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Vegetable grafting for combating stresses and to increase productivity

Vegetable production faces many challenges of biotic and abiotic stresses. Gene introgression for stress resistance is time consuming and laborious and limited by crossability barriers as well as linkage drag. Vegetable grafting is seems to be an easy and successful alternative to face these challenges.

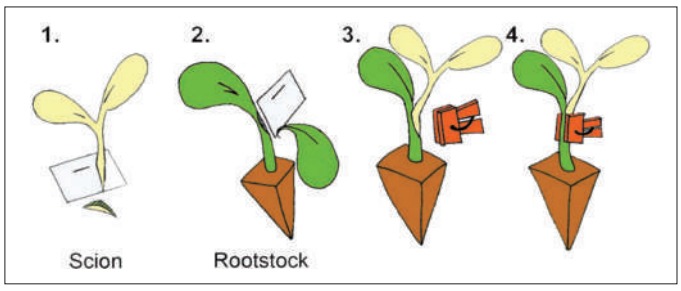
GRAFTED vegetable plants are 'physical hybrids' resulting from combining at least two genotypes/ varieties, a rootstock and at least one scion; the first used to provide important traits and the second used to produce fruit. Grafting is a surgical technique to facilitate fusion of two sets vascular tissue of two different plants. It serves as a rapid alternative approach to combat stress. This technique is becoming popular in the members of Solanaceous and cucurbitaceous crop to reduce infection by soil-borne pathogens and increase survival and to induce vigour, precocity, better yield and quality.

The process is analogous to organ transplantation in that rootstock and scion varieties and seedlings must be compatible, the operating room and patients clean and disease-free, the grafter using appropriate methods, and the newly-grafted plants allowed to recover under specific conditions.

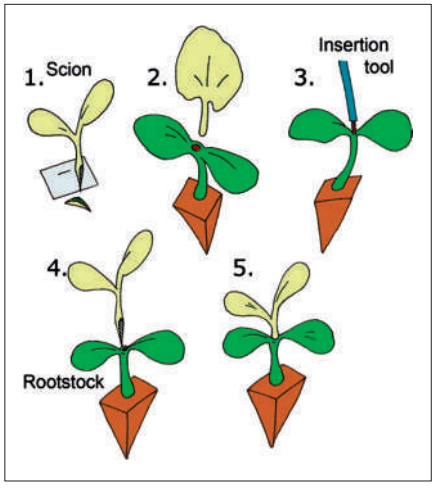
Objective of vegetable grafting are to reduce dependence on agrochemicals for organic production and to impart tolerance against biotic and abiotic stresses as well to increase the production and productivity.

Vegetable grafting history and Indian perspective

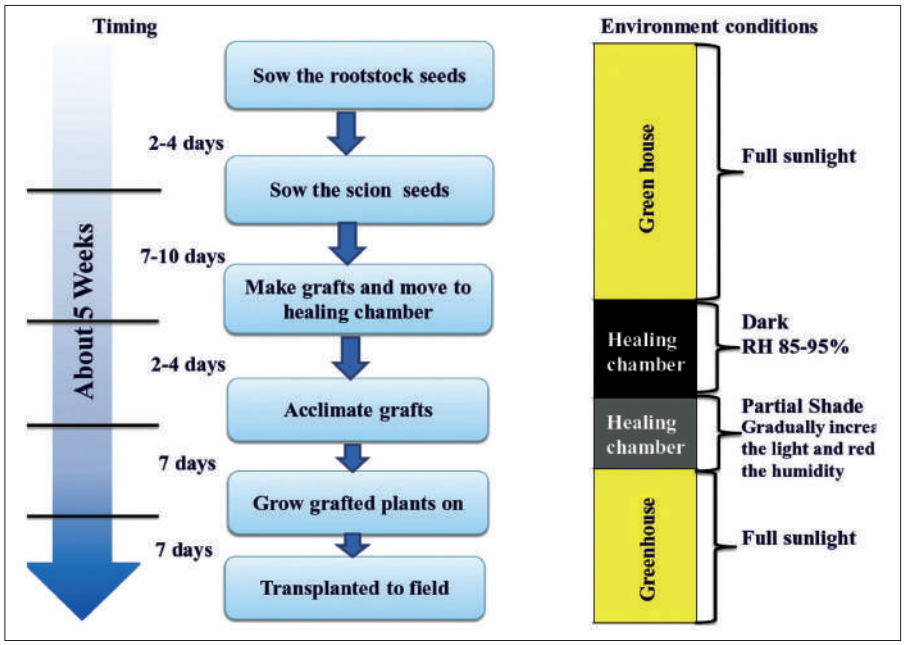
Grafting of vegetable seedlings is a unique horticultural technology practiced for many years in East Asia to overcome issues associated with intensive cultivation using limited arable land. This technique was first practiced by grafting watermelon (*Citrullus lanatus*) onto pumpkin (*Cucurbita moschata*) rootstock in Japan and Korea in the late 1920s. A serious crop loss caused by soil-borne diseases aggravated by successive cropping was avoided by production of vegetables with grafted seedlings. In many fruit-bearing vegetables such as watermelon, cucumber, melon, tomato, eggplant and pepper, the use of grafted seedling has become increasingly popular. Grafting is an environment-friendly approach which is used to control soil borne diseases and increasing the yield of susceptible cultivars. This technique is eco-friendly for sustainable vegetable production and by using resistant rootstock, it reduces dependence on agrochemicals. To induce resistance against low and high temperatures, grafts were generally used. Grafting increases the yield and promotes biotic/abiotic stress tolerance. Grafting is also used to induce tolerance to abiotic stresses *viz.* flooding, drought and salinity. In Japan (92%), Korea (98%) and China (20%), major share in watermelon production is from grafted seedlings. In Europe, Spain is leading in grafted seedlings production with 129 million grafted seedlings followed by Italy (47 million grafted seedlings) and France (28 million grafted seedlings). Grafting as a technology for the commercial production of vegetables was later on adopted by many countries in Europe, Middle



