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Vegetable grafting: a boon to vegetable growers to combat biotic and abiotic stresses

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Abstract

Grafting is an alternative approach used in vegetable production to fight against soil-borne diseases such as *Fusarium* wilt, bacterial wilt and nematodes since 1920s in Japan and Korea. Grafting as a technology for the commercial production was later on adopted by many countries in Europe, Middle East, Northern Africa, Central America and other parts of Asia. For the production of many fruit-bearing vegetables which include watermelon, cucumber, melon, tomato, eggplant and pepper, grafted seedlings were used. These seedlings besides providing resistance against biotic/abiotic stresses, increase the yield of the cultivars. This technique is considered eco-friendly for sustainable vegetable production because the resistant rootstock reduces dependence on agrochemicals. Grafting improves quality of the plant and is used to induce resistance against low and high temperatures. Growth, yield and fruit quality of the scion is greatly influenced by the type of rootstock used. Due to high post graft mortality of seedlings, this technology is still in infancy in India. For its commercial application in India, sharpening of grafting skills and healing environment need to be standardized.

Key words: Grafting, advantages, methods, basic pre-requisites, precautions

Grafting is a method of propagation where two pieces of living plant tissues are joined together to develop as a single plant. 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 (Lee 1994). A serious crop loss caused by soil-borne diseases aggravated by successive cropping was avoided by production of vegetables with grafted seedlings. In many fruit-bearing vegetables such as watermelon, cucumber, melon, tomato, eggplant and pepper, the use of grafted seedling has become increasingly popular. Grafting is an environment-friendly approach which is used to control soil borne diseases and increasing the yield of susceptible cultivars (Lee and Oda 2003). This technique is eco-friendly for sustainable vegetable production and by using resistant rootstock, it reduces dependence on agrochemicals (Rivard et al. 2008). To induce resistance against low and high temperatures, grafts were generally used (Venema 2008). Grafting increases the yield and promotes biotic/abiotic stress tolerance. Grafting is also used to induce tolerance to abiotic stresses *viz*. flooding, drought and salinity. In Japan (92%), Korea (98%) and China (20%), major share in watermelon production is from grafted seedlings. In Europe, Spain is leading in grafted seedlings production with 129 million grafted seedlings followed by Italy (47 million grafted seedlings) and France (28 million grafted seedlings) (FAO 2009). Grafting as a technology for the commercial production of vegetables was later on adopted by many countries in Europe, Middle East, Northern Africa, Central America and other parts of Asia (Kubota *et al*. 2008).

In India, grafting work has been started in IIHR Bangalore by Dr RM Bhatt and his associates. Their work was on identification of rootstocks for waterlogged conditions. For this purpose they have imported semiautomated grafting machine. IIHR Bangalore organized first ever short course on vegetable grafting during the year 2013. NBPGR regional station, Thrissur, Kerala have done work on Cucurbit grafting by taking *Momordica cochinchinensis*, a dioecious plant. The female plants were grafted on to the male plants to increase its production. Graft success was 98%. CSKHPKV, Palampur initiated work on grafting and identified more than 22 rootstocks of brinjal, chilli, tomato and cucurbits for importing resistance to bacterial wilt and nematodes. Some private players are also involved in grafting. One of them is ‘VNR Seed Private Limited’ in Chhattisgarh which is supplying grafted brinjal seedlings resistant to bacterial wilt to farmers. The other seed company is ‘TAKII SEED INDIA PRIVATE LIMITED’**.**

Advantages of grafting

Tolerance to soil-borne diseases: Grafting is used to get rid of soil-borne diseases such as *Fusarium* wilt in Cucurbitaceous crops (cucumber, melon etc.) and Bacterial wilt in Solanaceous crops (tomato, pepper etc.) (Oda *et al*. 1999). Grafting is a quick method in melon for controlling race 1 and 2 of *Fusarium oxysporum f. melonis* (Nisini *et al.* 2002). Grafting is an effective tool for disease resistance by using rootstocks resistant to both *Phytophthora* blight and bacterial wilt. Pepper scion (‘Nokkwang’) grafting onto breeding lines (‘PR 920’, and ‘PR 921’, and ‘PR 922’) resistant to both *Phytophthora* blight and bacterial wilt showed greater rate of survival when they were inoculated with *Phytophthora capsici* and *Ralstonia solanacearum* (Jang *et al*. 2012). When the susceptible commercial pepper variety (cv. Gedon) grafted onto rootstocks resistant to *Rhizoctonia* root rot and *Fusarium* wilt grown in the infested soil was less attacked with wilt disease, while ungrafted plants were severely infected (Attia *et al*. 2003).

