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Vegetable Grafting: A Recent Advance in Olericulture: A Review

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Vegetable grafting is a technology whose main objective is to increase yield under biotic and abiotic stresses such as sub and supra-optimal temperature, salinity, drought, Pest damage, diseases etc. Commercial vegetable grafting has been started since few decades and the area under vegetable grafting is progressively increasing. Vegetable grafting is having potential to expand area under cultivation of vegetables under non-traditional conditions and unstable agro-eco-systems and there it has a scope to increase production per unit land available. Vegetable grafting is one of the cheapest and alternative tool to long and slow breeding procedures in development of resistant varieties.

Introduction

Grafting is an art of joining together two plant parts (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 (Janick, 1986). Grafting of fruit trees has been practiced for thousands of years, but in Olericulture, vegetable grafting is a relatively new one technique which is centuries-old technique. Commercial vegetable grafting using resistant roots stocks is one of the best tool for sustainable vegetable production Vegetable grafting reduces dependence on the agrochemicals for the organic production (Rivard *et al.*, 2008). Vegetable grafting also induce vigour, precocity, better yield and quality, survival rate, reduce infection by soil-borne pathogens and tolerance against abiotic stresses by using desired rootstocks. In world, vegetable grafting is getting popularity in case of cucurbits, tomato, eggplant and pepper using vigorous and disease -resistant rootstocks to ensure adequate yields where biotic and abiotic stresses limits the productivity (Lee and Oda, 2003; Chang *et al.*, 2008; Buller *et al.*, 2013).

History

The first attempt in vegetable grafting was done by grafting watermelon (*Citrullus lanatus*) onto pumpkin (*Cucurbita moschata*) rootstock in Japan and Korea in the late 1920s (Leonardi, 2016). Self-grafting was used as a technique to produce large-sized gourds fruits, as reported in a Chinese book written in the 5th century and Korean book written in the 17th century (Lee and Oda, 2003). However, commercial grafting of vegetables only originated in the early 20th century with the aim of managing soil borne pathogens (Louws *et al.*, 2010). Among the Solanaceous crops, aubergine (*Solanum melongena* L.) was first grafted on to scarlet onto scarlet aubergine (*Solanum integrifolium* Lam.) was started in the 1950s (Oda, 1999).

Similarly, grafting of tomato (*Solanum lycopersicum* L.) was started in the 1960s (Lee and Oda, 2003). By 1990, the percentage of grafted Solanaceae and Cucurbitaceae vegetables had increased to 59% in Japan and 81% in Korea (Lee, 1994). In India, grafting work has been started in IIHR, Banglore by Dr. R M Bhatt and his associates. TNAU, Coimbatore has done work on brinjal grafting using *Solanum nigrum* as rootstock. NBPGR regional station, Thrissur, Kerala have done work on cucurbit grafting by taking *Momordica cochinchinensis* as rootstock with success rate of 98%. CSKHPKV, Palampur initiated work on grafting in cucurbits and solanaceous vegetables and have identified more than 22 rootstocks of these vegetables to impart resistance to bacterial wilt- and nematodes. Private companies like 'VNR Seed Private Limited' and 'TAKII SEED INDIA PRIVATE LIMITED' are also involved in vegetable grafting and supplying grafted quality seedlings.