Step-wise One cotyledon grafting (OCG) method followed in cucurbits



Step-wise Hole insertion graft (HIG) method followed in watermelon



Grafted timeline for solanaceous and vegetable crops

East, Northern Africa, Central America and other parts of Asia.

In India, vegetable grafting work was first started in IIHR Bengaluru by Dr RM Bhatt and his associates. Their work was on identification of rootstocks for waterlogged conditions. For this purpose they have imported semi-automated grafting machine. IIHR Bengaluru organized first ever short course on vegetable grafting during the year 2013. Later on at many places work on vegetable grafting was started in a scattered manner. NBPGR regional station, Thrissur, Kerala have done work on Cucurbit grafting by taking *Momordica cochinchinensis*, a dioecious plant. The female plants were grafted on to the male plants to increase its production. Graft success was 98%. SAUs and ICAR institutes like CSKHPKV, Palampur; ICAR-IIVR, Varanasi; ICAR-CAZRI, Jodhpur also initiated work on grafting and identified more than 22 rootstocks of brinjal, chilli, tomato and cucurbits for importing resistance to bacterial wilt and nematodes. Some private players are also involved in vegetable grafting. One of them is 'VNR Seed Private Limited' in Chhattisgarh which is supplying grafted brinjal seedlings resistant to bacterial wilt to farmers. The other seed company is TAKII SEED INDIA PRIVATE LIMITED and very recently CCSHAU has also established a vegetable grafting nursery in public private partnership with VNR Seeds at Hisar, Haryana. Recently Center for Protected Cultivation Technology, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi has started working on evaluation of different rootstocks and their suitability for vegetable grafting and in near future grafted plants will be made available to the farmers also.

Grafting techniques

One-cotyledon grafting

This method is common method used for watermelon and melons in Korea, Europe and North America. This method is also known as the splice graft, and was originally developed by Japanese engineers for use with automated grafting. The splice graft is used in greenhouse production of vegetable crops for grafting disease-resistant rootstocks. The graft can be performed manually or with sophisticated, robotic grafting machines. Grafting machines can be used to graft watermelon and melons using this method, but high initial cost for equipment and strict requirement for uniformity of seedlings present obstacles for wider adoption of grafting automation of cucurbit crops. Rootstock seedlings should have one true leaf, and scion seedlings should have two true leaves. Cut the rootstock at a 60° angle so one cotyledon remains and one is removed. Cut carefully so as to keep the remaining cotyledon firmly attached to the rootstock stem. The angled cut should also remove the apical meristem in the remaining cotyledon.

Merits

- Most simple and rapid technique for grafting watermelon.
- Grafting automation can be conveniently accomplished.

Demerits

- Requires careful control of humidity, light, and temperature after grafting.

Tomato grafted on brinjal at IARI

Watermelon grafted on bottle gourd by hole insertion method

- High losses and possible diseases or physiological disorders may occur if the healing environment is not optimal.
- Some meristem tissue may remain in the rootstock, requiring removal later in the production cycle.

