Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(6): 1170-1174
Received: 27-08-2020
Accepted: 19-10-2020

Diksha Thakur
Lovely Professional University, Phagwara, Jalandhar, Punjab, India

Savita
Lovely Professional University, Phagwara, Jalandhar, Punjab, India

Corresponding Author:
Savita
Lovely Professional University, Phagwara, Jalandhar, Punjab, India

Role of grafting in vegetable crops: A review

Diksha Thakur and Savita

Abstract
Grafting is a process in which two living parts are joining together to grow as a one and the method used to improve crop production. To overcome fusarium wilt, the first grafted vegetable seedlings used were for watermelon plants grafted on bottle guard. Since then this technology is being widely adopted in vegetable crops. Now a day's mostly watermelon, cucumber and various solanaceous crops are grafted before transplanting in the field. The use of grafting is increasing day by day due to its ability to provide tolerance to biotic stress such as soil borne pathogen, and to abiotic stresses such as cold, salinity, drought and heavy metal toxicity. For getting higher production mainly female plant were grafted on male plant. It was seen that more than 22 rootstocks of tomato, chilli, brinjal and cucurbits are used for bringing resistant from bacterial wilt and nematodes have been identified till now but still the interactions between rootstock/scion are unrevealed which results in loss of fruit quality, loss in production, shorter post harvesting time become shorter, and incompatibility between rootstock and scion are seen mostly. The selection of rootstock and scion cultivars must be done carefully so to avoid any loss.

Keywords: Grafting, scion, stress, vegetable, resistant and rootstock

Introduction
In vegetable production, India comes as a second largest producer in the world after China and mostly areas covered under vegetables is 10.29 million ha and total production 176.17 million Tonnes (NHB, 2018). Grafting is the best methods used for the production of sustainable vegetable by using resistant rootstock with an objective of increases in vegetable production with respect to increase in population. Grafting is a method of growing together two plant parts (a rootstock and a scion) by the process of tissue regeneration and finally grows as a one plant. Grafting of fruit trees has been practiced for many years, but in Olericulture, grafting of vegetable is a new technique. Vegetable grafting reduces the agrochemicals dependence on organic production (Rivard*et al.*, 2008) [31]. Vegetable grafting helps in producing vigour plant, high yield and quality and reduces the infection of soil-borne pathogen and also induces tolerance against a-biotic stresses with the help of desired rootstocks. Grafting method is very popular method with the help of vigorousity and disease -resistant rootstocks which provides high yields and tolerance to biotic and a-biotic stresses in vegetables like cucurbits, tomato, eggplant and pepper. In protected crops, Grafting is used to improve the production and resources of vegetable crops and the assumption of grafting depends on the use of appropriate grafting methods and through breeding the vigorous development of rootstock can take place. (King *et al.*, 2010) [15]. Dr. RM Bhatt and his associates started working with Grafting for first time in IIHR Bangalore (India) by grafting female plant on male plant to get high production.

Grafting method
Selection of grafting is done on crop with the help of the farmers experience, the number of grafts required, the motive of grafting and available facilities required for machinery and infrastructure (Lee *et al.*, 2010) [18]. Manual grafting is better and mostly practices as compared of using machines and grafting robots (Lee *et al.*, 2010) [18].

Tongue / approach grafting
Equal size of rootstock and scion are used for grafting. This method requires more labour and space but percentage of seedling survival is high and most commonly practice by small nurseries farmers. This method is not used in rootstocks with hollow hypocotyls.

Cleft grafting
It is also called apical or wedge grafting. In this method slant angle is made in lower stem and scion is pruned with 1-3 true leaves and scion is placed into split and clip is attach in between scion and rootstock (Johnson *et al.*, 2011) [14]. This is done in mainly Solanaceous crops.

Hole insertion
This is also known as top insertion grafting and mostly practices in china. This is mostly done in watermelon as the seedling size is smaller than the than rootstock of bottle gourd or squash. For transplanting optimum temperature required is 21-36℃.

Splice grafting
This method is mostly used by growers. It can be practice by hand or machines in most Cucurbits and Solanaceous vegetable crops.

Pin grafting
In this method designed pins are used to hold the grafted position instead of placing grafting clips. It is similar method as splice grafting.