Importance and use of vegetable grafting

Resistance to biotic and abiotic factors

Grafting used as tool for reducing the effect of biotic and abiotic stresses. The watermelon grafted onto bottle gourd rootstock in heavy or loamy soils enhances flooding tolerance. Cucurbits grafted on pumpkin provide drought tolerance in sandy soil (Anonyms, 2013). Mini watermelons grafted onto a commercial rootstock PS1313 (*Cucurbita maxima Duchesne* × *Cucurbita moschata Duchesne*) have shown 60% increase in yield when grown under irrigation stress conditions in contrast to ungrafted melon plants. (Rouphael *et al.*, 2008) found that cucumber grafted on Shintoza-type rootstock (*Cucurbita maxima Duchense* × *Cucurbita moschata*) has shown low temperature resistance and copper toxicity resistance. The watermelon grafted onto saline-tolerant rootstocks increases around 81% yield under greenhouse production (Colla *et al.*, 2010). Goreta *et al.*, (2008) reported that watermelon Cv. Fantasy grafted onto Strongtosa rootstock (*C. maxima Duch* × *C. moschata Duch*) increases the shoot weight and leaf area even under saline conditions. Soil bore diseases like verticilium wilt, bacterial wilt, fusarium wilt, corky root etc. and nematodes area some of the biotic stresses cause damage in vegetable production especially in continuous cropping of greenhouses (Lee *et al.*, 2003; Pogonyi *et al.*, 2005). Pepper scion (Nokk wang) grafting onto breeding lines (PR 920, PR 991 and PR 922) resistant to *Phytophthora* blight and bacterial wilt showed greater rate of survival when they were inoculated with *Phytophthora* *capsici* and *Ralstonia solanacearum* (Jang *et al.,* 2012).

Effect of grafting on qualitative and quantitative characters

Grafting is an effective approach to improve fruit quality under both optimum growth conditions and salinity. The fruit quality of shoot, at least partially, depends on the root system (Flores *et al.,* 2010). In soil less tomato cultivation, grafted plants had higher marketable yield, fruit quality (Gebologlu *et al.,* 2011). Grafting of eggplants onto *S. torvum* increased the fruit size without any effect on quality and yield. Sugar, flavor, colour, carotene content and texture can be affected by grafting and the type of rootstock used (Davis *et al.,* 2008). A study reported that the solutes associated with fruit quality are translocated in the scion through the xylem, whereas quality traits, e.g. fruit shape, skin colour, skin or rind smoothness, flesh texture and colour and soluble solids concentration are influenced by the rootstock (Nicoletto *et al.,* 2012). In contrast, grafting eggplant on *Solanum torvum* and *Solanum sisymbrifolium* negatively affected vitamin C content, firmness and some sensory attributes but overall impression was not influenced (Arvanitoyannis *et al.,* 2005). Di-Gioia *et al.*, 2010 recorded no significant differences in total soluble solids by tomato "Oxheart" grafted onto 2 inter-specific *S. lycopersicum* × *S. habrochiates* and also found that vitamin C content was decreased by 14-20 % if tomato plants grafted onto Beaufort F_1 and Maxifort F_1. So, there is need of further research regarding improvement of qualitative traits via grafting techniques.

Flowering and harvest period

Flowering is delayed in grafting pumpkin, bottle gourd, wax gourd and watermelon, especially in plants with 'Shintosa'- type rootstocks (Yamasaki *et al.,* 1994). (Sakata *et al.,* 2007) stated that when compared with other gourd, it causes early formation of female flowers. Flowering date affects fruit harvest time, which can have a direct impact on quality. No much report found that could provide more information about grafting effects on flowering and earliness. The late flowering in grafted plants may be due to the growth of scion plants.

Basic pre-requisites for vegetable grafting

Selected rootstock and scion should have same diameter for successful union and to overcome graft incompatibility problem. Grafting should be done at 2-3 leaf stage.

The seed of scion cultivar should be selected based on purity, viability, yield, fruit quality and market demand. Similarly, rootstock cultivars should be selected based on purity, viability, resistance to diseases, compatibility with the scion cultivar and adaptability to local soil and other environmental conditions.

Grafting blade, pins should be contamination free.

Temperature of 25-30˚c, relative humidity of 85-90 % and low light intensity is maintained for healing process.

Grafting seedlings are kept for 7-10 days for acclimatization as hardening treatment.

Grafting method

Selection of grafting method depends on the crop, the farmers experience, personal choice, the number of grafts required, the purpose of grafting, access to labour and the availability of machinery and infrastructure facilities (Lee *et al.,* 2010). Although many machines and grafting robots have been developed but manual grafting is the most popular and widely used method (Lee *et al.*, 2010)

Tongue / approach grafting

Equal sized rootstock and scion material used for this grafting. Therefore, to attain uniform size, scion seeds are sown 5-7 days earlier than rootstock seeds. This method is labour intensive and requires more space but seedling survival rate is high, hence, most widely used by farmers and small nurseries. This method is not suitable for rootstocks with hollow hypocotyls.

