www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(8): 1580-1584
© 2021 TPI
www.thepharmajournal.com
Received: 14-06-2021
Accepted: 20-07-2021

Rupan Dash
Department of Vegetable Science, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Chinmaya Jena
Department of Fruit Science and Horticulture Technology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Kartik Pramanik
Department of Vegetable Science, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Priyadarshani P Mohapatra
College of Agriculture, Central Agriculture University, Kyrdemkulai, Meghalaya, India

Corresponding Author:
Chinmaya Jena
Department of Fruit Science and Horticulture Technology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Vegetable grafting: A noble way to enhance production and quality

Rupan Dash, Chinmaya Jena, Kartik Pramanik and Priyadarshani P Mohapatra

Abstract
Severity of biotic and abiotic stresses are increasing day by day which is a major hindrance in case of vegetable crop production and incidence of soil borne pathogen and extreme climate conditions causes low productivity. To tackle such adverse situation and increase productivity is a tough challenge at farmers' field. So, vegetable grafting is a sustainable technique in the field of research and development to identify potential rootstocks and its standardization and commercialization which will be tolerant/ resistant to such adverse conditions. Grafting is considered as union of two different plant parts i.e. rootstock and scion to form a single new plant. First vegetable grafting work was started at Japan and Korea during 1920s and Dr. R M Bhatt and his associates worked on vegetable grafting in India to identify desirable rootstocks for water logged condition. Rootstocks have positive effects on biotic an abiotic stresses and on quality and quantity parameters of scion in solanaceous and cucurbits. It also reduces chemical load on final harvested vegetables and can be considered as low cost sustainable technique in vegetable production.

Keywords: vegetable grafting, biotic stress, abiotic stress, solanaceous, cucurbits

Introduction
Two different plant parts are united to develop a new plant is named grafting. It's an old age technique adopted in the field of plant science to boost up economic benefits. Both parts are having certain effects on each other w.r.t. growth and development. In grafting method, both the parts are of may be same species or different. As per Lee (1994) [12] in late 1920s research was made in vegetable grafting in cucurbits watermelon as scion and pumpkin as rootstock in Japan and Korea. As vegetables are the succulent in nature so these are mostly affected by a number of diseases and pests as well as other abiotic stress. More commonly soil borne pathogens are most destructive and causes a serious crop loss in vegetables like tomato, brinjal, pepper, watermelon, cucumber. Lee and Oda (2003) [13] suggested that soil borne diseases can be controlled and yield can be increased in vegetables by adopting asexual propagation method namely grafting. For sustainable vegetable cultivation grafting method is known as more beneficial and eco-friendly and use of plant protection measures load can be reduced by using resistant/ tolerant rootstocks (Rivard *et al.* 2008) [21].
In case of vegetable crops which are cultivated under protected structure are seems to be response well to grafting method which enhances production as well as better utilization of resources. King *et al.* (2010) [11] stated that adaptation of exact grafting techniques and utilization of proper rootstocks through breeding is key to enhance vegetable production whereas Goldschmidt (2014) [7] suggested that irrespective of advantages not all the vegetable species are suitable for grafting due to certain genetic, morphological and biochemical parameters are responsible for success of grafting.
Vegetable grafting work in India was initiated at IIHR, Bangalore by Dr. R. M. Bhatt and his associates to identify best rootstocks for water logged condition and in the year 2013 IIHR, Bangalore started first ever short course in vegetable grafting. Now-a-days, a full-fledged research work is carried out by both public and private sectors. An increase in yield up to 80% in Solanaceae and up to 60-90% in cucurbits has been witnessed with the deployment of vegetable grafting. To attain success in vegetable grafting a potential rootstock that is compatible and appropriate to impart tolerance should be selected which is most often varietal/ species specific.