Hole insertion grafting

The hole insertion method is the most widely used method for watermelon and melon grafting. Root-stock seedlings should have one small true leaf, and scion seedlings should have just the cotyledons or the first true leaf just emerging. The diameter of the scion stem must be smaller than the diameter of the rootstock stem so that the scion can be inserted into a hole made between the two cotyledons of the rootstock. With a pointed probe, remove the true leaf, the apical meristem, and the axillary buds from the topmost growing point of the rootstock plant. It is important to remove all of the apical meristem and the axillary buds to prevent future shoot growth of the rootstock. Use the probe to create a hole in the top of the rootstock where the tissue was removed; leave the probe inserted in the growing point while cutting the scion. Cut the scion below the cotyledons at a 45° angle on two sides to form a wedge and insert it into the rootstock as the probe is removed. Mist the grafted plants with water and place in healing chamber.

Merits

- A grafting clip is not essential, which saves time and labor involved in collecting grafting clips after healing.
- Tends to have a high success rate.
- Maximizes the contacting surface area between rootstock and scion which helps create a strong graft union.

Demerits

- Requires slightly more skill than most other grafting techniques.
- It may require more time to graft than some of the other grafting techniques depending on the grafter's skill and the grafting operation.
- Regrowth of the rootstock will occur if not all the meristem tissue has been removed.

Prerequisites for grafting

Selection of compatible rootstock and scion.

- Grafting aids: Grafting clips, Tubes, Pins and Blade.
- Screening house: To grow seedlings prior to grafting.
- Healing Chamber: To provide 28-29°C temperature, 90-95% RH for 5-7 days, darkness for initial 1-2 days to promote callus formation and acclimatization of grafted seedlings.

Biotic stress management

- *S. torvum* rootstock confers resistance to *F. oxysporum* f. sp. *melongenae* in brinjal scion against *Verticillium* and bacterial wilt.
- Interspecific hybrid rootstock 'Brigeor' controls root knot nematode in brinjal.
- Resistant brinjal rootstocks: Good for bacterial wilt resistance in tomato.
- *Cucurbita moschata*: Tolerance to both *Fusarium* wilt and *Phytophthora* blight in cucumber.
- Burr cucumber and African horned cucumber: Best nematode tolerance to most cucurbits.
- Wild *Solanum sp.* rootstock: Reduces white-fly transmitted virus symptoms in tomato.

Cucumber grafting by tongue approach method

Approach grafting method in cucurbits

Watermelon on *C. moschata* by hole insertion method

Tomato grafting by tongue and cleft method

Table 1. Countries position of vegetable grafting in world

Country	Watermelon	Cucumber	Melon	Tomato	Brinjal	Pepper
Israel	70%	--	5	15	5	---
Japan	93%	72	30	48	65	5
Korea	98%	95	95	15	2	25
Greece	100%	5-10	40-50	2-3	---	---
Spain	98%	--	3	4500 ha	---	---
Morocco	--	--	--	75%	---	---
Cypria	80%	--	--	170 ha	---	---
Italy	30%	--	5-6 million	1200 ha	---	---
France	--	3	1000 ha	2800 ha	---	---
Netherland	--	5	--	50	---	---
Turkey	30%	5	--	25	10	---

Source: Histil South Africa (PTY), 2007 cited by Yassin and Hussen

Abiotic stress managment

- Fig-leaf gourd: Low soil temperature tolerance to cucumber, watermelon, melon and summer squash.
- Bottle gourd imparts salt, alkalinity and flooding tolerance and improves water use efficiency in watermelon; increases nutrient uptake in melon.
- Sweet pepper recorded highest yield under high-temperature conditions on chilli rootstock.
- Minimizes negative effects of boron, copper, cadmium, and manganese toxicity in tomato.
- Commercial rootstock (PS 1313: *Cucurbita maxima* × *Cucurbita moschata*): 60% more marketable yield in watermelon.
- Bitter gourd cv. New Known grafted onto sponge gourd showed flooding tolerance.