Basic requirement for vegetable grafting
1. **Selecting the correct rootstock/scion**: Grafting is mainly done at 2-3 true leaf stage and Selection of the rootstock and scion is done on the basis of same stem diameters.
2. **Compatibility of Graft:** Graft compatible helps in reducing the Mortality rate even in later stage of growth. The formation of vascular bundles is due to Callus formation between scion and rootstock.
3. **Grafting aids:** it is done with the help of Grafting clips, Tubes, Pins, and Grafting Blade.
4. **Screening house:** it is made with 60-mesh nylon net used for growing seedlings previous to grafting.
5. **Healing of grafts:** temperature range and relative humidity in healing chamber should be 28-29ºc and 95% respectively for the growth of callus formation in seedling for 5-7days. This also helps in better attachment of scion and rootstock by reducing light intensity, transpiration with the help of controlled temperature and humidity.
6. **Acclimatization of the grafted plants**: acclimatization is done after callus formation end, when wounded surface are healed properly then the grafted plants are shifted to mist chamber of greenhouse or placed under clean plastic to prevent leaf burning and wilting.

Grafting in cucurbitaceous vegetable crops
Grafting is done to control Fusarium wilt and tolerant to drought and flooding. Currently, in this family watermelon is one crop in which grafting is practiced in the world (Yetisir *et al.*, 2003) [44]. There are different grafting methods used in cucurbits are listed in the below Table.

Table 1: Grafting methods and rootstocks used in vegetable crops

Scion plant	Rootstock	Method
Cucumber	Cucurbita moschata, Cucurbita maxima	Tongue and top insertion method
Watermelon	*Benincasa hispida, Cucurbita moschata Cucurbita melo, Cucurbitamoschata* × *Cucurbita maxima Lagenaria siceraria*	Top insertion and cleft method and slice grafting
Bitter gourd	*Cucurbita moschata Lagenaria siceraria*	Top insertion and tongue method
Bottle gourd	*Cucurbita moschata, Luffa sp.*	Top insertion and tongue method.

Grafting of Solanaceous vegetable crops
Grafting is practiced on a large scale so to control diseases like bacterial wilt in tomatoes that can destroy the crop completely. In 1960s, Grafting is commercial practice in tomato crop (Lee, *et al*. 2010) [18]. Grafting is a method which is done in tomato used for solving the problems caused by insect pests, occurrence of weeds and diseases like late blight and Fusarium wilt due to this yield will be reduced (Pogonyi, *et al*. 2005) [28].

Table 2: Grafting methods and rootstocks used in vegetable crops

Scion Plant	Rootstock	Method
Tomato	*Lycopersicum pimpinellifolium*	Cleft grafting
	Solanum nigrum	Tongue and cleft grafting
Brinjal	*Solanum torvum*	Tongue and cleft grafting
	Solanum sissymbrifolium	Cleft method
	Solanum khasianum	Tongue and cleft method

Effect of grafting on qualitative and quantitative characters
Fruit quality and salinity conditions can be improved by grafting method. Yetisir *et al.* (2003) [44] observed that grafting helps in changing the quality of watermelon i.e. fruits size, texture or TSS content mostly depends on which type of rootstock is used. When brinjal grafted on gave negative effect on firmness of fruits, content of vitamin C but generally their contribution was not very much successful (Arvanitoyannis *et al.*, 2005). (Davis *et al.*, 2008) [4, 7] concluded this when *Solanumtorvum* grafted with eggplant make the fruit size bigger but not changing their yield and quality. With the help of grafting the content of Sugar, carotene, flavor, colour, texture can be affected. Di-Gioia *et al.* (2010) [8] concluded this with the help of grafting there is change in TSS content when tomato "Oxheart" grafted with *Solanumlycopersicum* × *Solanumhabrochiates* and also found that if tomato plants grafted onto Beaufort F1 and Maxifort F1 vitamin C content was decreased by 14-20%. According to Flores *et al.* (2010) [9] the quality of fruits present on shoot is mainly dependent on the structures of root system. Gebologlu *et al.* (2011)[10] observed that when tomato grown in soil less cultivation then due to this grafted plants gives higher marketable yield, fruit quality. (Marsic and Jakse, 2010) [22] proved that when cucumber is grafted in soilless medium then there is change occurs in the stem and root system which leads to increases of yield up to 24% and similar to this also concluded by Reid and Klotzbach (2011)[30] that grafting helps in increasing the cucumber yield. Sánchez-Rodríguez *et al.* (2012 and 2013) [35] concluded that when tomato "Josefina" is grafted onto the rootstock "Zarina" which is drought tolerant under stress condition gives effect on fruit quality, minerals, sugars and organic acids. However, when tomato plant are used as a grafting leads to degradation in quality of fruits (Turhan *et al.* 2011; Al-Harbi, *et al.*, 2017) [39, 2]. Rouphael *et al.* (2010) [6] and Kyriacou *et al.* (2017) [17] concluded that use of grafting lead to creating the variation on sweetness, acidity and fruit ripening time.

