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Vegetable Grafting for Disease Resistance and Increased Productivity

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The grafting is one of the tools for sustainable vegetable production by using resistant rootstock. Grafting is an art of joining together two plant parts such as different species of same genera (a rootstock and a scion) by means of tissue regeneration, in which the resulting combination of plant parts achieves physical reunion and grow as a single plant. In Olericulture, vegetable grafting is a relatively new one technique but in Pomology, grafting of fruit trees has been practiced for thousands of years, which is centuries-old technique. Commercial vegetable grafting using resistant roots stocks is one of the best tools for sustainable vegetable production. Vegetable grafting reduces the agrochemicals dependence on organic production (Rivard *et al.*, 2008).

Main countries where grafted vegetables are produced and/ or cultivated on a commercial scale

Continent	Countries
East Asia, Europe	China, Japan, Korea, The Philippines, Spain, Italy, the Netherlands, France, Greece, Cyprus, Belgium, Portugal, Germany, Croatia, Bosnia and Herzegovina
Middle East and North Africa, America	Middle East, North Africa, Turkey, Israel, Morocco, Egypt, Iran, Algeria, Americas Mexico, Canada, the USA and Argentina

What is Grafting?

Grafting is an art and technique in which two living parts of different plants i.e., rootstock and scion are joined together in such a manner that they would unite together and subsequently grow into a composite plant. There are different methods of grafting which can be employed in vegetable crops namely, Tongue approach grafting (Melon and Cucumber), Hole insertion grafting (Water melon), Splice grafting (Water melon), Cleft grafting (Tomato, Brinjal and Capsicum), Tube grafting ((Tomato, Brinjal and Capsicum), Apical wedge grafting (Capsicum), Micro Grafting (Tomato), Side grafting (Water melon) and Cut grafting (Water melon).

How does it Work?

A grafted plant consists of two parts: a scion and a rootstock with each being a different plant. The scion provides the shoot and the rootstock provides the root system. The point of attachment is called the union, which is the point where the vascular bundles of the two plants fuse and become one plant. A scion may be chosen for its fruit quality and the rootstock for its vigor, resistance to pathogens, and environmental stresses.

Purposes of grafting

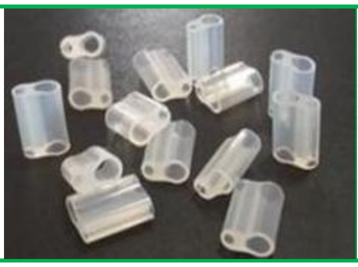
- Imparting disease and pest resistance
- Avoiding nematode infestation
- Minimizing the auto toxic effect
- Providing cold and heat hardiness
- Improving quality traits
- Manipulating the harvesting period
- Reduced fertilizer and agrochemical application
- Increase yield

For successful rising of the crop under biotic and abiotic stress, precocity, improvement of quality and other horticultural attributes.

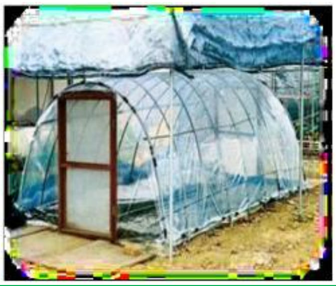
Crop	Objective
Bitter gourd	Tolerance to Fusarium (*Fusarium oxysporum* f. sp. *momordicae*)
Cucumber	Tolerance to Fusarium wilt, *Phytophthora melonis*, cold hardiness, favourable sex ratio, bloomless fruit
Brinjal	Tolerance to bacterial wilt, (*Pseudomonas solanacearum*) *Verticillium alboatrum*, *Fusarium oxysporum*, low temperature, nematodes, induced vigour and enhanced yield.
Muskmelon	Tolerance to Fusarium wilt (*Fusarium oxysporum*), wilting due to physiological disorder, *Phytophthora* disease, cold hardiness, enhanced growth
Tomato	Tolerance to corky root (*Pyrenochaeta lycopersici*), *Fusarium oxysporum f. sp. radicis-lycopersici,* better colour and greater lycopene content, tolerance to nematode.
Watermelon	Tolerance to Fusarium wilt (*Fusarium oxysporum*), wilting due to physiological disorder, cold hardiness and drought tolerance

Basic prerequisites of grafting

- Root stock
- Scion
- Compatibility
- Grafting aids like grafting clips, tubes, pins, blade, cutter *etc.*