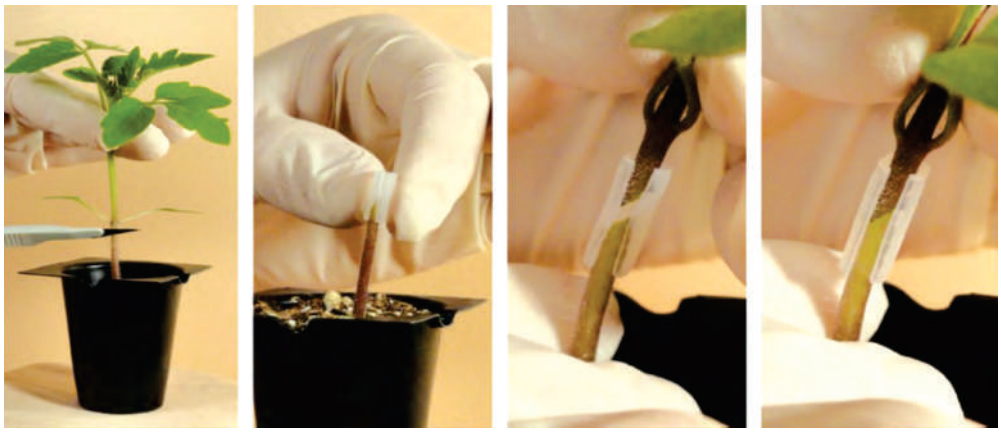
Higher yield and improved quality

- Pumpkin rootstock gave 27% more marketable yield on cucumber seedlings.
- Watermelon grafted onto the bottle gourd exhibited 27-106% more yield over the control, while, grafting on *Cucurbita* spp. resulted in 127-240% reduction in fruit yield.

Tomato on *S. pimpinellifolium* by cleft method

Conclusion

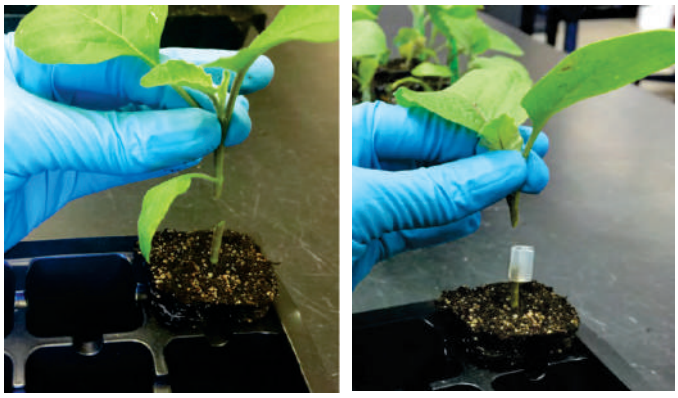
Grafting is a method of plant propagation which is site specific management tool for soil borne diseases and nematodes by utilising selective rootstock and scion combinations. It has the potential to increase the area under vegetable cultivation in the disease hotspots or in non-traditional and fragile



Tomato grafting by Splice grafting

Table 2. Grafting methods and rootstocks used in vegetable crops

Scion plant	Rootstock	Method of grafting
Egg plant	*Solanum torvum*	Tongue and cleft method
	Solanum sissymbrifolium	Cleft method
	Solanum khasianum	Both tongue and cleft methods
Tomato	*Solanum pimpinellifolium*	Cleft method
	Solanum nigrum	Tongue and cleft methods
Sweet pepper	*Capsicum annum*	Splice grafting
Cucumber	*Cucurbita moschata*	Hole insertion and tongue method
	Cucurbita maxima	Tongue method
	Cucurbita ficifolia	Hole insertion and cleft method
Watermelon	*Benincasa hispida*	Hole insertion and cleft method
	C. moschata	Hole insertion and cleft method
	C. melo	Cleft method
	C. moschata × *C. maxima*	Hole insertion method
	Lagenaria siceraria	Splice grafting
	Sicyos angulatus	Hole insertion and cleft method
Bitter gourd	*C. moschata*	Hole insertion and tongue method
	Lagenaria siceraria	Hole insertion
Bottle gourd	*C. moschata, Luffa sp.*	Hole insertion and tongue method
Pak-Choi	*R. sativus var. longipinnatus*	Splice grafting



Brinjal grafted in *Solanum torvum* by Splice grafting

agro-ecosystems. It is a rapid alternative means to the moderately slow breeding methodology. In recent days, grafting application leads the limit use of harmful soil disinfectants which minimizes the toxic residues in vegetables and environmental pollution. Hence, it is suggested that, by adopting modern innovations and indigenous wild relatives, we can realize commercial use of grafting to attain the low input sustainable horticulture in future. Since it provides disease tolerance and results in better vigour of the crops, it will be useful in the low-input sustainable horticulture in near future.

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