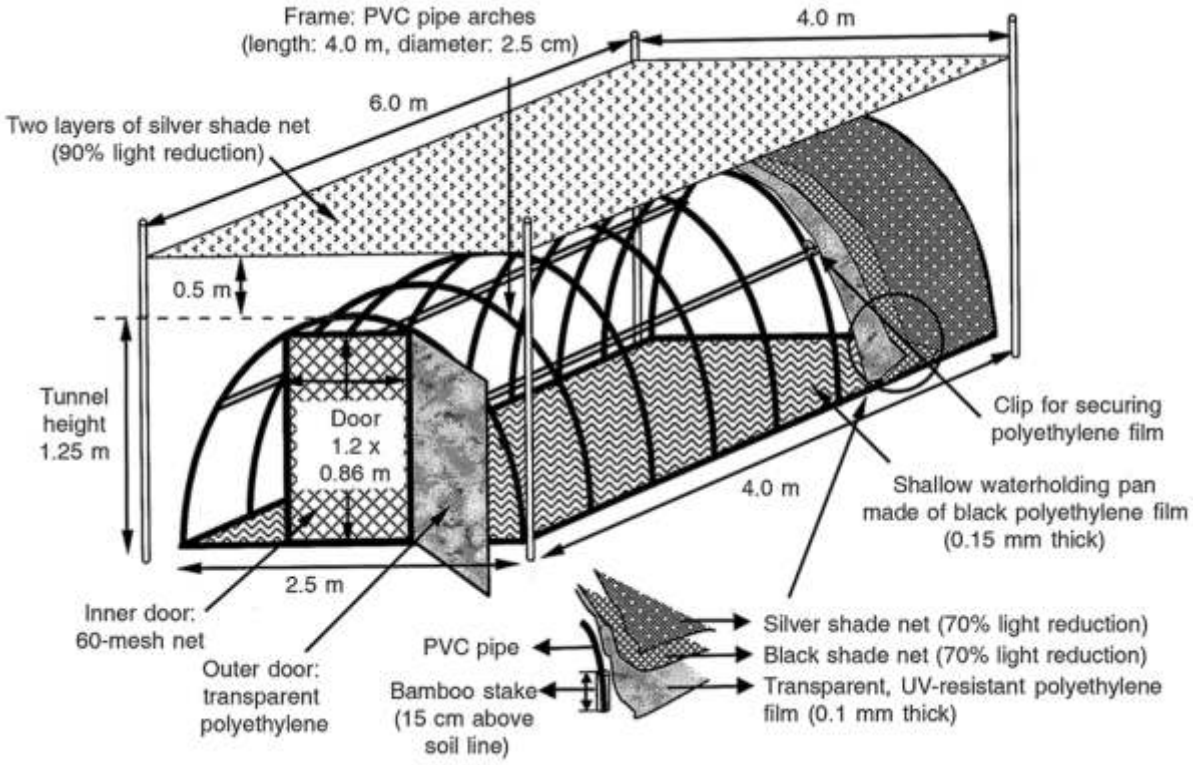

Photo: Black (2003)

Figure B. Grafting healing chamber as in Figure A, covered with shade nets

Figure C. Grafting healing chamber as in Figure A, built at lower cost with bamboo

Figure D. Simple design invented in Bangladesh

A gunny sheet provides shade; water in the bottom of the chamber increases air humidity; wooden planks form a box, on which a frame with a plastic sheet cover is attached with hinges; the top is normally closed to maintain high humidity in the chamber to help grafted plants heal.

Figure E. Seedlings in grafting healing chamber in Bangladesh

Red trays are elevated above the water with bamboo.

Figure F. Small grafting chamber design invented in Indonesia

A wooden frame is completely covered with plastic sheet.

Figure G. Small grafting chamber with opened front side

The front side can be uncovered to access the chamber and plants and for air circulation, if necessary; the lowest rack holds trays filled with water for high air humidity, the upper rack will hold trays with grafted seedlings. This grafting chamber should stand in a shaded location.

SATNET Asia agriculture technology fact sheets

This fact sheet provides information of a sustainable agriculture technology or good practice that has shown its potential to enhance resource efficiency, provide economic benefits, and has a low risk of societal disturbance. The fact sheet is a result of the analytical work conducted by the Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and South-East Asia (SATNET Asia). In consultation with SATNET Asia participants, the Food Security Center (FSC) of the University of Hohenheim in Germany has led the development of an analytical framework to assess the sustainability- and productivity- enhancing potential of agricultural technology options based on an extensive review of scientific literature. Examples of technology options are collected from various sources, including SATNET participants, experts from outside the region and online knowledge portals and literature. For technologies where sufficient information is available, the analytical framework is used to calculate a sustainability indicator for the technology.

About SATNET Asia

SATNET Asia is a network funded by the European Union. It is implemented by the Centre for Alleviation of Poverty through Sustainable Agriculture (CAPSA) of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) in collaboration with the Asian and Pacific Centre for Transfer of Technology (APCTT), AVRDC - The World Vegetable Center, the Food Security Center of the University of Hohenheim and the Trade and Investment Division of UNESCAP.

SATNET Asia was launched in 2012 to support innovation for sustainable agriculture by strengthening South-South dialogue and intraregional learning. Operating in 10 countries of South and South-East Asia, SATNET facilitates knowledge transfer through the development of a portfolio of best practices on sustainable agriculture, trade facilitation and innovative knowledge sharing. Based on this documented knowledge, it delivers a range of capacity-building programmes to network participants who play roles as change agents and innovators, such as farmer organizations, traders, the private sector, the public sector and policymakers. This will enable network participants to transfer this knowledge to those who need it most – smallholder farmers and small-scale entrepreneurs.

Because the public sector no longer predominates agricultural development, SATNET explicitly aims to include the following groups in the innovation process: universities, private companies that develop and sell technology products or provide trade facilitation services, agricultural foundations, farmer organizations and NGOs. For, and together with, these target groups, the project aims to create a knowledge environment that is focused on poverty reduction and conducive to continuous and sustainable innovation.

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