Resistance to biotic and a-biotic factors
Grafting helps in reducing the effect caused by biotic and a-biotic stresses. Pulgar *et al.* (2000) [29] concluded that Pepper scion (Nokk wang) grafting breeding lines (PR920, PR 991) produce resistant from *Phytophthora* blight and bacterial wilt

and survival rate is also high in *Phytophthora*. Pavlou *et al.* (2002) [25] concluded that when cucumber cv. BrunexF1, and other Dutch type onto *Cucurbita ficifolia, Cucurbita moschata, and Cucurbita maxima* provides resistant from stem and root rot. Bletsos *et al.* (2003) [5] reported that grafted brinjal produced good yield when planted in soil infected with wilting diseases as compared to non-grafted plant. (Lee *et al.* (2003) [20] and Pogonyi *et al.* (2005) [28] stated that when mini watermelon grafted onto rootstock PS1313 (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne) under irrigated stress condition resulting in the 60% increasing in yield. Siguenza *et al.* (2005) [37] reported that when *Cucurbita moschata* used as a rootstock shows tolerance against root knot nematode. Grafting seedlings can improve the yield and quality of plant studied by Xu *et al.* (2006). Goreta *et al.* (2008) [41, 11] observed that leaf area and shoot weight increased under saline condition when watermelon cv. Fantasy grafted onto Strong Tosa rootstock (*C. maxima* Duch × *C. moschata* Duch). Rouphael *et al.* (2008) [32] observed that to provide resistant against copper toxicity and low temperature, cucumber is grafted on Shintoza-type rootstock (*Cucurbita maxima* Duchense × *Cucurbita moschata).* Albacete *et al.* (2010) [1] concluded when under salt stress condition the tomato cultivars grafted onto *Solanumlycopersicum* L. × *Solanumcheesmaniae* L. shows relationships to leaf xylem concentration, indole-3-acetic acid and ABA. Under greenhouse cultivation when watermelon grafted onto saline-tolerant rootstocks give 81% increased in yield (Colla *et al.*, 2010) [6]. According to Lee *et al.* (2010) [18] the growth and productivity of crops hindered due to biotic and abiotic stress when grown under open as well as greenhouse. Savvas *et al.* (2010) [36] proved that the crop loss occurs due to physiological and pathological conditions. According to (Tuberosa, 2012) [38] drought responsive trait affects the crop quality and yield when grafted under water-stressed conditions. (Altunlu and Gul, 2012) [3] observed that when tomato hybrid "Beaufort" (*Solanumlycopersicum* L. × *Solanumhabrochaites* S.) grafted onto rootstock ("Resistar") reduced the plant growth due to occurrence of water stress condition. (Petran, 2013) [27] reported that when tomato scions ("Celebrity" and "3212") onto turkey berry rootstock (*Solanum torvum* S.) under water-stressed conditions helps in delayed wilting of plant. According to Nilsen *et al.* (2014) [24] when tomato cv. "BHN602" grafted onto the tomato rootstock "Jjak Kkung under well-water condition leads to reduction in the leaf area and growth of plant. Penella *et al.* (2014) [26] concluded that when (*Capsicum annuum* L.cv. Verset) grafted onto the rootstocks "Atlante," "PI-15225," and "ECU-973 under water-stresses conditions helps in improving the marketable yield of crop by maintaining the photosynthetic rate. Ibrahim *et al.* (2014) and Al-Harbi *et al.* (2016) [13, 2] stated this when grown under full or deficit irrigation reign tomato cv. Faridah grafted onto the tomato hybrid "Unifort" (*Solanum lycopersicum* L. × *Solanum pimpinellifolium* L.) results in the expanding of yield. López-Marín *et al.* (2017)[21] stated when rootstock "Atlante" used as the scion acts differently when the grafting combination of Atlante/Verset and Atlante/Herminio .Similarly, it is important to test it for drought tolerance because it influence yield and growth component.

