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Vegetable Grafting: A New Approach to Increase Yield and Quality in Vegetables

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Introduction

Grafting has been utilized in horticulture ever since the first millennium, especially in fruit crops. Nevertheless, vegetable grafting is gaining momentum in recent years among vegetable growers worldwide (**Kumar and Kumar, 2017).** In the recent past, grafting is recognized as a rapid alternative tool for sustainable vegetable production by using resistant rootstock which reduces dependence on agrochemicals (**Rivard and Louws, 2008)** to mitigate the soil-borne problems. The first attempt in vegetable grafting was initiated in watermelon (*Citrullus lanatus*) with pumpkin (*Cucurbita moschata*) rootstock to combat *Fusarium* wilt problem during the late 1920s at Japan**.** Since then, the use of grafting in vegetable crops has spread around the world. Currently, the cultivation of all the cucurbits under greenhouse conditions in Japan and Korea is based on grafting techniques (**Kumar *et al.*, 2018)**. Though, the benefits of using grafted plants are profuse, not all vegetable species are capable of being grafted, because genetic background, growth characteristics, anatomy, and physiological and biochemical factors of the species influence the success per cent of grafted plants **(Martinez *et al.*, 2010; Fan *et al.*, 2015)**. Among vegetable crops, grafting is commonly and economically practiced in solanaceous and cucurbitaceous vegetables *viz.*, Tomato (*Solanum lycopersicum* L.), Eggplant (*S. melongena* L.), Sweet pepper, Watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai], Melon (*Cucumis melo* L.), Bitter gourd (*Momordica charantia*), and Cucumber (*C. sativus* L.). In this article, the information on purpose, prospects and dispute of grafting, grafting techniques/methods and graft compatibility among the rootstock and scions towards yield improvement and soil-borne pest and disease management in the aforementioned vegetable crops were described here under.

History of vegetable grafting in India

Though the grafting technique was invented by Chinese ancestors and recorded in an ancient book during the first century BC, vegetable grafting in India was initiated during the 19th century only. During recent years, the production and cultivation of grafted

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solanaceous and cucurbitaceous plants are ever-increasing across Asia, Europe, and North America due to its ability to provide tolerance to biotic stress and abiotic stresses. However, this technology is still infancy in India. Grafting in vegetable crops has been initiated by the Indian Institute of Horticultural Research, Bangalore mainly to mitigate water logging. Moreover, they have conducted "short course on vegetable grafting" during 2013 to create awareness among the scientist for the same. The National Bureau of Plant Genetic Resources (NBPGR) regional station, Trissur, Kerala attempted inter-specific grafting in a sweet gourd (*Momordica cochinchinensis*) by using female plants as scion and male plants as rootstock and recorded 98% graft success and higher production.

Methods of grafting

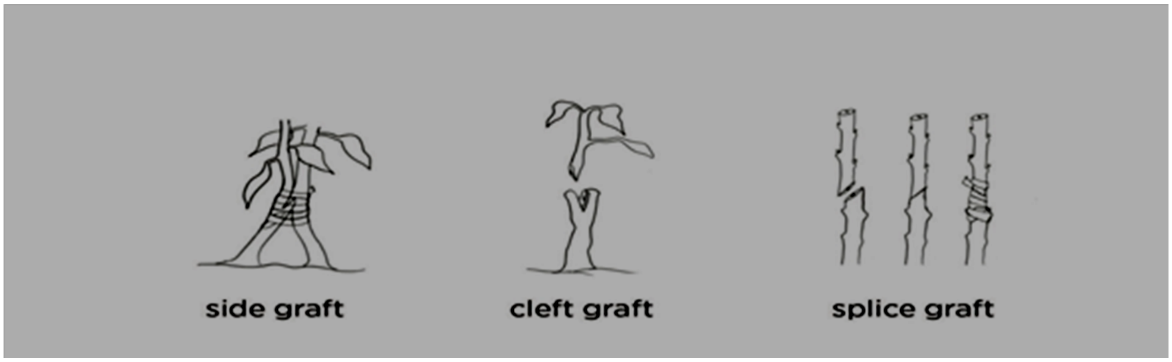
1. **Approach Grafting**: It is done by cutting opposing and complementary notches in the stem of the rootstock and scion. The complementary notches are fit together and held with a spring clip or some type of tape.

Once the graft union has healed, the root system is cut from the scion (plant and the shoot is removed from the rootstock plant, **Lee *et al*., 2003)**.

2. **Cleft Grafting:** It is carried out when the plants are slightly larger, and a V shaped cut is made in the stem of the scion. The scion is then inserted into the rootstock, which has a vertical slice cut down the center of the stem. The rootstock and scion are then held together by a spring clip while the graft union forms (**Oda, 1999).**

Tube Grafting or Japanese Top-Grafting: It is carried out when the plants are very small and the rootstock and scion are held together with a 1.5–2 mm silicone clip or tube **Rivard and Louws (2006).**

3. **Hole insertion grafting**: This is the most popular methods of grafting in watermelon. Watermelon seeds are sown a few days after the rootstock. Grafting begin 7-8 days after the watermelon seeds are sown, and requires at least one leaf on the watermelon scion and one small leaf on the rootstock. A specialized tool, such as a



bamboo stick or small drill bit, is used to remove all of the meristem from the rootstock leaving a small hole with a small splice along both sides. The disadvantage to the hole insertion graft is that it is much more technical and also requires careful control of the healing chamber. This technique is preferred by many commercial growers because it requires the removal of the clamp after the healing has taken place.

