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) [18]. 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°C.

Splice grafting
This method is mostly used by growers. It can be practice by hand or machines in most Crucibits and Solanaceae 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.

Table 1: Grafting methods and rootstocks used in vegetable crops

<table>
<thead>
<tr>
<th>Scion plant</th>
<th>Rootstock</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>Cucurbita moschata, Cucurbita maxima</td>
<td>Tongue and top insertion method</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Benincasa hispida, Cucurbita moschata Cucurbita melo. Cucurbitamoshata × Cucurbita maxima Lageneraria siceraria</td>
<td>Top insertion and cleft method and slice grafting</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>Cucurbita moschata Lageneraria siceraria</td>
<td>Top insertion and tongue method</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>Cucurbita moschata, Luffa sp.</td>
<td>Top insertion and tongue method</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Scion Plant</th>
<th>Rootstock</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Lycopersicum pimpinellifolium</td>
<td>Cleft grafting</td>
</tr>
<tr>
<td>Brinjal</td>
<td>Solanum nigrum</td>
<td>Tongue and cleft grafting</td>
</tr>
<tr>
<td></td>
<td>Solanum torvum</td>
<td>Tongue and cleft grafting</td>
</tr>
<tr>
<td></td>
<td>Solanum sisymbriifolium</td>
<td>Cleft method</td>
</tr>
<tr>
<td></td>
<td>Solanum khasianum</td>
<td>Tongue and cleft method</td>
</tr>
</tbody>
</table>

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 × Solanumhabrochaites 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. Gobuloglu 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) [12] 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-Harbî, 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. Bletos 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 Poganyi et al. (2005) [28] stated that when mini watermelon grafted onto rootstock PS131 (*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 Shintosa-type rootstock (*Cucurbita maxima* Duchesne × *Cucurbita moschata* moschata). Albacete et al. (2010) [11] concluded when under salt stress condition the tomato cultivars grafted onto *Solanum lycopersicum* L. × *Solanum melongena* L. shows relationships to leaf xylem concentration, indole-3-acetic acid andABA. 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) [28] 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” (*Solanum melongena* L. × *Solanum habrobaechites* S.) grafted onto rootstock (“Resister”) reduced the plant growth due to occurrence of water stress condition. (Petran, 2013) [27] reported that when tomato scions (“Celebrity” and “3212”) onto turky 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. “BH6N602” 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 when (*Capsicum annuum* L.cv. Verset) grafted onto the rootstocks “Atlanta,” “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 reigne tomato cv. Faridah grafted onto the tomato hybrid “Unifort” (*Solanum lycopersicum* L. × *Solanum pimpinellifolium* L.) results in the expanding of yield. López-Marin et al. (2017) [21] stated when rootstock “Atlanta” 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

<table>
<thead>
<tr>
<th>Scion plant</th>
<th>Rootstock</th>
<th>Effect</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brinjal</td>
<td>Heat-tolerant rootstock (cv. Niammaoquie)</td>
<td>Extend the growth stage and yield increase by 10%</td>
<td>Wang, <em>et al.</em> [40]</td>
</tr>
</tbody>
</table>

### 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) [35].

### New technique used for grafting of vegetables

There are different methods of grafting used in vegetables and the 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:

   - 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.
   - Double grafted in tomato: In the tomato 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.

### Table 4: robot developed for grafting vegetables.

<table>
<thead>
<tr>
<th>Vegetable crops</th>
<th>Robots</th>
<th>Model</th>
<th>Developed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solanaceous</td>
<td>AG1000 robot</td>
<td>fully automated</td>
<td>Yanmar Agricultural Equipment Co. (Osaka, Japan) 1994,</td>
</tr>
</tbody>
</table>
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 grafted 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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