Table 3: Abiotic Resistant Through Grafting

Scion plant	Rootstock	Effect	Reference
High Temperature			
Brinjal	*Heat-tolerant rootstock (cv. Nianmaoquie*	Extend the growth stage and yieldincrease by 10%	Wang, *et al.* [40]

Flowering and harvest period

Flowering date are mainly influenced by the fruit quality and harvesting time. Few reports has been found which give details about flowering and harvesting periods with the help of grafting plants, but when gourds are grafted gives rise to more number of female flowers, it causes early formation of female flowers (Sakata *et al.*, 2007)[34]. When pumpkin, bottle gourd, wax gourd and watermelon, are grafted onto rootstock, "Shintosa" cause delay in flowering in cucurbits (Yamasaki *et al.*, 1994)[42].

New techinique used for grafting of vegetables

There are different methods of grafting used in vegetables crops are following:

1. **Grafting is done by the help of Robots:** In Netherlands, grafting of vegetables is done by fully automatic model of robots. It can graft 1,000 tomato or eggplant seedlings per hour. It can perform various functions like automatically selecting matching rootstock and scion seedlings, this helps in increasing the success rate. Kobayashi states that in 1993 for grafted of cucurbits fully or semi automatic robots (GR800 series; Iseki & Co. Ltd., Matsuyama, Japan) are used. The countries used robots grafting are :

Table 4: robot developed for grafting vegetables.

Vegetable crops	Robots	Model	Developed by
Solanaceous	AG1000 robot	fully automated	Yanmar Agricultural Equipment Co. (Osaka, Japan) 1994,

i) **Use of Micro-grafting**: In this technique of grafting, use of small part of a plant i.e. explant (< 1/1000th mm3) from meristematic tissues to eliminates the infected plants from different virus. It is used in herbaceous plants. This method is expensive that is why not used as commercial means.

ii) **Double grafted in tomato**: In the pomato is an example of vegetable grafting. With the help of cleft grafting, tomato scion were grafted onto potato rootstock. In U.S. Log House in 2010 has used the technique of producing double grafted red and yellow pear tomato as scions by using on Big Beef or Geronimo rootstock and then marketed.

Occurrences of problems during grafting of vegetable;

Various problems related to the production and management of grafted transplants is following:

- This technique requires large amount of intensive labour and specialized trained workers.

- It required time management for rootstock and scion seeds sowing.
- It required a controlled environment for graft healing.
- During the initial stages or after transplantation under field conditions, Rootstock-scion incompatibility is observed.

Marucci *et al.* (2012) [23] stated that grafting can increase the chance of occurrences of pathogen, especially for seed borne pathogens in the nursery. Workers started doing grafting within a greenhouse and growth chamber faces the problems of heat stress and discomfort during the month of April-June, September and October.

Current status of vegetable grafting

East Asia is the one of the largest market for the vegetable grafting because of high concentration of cucurbits, solanaceous and other grafted vegetables. In Greece, Spain, Korea, Japan and Cyprea, 100%, 98%, 98%, 93% and 80% of watermelon respectively are produced through grafted transplants. In case of Solanaceous vegetables, In Japan 45% tomatoes and 65% eggplants and 5% of peppers are produced through grafted transplants (Yassin and Hussen, 2015) [43].

Conclusion

Grafting is an eco-friendly technique which promotes organic vegetable production. In India, Grafting can also helps in the reduction of the problems created by vegetables industry and also reduced the use of fertilizers and pesticides leads to increases in yield and quality of produced also improved. When watermelon is grated on inter-specific cucurbit rootstocks then texture is affected leads to increase of firmness in pulp. Nursery production and management is labour intensive. To solve this problem, scientist trying to develop new technique, equipment and reducing the cost of labour and improves the efficiency of grafting with the help robots. Grafting application helps in reducing in the occurrence of soil borne infections leads to reduction in toxicity level vegetables and environmental pollution. From this it was concluded that use of modern and indigenous techniques helps in the reduction of input used by grafting in horticulture of future.

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