History of vegetable grafting
Vegetable grafting work was started during late 1920s in Japan and Korea with prime focus to prevent fusarium wilt in cucurbits *viz*. watermelon (*Citrullus lanatus* L.) on pumpkin (*Cucurbita moschata*) (Leonardi, 2016; Kawaide, 1985) [15, 10]. 1920s onward vegetable grafting techniques transferred to other parts of world. In solanaceous vegetables, first grafting method was tried on aubergine (*Solanum melongena* L.) which was grafted on scarlet aurbergine (*Solanum integrifolium* L.) during 1950 (Oda, 1995) [20] and in tomato in 1960 (Lee and Oda, 2003) [13]. Lee (1994) [12] stated that grafted seedlings of Solanaceae and Cucurbitaceae were dominate upto 59 percent and 81 percent respectively during 1990. According to Lee *et al.* (2010) [14] Japan and Korea both are using grafted seedlings for watermelon cultivation in area of about 92 percent and 95 percent respectively.
After initiation of vegetable grafting in India by R.M Bhatt and his associates at IIHR, Bangalore; NBPGR regional station, Thrissur, Kerala was worked on Cucurbit grafting in *Momordica cochinchinensis* to improve production by grafting of female plant on male followed by some private sectors like VNR seed Pvt. Ltd., Chhattisgarh and Takki Seed India Pvt. Ltd. to supply bacterial wilt resistant planting materials to farmers for commercial vegetable cultivation. More than 22 rootstocks of tomato, brinjal, chilli and cucurbits were identified to import bacterial and nematodes by CSKHPKV, Palampur. TNAU, Coimbatore also worked on brinjal grafting utilizing *Solanum nigrum* as stock plant.

Necessity of vegetable grafting
Prime objectives of vegetable grafting is to impart resistance against serious diseases and pests, reduce chemical loads on plants and fruits, resistance against abiotic stresses, quality improvements and quantitative improvements through use of desirable stock plants.

Benefits of grafting technique in vegetable cultivation
Tolerance to Biotic stresses (soil-borne diseases)
Soil-borne diseases like fusarium wilt and bacterial are the serious problem in cucurbits and solanaceous vegetable cultivation. To overcome such problem grafting method is most useful in vegetable production (Oda *et al.*, 1995) [20]. Nisini *et al.* (2002) [19] suggested that to control race 1 and 2 of *Fusarium oxysporum* and *f. melonis* in melon grafting emerge as best and quickest method. When pepper scion Nokkwang grafted on PR 920, PR 921 and PR 922 lines showed resistance against Phytopthera blight and bacterial wilt with highest success percentage when *Phytophthora capsici* and *Ralstonia solanacearum* used for inoculation of causal organism (Jang *et al.*, 2012) [8]. Attia *et al.* (2003) [2] stated that when susceptible pepper scion (cv. Gedon) grafted on stock plants resistant to Rhizoctonia root rot and Fusarium wilt cultivated in disease infested soil showed less disease infestation whereas in case of non-grafted plants infested more.

Tolerance to abiotic stresses
Continuous change in climatic condition is the major concern of vegetable production in whole world. Now development of tolerant variety or planting materials is the utmost important with changing scenario. Venema (2008) [25] suggested that development of variety with tolerance to extreme temperature for winter greenhouse fruit vegetable production is crucial factor. Rouphael *et al.* (2008) [22] reported that during grafting of mini watermelons on commercial rootstock PS1313 (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne) exhibits higher production up to 60% under water stress condition (drought) compare to ungrafted. Increase in production in grafted plants is enhanced by improve in water and nutrient uptake as the influence of rootstock on scion (Schwarz *et al.*, 2010) [23]. Use of salt tolerant rootstocks in watermelons can increase yield up to 81% under protected structure (Colla *et al.*, 2010) [23]. Zhou *et al.* (2007) [27] found that flavour, taste and nutrient contents of grafted cucumber improves under NaCl stress soil compare to non-grafted. Liao and Lin (1996) [16] suggested that tolerance of plants against flood in bitter gourd cv. New Known was enhanced by grafting on *Luffa cylindrica* Roem cv. Cylinder.

Impact of grafting on qualitative and quantitative aspects of vegetable production
Under a number of biotic and abiotic stress conditions use of tolerant/resistant rootstock for vegetable production is consider as sustainable method. Rootstock has direct impact on quality of fruits (Flores *et al.*, 2010) [6]. Grafted tomato plants produced high yield with good quality produce under soilless cultivation practices (Gerbologlu *et al.*, 2011). Rootstock *Solanum torvum* when used for grafting of brinjal it improves fruit size. Rootstocks can affect sugar, flavour, colour, carotene content and texture of grafted plants (Davis *et al.*, 2008) [5]. Nicoletto *et al.* (2013) [18] reported that solutes responsible for quality of fruits are translocated through xylem and rootstock directly influenced quality parameters like fruit shape, colour, smoothness, texture, colour (flesh) and TSS of fruits. Whereas, vitamin C and firmness of brinjal was negatively affected when grafted on *Solanum torvum* and *Solanum sisymbrifolium* (Arvanitoyannis *et al.*, 2005) [1]. Yamasaki *et al.* (1994) [26] reported that grafting delayed flowering in pumpkin, bottle gourd, wax gourd and watermelon when Shintosa used as rootstock. The delayed in flowering in grafted vegetable plants may be due to age and growth of scion taken for grafting (Maurya *et al*., 2019) [17].