Suitable rootstocks

i) . Root stock for Tomato

1. *S. lycopersicum* L.: Vigour, virus tolerances and high temperature tolerance
2. *S. habrochaites S*. Knapp & D.M Spooner: Resistant to corky root disease
3. *S. sodomaeu*m L. S. auricularum Ait. and *S. melongena* L.: Growth & yield reduction
4. *S. laciniatum* Ait.: Resistant to water-logging
5. *S. integrifolium* Poir. Sugar content increase
6. S. *sisymbrifolium* Lam. Disease resistance,
7. *S. torvum* Sw. Disease resistance,
8. *S. toxicarium* Lam.: Disease resistance
9. S. nigrum L.: Fruit size and quality control
10. *S. lycopersicum L. ×S. habrochaites* S. Knapp & D.M Spooner: Low Fusarium infection
11. *S. melongena* L.: Low & high temperature tolerance

ii) Root stock for Brinjal

1. Solanum torvum Sw: Resistant to nematodes
2. *S. torvum Sw. ×S. sanitwongsei* Craib.: Resistance to bacterial wilt
3. *S. integrifolium Poir. ×S. melongena* L.: High temperature tolerance

iii) Rootstock for Cucurbits crop

Rootstocks for Cucurbit crop are given in the table (1).

Conclusion

Grafting technique is a rapid alternative means to the moderately slow breeding methodology. In recent days, grafting limits the use of harmful soil disinfectants which minimizes the toxic residues in vegetables and environmental pollution. Hence, Grafting in vegetable crops may be useful for low-input, sustainable horticulture of the future. Moreover, advances have been made to expand adoption of techniques such as grafting robots to produce a large number of grafted plants in a short period which reduces the price of grafted seedlings. However, the range of commercial rootstocks is limited; hence further research needs to focus on the development of rootstocks by using unexplored wild relatives to mitigate unpredictable biotic and abiotic stresses.

Table No. 1: Rootstocks for Cucurbit crop			
Rootstock	Cultivar	Major characteristics	Possible disadvantage
		Watermelon	
Bottle gourd (*Lagenaria siceraria* L.)	Dongjanggoon, Bulrojangsaeng, Sinhwachangjo (Korea),FR Dantos, Renshi, Friend, Super FRPower (Japan),	VRS, FT, LTT	New *Fusarium*race, susceptible to anthracnose
Squash (*Cucurbita moschata* Duch.)	Chinkyo, No. 8, Keumkang (Korea)	VRS, FT, LTT	Inferior fruit shape and quality
Interspecific hybrid squash (*Cucurbita maxima*Duch. × C. moschata Duch.)	Shintozwa, Shintozwa Shintozwa, Chulgap, (Japan, China, Taiwan, Korea)	VRS, FT, LTT, HTT, SV	Reduced fertilizers required. Some quality reduction may result.
Pumpkins (*Cucurbitapepo* L.)	Keumsakwa,Unyong, Super Unyong	VRS, FT, LTT	Mostly for cucumbers
Wintermelon (*Benincasahispida* Thunb.)	Lion, Best, Donga	GDR	Incompatibility
African horned (AH) cucumber (*Cucumis metuliferus* E. Mey. Ex	NHRI-1	FT, NMT	Medium to poor graft Compatibility
		Cucumber	
Figleaf gourd (*Cucurbita ficifolia* Bouché)	Heukjong (black seededfigleaf gourd)	LTT, GDT	Narrow graft compatibility
Squash (*Cucurbita moschata* Duch.)	Butternut, Unyong ,	FT, FQ	Affected by Phytophthora
Interspecific hybrid squash (*Cucurbita maxima* Duch. ×*C. moschata* Duch.)	Shintozwa, Keumtozwa,Ferro RZ, 64-05 RZ GangryukShinwha	FT, LTT	Slight quality reduction expected
Bur cucumber (*Sicyos angulatus* L.)	Andong	FT, LT T,SMT, NMT	Reduced yield
AH cucumber (*Cucumis metuliferus* E. Mey. ex Naud)	NHRI-1	FT, NMT	Weak temperature tolerance

Rootstock	Cultivar	Major characteristics	Possible disadvantage
		Melon	
Squash (*Cucurbita moschata* Duch.)	Baekkukzwa, No.8, Keumkang, Hongtozwa	FT, LTT	Phytophthora infection
Interspecific hybrid squash (*Cucurbita maxima* Duch. ×*C. moschata* Duch.	Shintozwa, Shintozwa, Shintozwa	FT, LTT, HTT,SMT	Phytophthora infection, poorfruit quality
Pumpkin (*Cucurbita pepo* L.)	Keumsakwa,Unyong, Super Unyong	FT, LTT andHTT, SMT	Phytophthora infection
Melon (*Cucumis melo* L.)	Rootstock ,Kangyoung, Keonkak, Keumgang	FT,	FQ Phytophthora problem

Advantages of grafting

- Yield Increase
- Disease resistant/tolerance
- Low and High temperature tolerance
- Enhance nutrient/ water uptake
- Quality chances
- Nematode tolerance and resistant

Disadvantage of grafting

- Incompatibility symptoms shows in later stages
- Additional seeds for rootstock
- Skilled labor needed
- High price of seedlings
- Increase incidence of physiological disorder

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