Cleft grafting

It is also called apical or wedge grafting. Here scion plants are pruned with 1-3 true leaves and the lower stem is cut to slant angle to make a tapered wedge and clip is placed to make contact between scion and rootstock after placing scion into split made (Johnson *et al.*, 2011). This method is most widely used in Solanaceous crops.

Hole insertion/ Top insertion grafting

This method is preferred for grafted watermelon transplant production because the size of watermelon seedlings is relatively small than rootstock of bottle gourd or squash. This method require optimum temperature of 21-36˚c up to transplanting. This method is very popular in china because it results in a strong union and vascular connection compared with the tongue grafting approach (Oda, 1994).

Splice grafting/ tube grafting/ one cotyledon splice grafting

This method is most widely used and preferred by growers and commercial grated transplant producers. It can be performed in most vegetables by hand or machines. This method is popular in Cucurbits and Solanaceous vegetable crops.

Pin grafting

Pin grafting is similar to splice grafting. Instead of placing grafting clips, especially designed pins are used to hold the grafted position.

Post-graft healing environment

Proper care of newly grafted transplants is necessary to secure a higher success rate for the grafting process. Loss of water from the scion during the first 2 days may lead to wilting of scion and ultimately failure of the grafting process; therefore, humidity should be maintained to prevent (95%) water loss.

Grafted transplants should be covered for 5-7 days after grafting with black plastic sheeting to increase humidity, reduce light intensity and to promote healing process.

Plastic tunnels are used as healing chambers 95% grafting success can be obtained on commercial scale using healing room (Dong *et al.*, 2015). Avoid the grafted plantlets to direct sunlight during the healing process.

Problems faced during vegetable grafting

Various problems associated with the production and management of grafted transplants is as following:

This technique is labour intensive and required specialized trained workers.

Requires time management for rootstock and scion seeds sowing.

Require a controlled environment for graft healing.

Rootstock-scion incompatibility is observed during the initial stages or after transplantation under field conditions.

Grafting can increase the risk of pathogen spread, especially for seed borne pathogens in the nursery. Workers performing grafting within a greenhouse and growth chamber face the problems of heat stress and discomfort, especially during April-June, September and October (Marucci *et al.,* 2012)

Current status of vegetable grafting

East Asia is the largest market for vegetable grafting because of high concentration of cucurbits and other grafted vegetables. In Korea, Japan and China, 99 %, 94 % and 40 % of watermelon respectively are produced through grafted transplants (Bie *et al.,* 2017). In case of Solanaceous vegetables, about 60-65 % tomatoes and eggplants and 10-14 % of peppers are produced through grafted transplants. In the Netherlands all the tomato under soilless culture conditions utilize grafted tomato transplants (Bie *et al.,* 2017). Currently, vegetable grafting is expanding worldwide particularly in Eastern Europe, North and South America, India and Philippines. In china, over 1500 commercial nurseries are producing grafted transplants. Canada exporting grafted transplants to Mexico, thus the international trading of grafted vegetable transplants is rapidly increasing (Bie *et al.,* 2017).

Conclusion and future perspectives

Considering the diverse applications of vegetable grafting worldwide, this technique has the potential to solve the problems of vegetable industry of India and can boost farmer's income by improving the crop yield and reducing the cost incurred on purchasing of huge amount of fertilizers and pest and disease control products. Grafting is an eco-friendly technology which promotes organic vegetable production. Nursery production and management is labour intensive. To solve this problem, scientists must focus on developing and popularizing facilities, equipment and grafting robots to increase the efficiency of grafting and reduce labour cost. Storage technology for grafted transplants demands the consideration of researchers the developments of databases, software, mobile applications and crop models related to grafted vegetables will assist nursery managers and farming communities in the selection of suitable scion and rootstock cultivars, in the international market the trading of grafted transplants is increasing rapidly, with the development of grafted vegetable industry in India this option can be availed to earn foreign exchange.

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