Techniques of vegetable grafting
Different grafting methods are adopted in vegetable crops. Cleft and tube grafting are used in solanaceous crops whereas for cucurbits like cucumbers tongue approach grafting is used. For watermelon and melon crops slant-cut grafting is more convenient and popular method. Slant-cut grafting is easier and has recently become popular for watermelon and melon. Lee *et al.* (2010) [14] stated that adoption grafting technique is mostly rely on crops selected for grafting, farmers experience on growing grafted plants, intent of grafting and machinery and infrastructure available for it and he also suggested that manual grafting method is mostly practiced and more convenient than machinery used.

(a) Cleft grafting
Otherwise known as apical and wedge grafting. Johnson *et al.* (2011) stated that pruning of scion plants is done at 1-3 true leaves stage and a slanting cut is given at bottom portion of the stem to make a wedged shaped tapering end and with the help of a plastic clip scion inserted to stocks. This cleft method is mostly adopted in solanaceous vegetables like tomato and brinjal.

(b) Tube or Japanese Grafting
Basically used when seedlings are grown in plug trays. It's a

more easy convenient and 2-3 times faster method of vegetable grafting than normal vegetable grafting. The small size seedlings can accommodate in healing chamber or acclimatization chamber. A sharp cut of 45^0 angle below cotyledon is giving in rootstock. Similar cut also given in scion. With help of tube both rootstock and scion are united and placed the tray in healing chamber up to 7 days.

(c) Tongue approach grafting

It is a more labour intensive method and more space requires but the success percentage is more compare to other methods. More commonly adopted by small farmers and nursery. Seedlings having hallow hypocotyls are not used as rootstocks. Size of the both scion and stock are similar. To achieve uniform size of scion seeds are sown one week prior to rootstock raising. Cucumber and pumpkin seeds are sown 10-13 days and 7-10 days respectively prior to rootstock seed sowing. Rootstock shoot tip is removed to avoid further growing of shoot. Tongue like cut is made in both scion and stock and union is done with help of plastic clip at graft union point.

(d) Slant-Cut Grafting: This is a more commonly practised and popular technique and developed for robotic grafting.

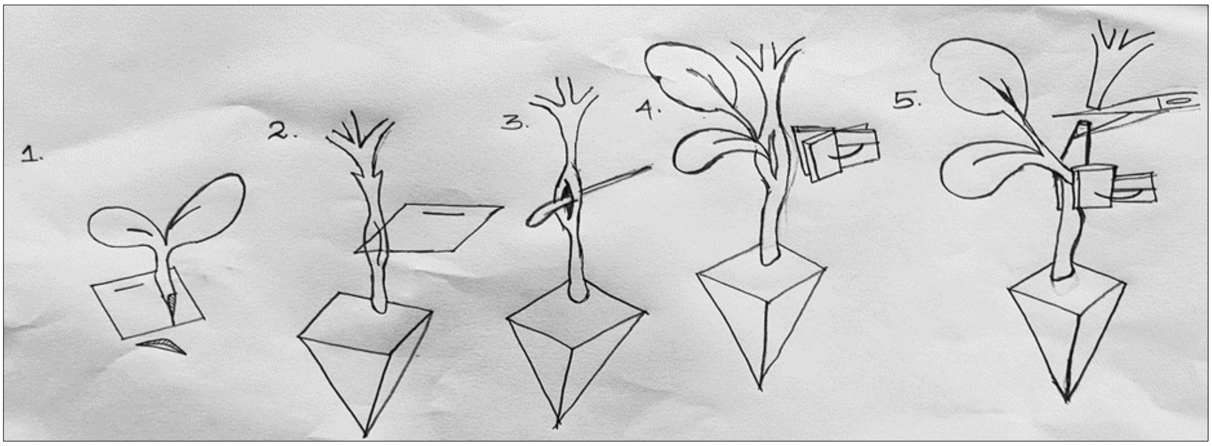

Fig 1: Vegetable grafting procedure (1) Collection and preparation of scion (2) & (3) Preparation of stock plant (4) Insertion of scion in rootstock, and (5) Placing of plastic clips and removal of shoot portion of rootstock above graft union.