		
Grafting tubes	**Grafting clips**	**Grafting pins**

- **Screen house:** It is used for growing seedlings prior to grafting. There must be provision for double door system at the entrance of screen house. The cladding material for covering the screen house should be made of UV stabilized polyethylene film to prevent UV light penetration.
- **Healing chamber/Grafting chamber:** The healing chamber is a covered structure with controlled humidity and low light. The purpose of healing chamber is to provide congenial temperature and humidity for better union of the grafts. Grafted plants can also be healed under in plastic tunnels maintaining almost near to optimum conditions for better healing. In general, optimum rage of temperature and relative humidity is 25-30 0C and 85- 90%, respectively with low light intensity.
- **Acclimatization chamber:** It is used for hardening of grafts prior to transplanting. This chamber helps to prevent leaf burning and wilting of the just healed seedlings. Grafted seedlings take 7 to 10 days for acclimatization.

		
Screen House	**Healing Chamber**	**Acclimatization Chamber**
		
Healing Process	**Union formation**	**Grafts ready for planting**

Grafting methods

The method of grafting is determined by the crop, the farmers' experience, the person chosen, the number of grafts required, the aim of the grafting, access to labour, and the availability of machinery and infrastructure (Lee *et al.*, 2010). Those methods as follows.

- **Splicing grafting:** This technique is often referred to as tube grafting or one cotyledon splice grafting. Producers and commercial vegetable transplant firms prefer and use this procedure the most. In most vegetables, it can be done by hand or by machine. This approach is popular for cucurbits and other solanaceous crops.

- **Pin grafting:** is comparable to splice grafting. To hold the grafted position, customized pins are utilized instead of grafting clips.
- **Top insertion grafting:** Because watermelon seedlings are smaller in size than bottle gourd or squash rootstock, this approach is recommended for producing grafted watermelon transplants. This approach necessitates a temperature range of 21-36 °C till transplantation occurs. This method is often used in China because it results in a strong union and vascular connection when combined with the language grafting strategy. (Oda, 1999)
- **Apical grafting:** In this instance, scion plants are cut with one to three true leaves, the lower stem is cut at a slanting angle to form a tapered wedge, and the clip is inserted to make contact between the scion and rootstock after splitting (Johnson *et al.*, 2011). This method is most widely utilized in the cultivation of sunflowers. Cleft grafting is another name for it.
- **Tongue grafting:** For grafting, the same size rootstock and scion material are used. To achieve consistent size, seeds are placed 5 - 7 days before rootstock seeds. This approach is labour intensive and takes up more room, but the survival rate of seedlings is high, thus farmers and small nurseries like it. This approach does not work with hollow hypocotyl rootstocks.

Selection of rootstock and scion cultivars

Selection of the correct rootstock and scion cultivars is a critical step for the success of grafted vegetable production. The seed of the scion cultivar is selected based on purity, viability, yield, fruit quality and market demand. Rootstock cultivars are selected based on purity, viability, resistance to diseases, compatibility with the scion cultivar, and adaptability to local soil and environmental conditions.

Advantages of Grafting

The use and demand for grafted vegetables have been growing worldwide over the last few decades. Advantages of using grafted vegetables include better resistance to pathogens, drought and other environmental stresses, more vigorous growth, and higher yield. These advantages also allow for fewer inputs such as pesticide applications and an extended harvest season. The need for grafted plants may also add a revenue source for growers wanting to sell.

Conclusion

Solanaceous and cucurbitaceous vegetables are now grown all over the world using grafting technology, which has become an essential aspect of production practices due to its usage in nematode resistance, disease management, and crop yield increase. Grafting has emerged as an efficient surgical technique for minimizing biotic and abiotic stresses in vegetable production systems now that effective grafting procedures have been established and disease-resistant rootstocks are also accessible. The Favourable impacts of dynamic interspecific rootstocks on scion concert are frequently reflected in fruit size, particularly in crops such as watermelon, cucumber, and tomato, although fruit shape is primarily governed by the scion genotype. Similarly, grafting has a limited and inferior effect on exocarp and mesocarp thickness compared to the scion genotype, and it interacts with fruit maturity. Variation in the epidermal and pulp coloration of annual fruits, as determined by changes in pigment concentrations, can be influenced directly and indirectly by grafting through its interaction with fruit ripening behavoir; such an interaction is common for watermelon, whereas coloration effects on tomato, melon, and pepper appear strongly rootstock-specific. Given the numerous applications of vegetable grafting around the world, this technique has the potential to solve the problems of India's vegetable industry and boost farmers' income by increasing crop yield and lowering the cost of purchasing massive amounts of fertilizer and pest and disease control products.

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