Tolerance to abiotic stresses: To induce resistance against low and high temperature, grafts were generally used**.** For the production of fruiting vegetables under the winter greenhouse conditions, tolerance to extreme temperature is crucial (Venema 2008**)**. Figleaf gourd rootstock has been used commercially to increase the tolerance of cucumber, watermelon, melon and summer squash to low soil temperature. Grafting led to salt and flooding tolerance (Yetisir *et al*. 2006), improved water use efficiency (Rouphael *et al*. 2008), increased nutrient uptake (Colla 2010) and alkalinity tolerance (Colla *et al*. 2010). Grafting helps in the survival of plants under low temperature because of the presence of more content of Linolenic acid. Chilli gave highest yield under high-temperature conditions when grafted on sweet pepper rootstocks (Palada and Wu 2008). Grafting minimizes the negative effect of boron, copper, cadmium, and manganese toxicity (Savvas *et al*. 2008). In tomato, grafting resulted in the formation of more number of internodes and flowers in outdoor cultivation and number and total weight of fruits in indoor cultivation (Voutsela *et al*. 2012).

Under the conditions of deficit irrigation, watermelons grafted onto a commercial rootstock (PS 1313’: *Cucurbita maxima* Duchesne x *Cucurbita moschata* Duchesne), gave 60% more marketable yield than ungrafted melons (Rouphael et al. 2008). Drought tolerance that was provided by either the rootstock or the scion resulted in increased nitrogen fixation in soybean (*Glycine max* L.) (Serraj and Sinclair 1996). Transgenic tobacco plants were successfully generated by maintaining photosynthetic activity and high water contents during drought (Rivero et al. 2007). Grafting improved flooding tolerance of bitter gourd (*Momordia charanthia* L. cv. New Known), when it was grafted onto luffa (*Luffa cylindrica* Roem cv. Cylinder) (Liao and Lin 1996). In the lowland tropics flooding occurs during the heat period. The AVRDC recommends growing tomatoes on eggplants ‘EG195’ or ‘EG203’ and pepper on chilli accessions ‘PP0237-7502’,’PP0242-62’ and ‘Lee B’ (AVRDC 2003 & 2009).

Effect on fruit quality: Grafting is an effective approach to improve fruit quality under both optimum growth conditions and salinity. The fruit quality of the shoot, at least partially, depends on the root system (Flores *et al*. 2010). In soilless tomato cultivation, grafted plants had higher marketable yield, fruit quality and pH content of fruits depending on rootstocks (Gebologlu *et al*. 2011). Grafting of eggplant onto *S. torvum* increased the fruit size and had no effect on quality and yield. The fruit size of watermelons grafted to rootstock having vigorous root systems was significantly increased as compared to the fruit from intact plants.

In cucumbers, especially for export, bloom development and external colour are important quality factors. These can be greatly influenced by the rootstock. The grafting technique affects various quality aspects of vegetables. Rootstock/scion combinations should be carefully selected for specific climate and geographic conditions. Appropriate selection can help to control soil borne diseases and also increases yield and fruit quality. Sugar, flavour, pH, color, carotenoid content and texture can be affected by grafting and the type of rootstock used (Davis et *al.* 2008).

Plant vigour promotion: The root systems of selected rootstocks, much larger and more vigorous, can absorb water and nutrients more efficiently as compared to non-grafted plants. In cucumber, vigorous root system of the rootstock can effectively absorb water so that less frequent irrigation may be practiced. By using vigorous rootstocks the frequency of agrochemical application can be significantly reduced. In watermelons, the amount of chemical fertilizers can be reduced to about one-half to two-third as compared to the standard recommendation for the non-grafted plants (Salehi-Mohammadi *et al*. 2009).

High yield: When plants are cultivated in problematic soils, grafts have been used to improve yield (Kacjan-Marsic and Osvald 2004). They found higher yield of tomato cv. 'Monroe' grafted onto rootstock of 'Beaufort'. In greenhouse as well as in open-field, grafted plants gave more yield than non-grafted ones (Khah *et al*. 2006). Tomato plants grafted onto 'Heman' and 'Primavera' produced higher yield in the greenhouse and the open field. Water use efficiency and yield were higher in grafted plants. The researchers of Korea and Japan have reported increases of 25 to 50% in yield of grafted tomato, melons, pepper, eggplant and watermelon compared to non-grafted plants.

Methods of Vegetable Grafting

A number of grafting techniques are employed in fruit bearing vegetables. Tomato and eggplants are mostly grafted by cleft and tube grafting. Tongue approach is used in grafting cucurbitaceae especially for cucumber. Slant-cut grafting is easier and has recently become popular for watermelon and melon. This method was developed mainly for robotic grafting. These methods have been discussed as under:

Cleft grafting: The seeds of the rootstock are sown 5-7 days earlier than those of the scion. The stem of the scion (at four leaf stage) are cut at right angle with 2-3 leaves remaining on the stem. The rootstock (at the four to five-leaf stage) are cut at right angles, with 2-3 leaves remaining on the stem. The stem of the scion is cut in a wedge, and the tapered end fitted into a cleft cut in the end of the rootstock. The graft is then held firm with a plastic clip. Move the tray filled with grafted plants to proceed for healing up.

Tube or Japanese Grafting: This grafting has been developed for vegetable seedlings grown by plug culture. This method makes possible to graft small plants grown in plug trays two or three times faster than the conventional method. The smaller the plants, the more plants can be fitted into healing chambers or acclimation rooms. Cut rootstock under cotyledons in a 45^{o} or sharper angle. Prepare the scion with matching hypocotyl width cut in the same angle at about 5- 10 mm below the cotyledons. Place one tube a half way down on top of the cut end of rootstock hypocotyl. Insert the scion into the grafting tube so that cut surface aligns perfectly with that of rootstock. Move the tray filled with grafted plants to proceed for healing up to 7 days.

Tongue Approach Grafting: In this method, seeds of cucumber are sown 10-13 days before grafting and pumpkin seeds 7-10 days before grafting, to ensure uniformity in the diameter of the hypocotyls of the scion and rootstock. The shoot apex of the rootstock is removed so that the shoot cannot grow. The hypocotyls of the scion and rootstock are cut in such a way that they tongue into each other and the graft is secured with a plastic clip. The hypocotyl of the scion is left to heal for 3-4 days and then crushed between the fingers. The hypocotyl is cut off with the razor blade three or four days after being crushed.

Slant-Cut Grafting: This grafting technique is easy to practice and has become popular. This method is mainly developed for robotic grafting. It is important to remove the 1st leaf and lateral buds when a cotyledon of rootstock is cut on a slant.

Basic pre-requisites

Root stocks and scion: Select the desirable rootstock and scion at two true leaf stage. Stem diameter of scion should be same as that of rootstock.

Compatibility: Callous formation takes place between scion and root stock and rebuilding of vascular bundles i.e. cambium formation between the graft union.

Grafting Aids: A. Grafting clips, B. Tubes, C. Pins, and D. Grafting Blade**.**

Screen house**:** Used for growing seedlings prior to grafting. It should be constructed with 60-mesh nylon net. Arrange double door, the upper half of the structure should be covered with a separate UV resistant polyethylene to prevent UV light penetration.

Healing chamber/Grafting chamber: It is used for formation of better graft union. In this chamber grafts should be kept for 5-7 days. Reduces water stress by reducing transpiration, maintains high humidity, maintains optimum temperature and reduces light intensity.

Healing conditions: Healing is the most critical process of grafted seedling production.Temperature of 25-30 ^{o}C, RH-85-90% and low light intensity are required for healing.

Acclimatization chamber**:** This chamber is used for hardening the grafted seedling prior to transplanting to prevent leaf burning and wilting. The grafted seedling takes 7 to 10 days for acclimatization as hardening treatment.

Precautions

To maximize the efficiency of the technique, a perfect co-ordination of the vegetative cycles must be achieved before the conjunction of the two plants. Expose seedlings to full sun and some water stress before grafting to keep the plants short and increase tolerance to water stress. During grafting, timing of the operations needs to be strictly controlled. Make grafts early or late in the day to avoid water loss. Appropriate sanitation measures have to be adopted (use of pest free high quality seeds and sub-

Always match scions and rootstocks of equal stem diameter. Cut them at exactly the same angle. Graft in a location that is protected from direct sunlight and away from greenhouse heater discharge. Make sure the cut surfaces make good contact when the plants are clipped together so that they have the best chance of successfully connecting to each other. Use physical barriers against virus vectors and specific pesticides against insects and fungi. During the entire process the environmental conditions (temperature, humidity, composition of the substrate, sun radiation, ventilation) have to be optimized and controlled.

Future prospects

Identification of compatible disease resistant rootstocks with tolerance to abiotic stresses is the basic requirement for continued success. Healthy grafted seedlings at reasonable price is the key point for wider use. Methods/ techniques should be of low cost so that these could be adopted by farmers for commercial production. More research is needed to minimize post grafting losses. There is a scope for vegetable breeders and private companies of India to develop resistant rootstocks. The companies should be involved in marketing these rootstocks to the field e.g. Dai power: Rootstock for Capsicum and Chilli. It is tolerant to diseases like Bacterial wilt, Phytophthora blight, Mosiac virus. Researches, extension specialists and seed companies need to work together to integrate this modernized technology as an effective tool for producing high-quality vegetables. Sharpening of grafting skills and healing environment need to be standardized for its application on commercial scale.

Conclusion

Grafting provides a site specific management tool for soil borne diseases. Grafting can affect various quality aspects of vegetables. Rootstock/scion combinations should be carefully selected for specific and geographic conditions. It fits well into the organic and integrated crop production system. It reduces the need for soil disinfectants and thereby environmental pollution. Grafting technology has a potential in promotion of cultivation in non-traditional and fragile agro-eco system. Grafting is a rapid alternative tool to the relatively slow breeding methodology aimed at increasing biotic and abiotic stress tolerance of fruit vegetables. Since grafting gives increased disease tolerance and vigour to crops, it will be useful in the low-input sustainable horticulture of the future.

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