Points to remember during vegetable grafting

1. **Selection of rootstock and scion:** Selection of desirable and uniform size of rootstock and scion and grafting method should be practised at 2-3 true leaf stage.
2. **Compatibility:** Use of compatible rootstock and scion can increase survival percentage with low mortality of seedlings also causes rapid callus formation which influence success and survival of grafts.
3. **Tools:** Use of grafting tools like clips, tubes, grafting blade
4. **Screening chamber:** Used for growing healthy seedlings. 60 mesh nylon net is used for covering side wall of the structure and UV resistant polythene is used for cladding of upper half.
5. **Healing of grafted plants:** It is the most critical pre-requisite for vegetable grafting. Under healing chamber favourable conditions like temperature (28-29^{0}C) RH (95%) should be maintained for around one week under partial shade condition for formation of callus at the grafting joint point.
6. **Hardening:** After callus formation at graft union point and successful union of stock and scion it's important to expose grafted plants to outside condition temporarily to harden then plants against adverse field conditions so that mortality of the grafts in field can be minimized.

Determination of success of grafting

When vascular bundle of both rootstocks and scion united together translocation of water and nutrients take place from stock to scion as well as transfer of photosynthetic materials from scion to stock is considered as successful grafting (Tirupathamma *et al.*, 2019) [24]. Sometimes to estimate success of grafting method is assessed by practical experience of grafter or nurserymen. In modern commercial nurseries, they are using certain methods to determine the graft success like;

1. **Thermic camera:** In this method water transfer from root to shoot is determined to judge the graft success. In case of successful grafts smooth transfer of water from root to shoot system whereas in unsuccessful grafted plants temperature of leaves is 2-3^0 C lower than root system due to transpiration loss of water. But, in partial successful grafted plants intermediate leaf temperature estimated (Bletsos and Olympios, 2008) [3].
2. **A vertical cut at the surface of the graft:** Bletsos and Olympios (2008) [3] stated that when tomato seedling grafted on its own rootstocks connection of vascular system is direct but when grafted on brinjal it is surface and in *Solanum torvum* it is larger.
3. **Measurement of the electric wave:** Electric wave is transferred through union point from scion to stocks. Histological changes during union process is recorded from high to medium and finally zero at which point callus formation is completed and vascular bundle becomes fully functional in tomato (Bletsos and Olympios, 2008) [3].

Drawbacks in vegetable grafting

Grafting method in vegetable cultivation is an advance and least adopted propagation methods and this is due to certain problems prevails during grafting and after care so that it's quite difficult in part of common grower and small scale nursery men to adopt. For vegetable grafting specially trained workers are required and it is more labour intensive, proper time management is required to raise stocks and scions as per requirement, controlled environment and healing chamber and stock-scion incompatibility. Apart from this occurrence/ spreading of pathogens like soil borne and viral diseases also takes place. Finally the cost of grafted seedling is higher compare to normal vegetable seedlings which is another drawback to adopt grafted seedlings in farmers' field.

Provision for successful grafting

To achieve maximum success in vegetable grafting some points should be taken in to consideration like use of grafting techniques w.r.t. crops and species specific, desirable environmental conditions for callus formation and healing of union point, right stage of scion and rootstock growth. Utmost care must be taken for provision of shade in grafting and growing areas as well as cut surface should not be allowed to dry. Prior to each succession of grafting tools and must be sterilized and growing media also sterilized to prevent any soil borne diseases at nursery stage. Personnel involved in grafting process must be well trained with good experience.

Apart from above mentioned precautions some limitations also prevails in vegetable grafting which directly influence its rate of success. Lack of primary information is on knowledge about appropriate rootstocks, availability, compatibility and adoptability to open field, production cost is too high compare to normal seedlings. Here we have to grow both rootstocks and scions for grafting purpose which increases seed cost and cost of trained personnel to carry out grafting technique. Controlled environmental protected structure is another pre requisite. As vegetable seedlings are herbaceous and succulent so it is difficult to do grafting. So, for that use of robotic machineries for commercial production also cost intensive which in overall increases production cost.

Future outlook

Apart from certain problems and limitations vegetable grafting has a better go after option for future. Distinguishing and screening of rootstocks taking various parameters like compatibility, tolerance to abiotic stresses and disease pest resistance into consideration and its multiplication. Identification and standardization of techniques for different crops with low cost planting materials production. Maximization of success percentage with minimal mortality is another aspect.

Conclusion

With changing scenario of global climatic conditions and occurrence of more diseases pests it is become difficult to harvest optimum yield for crops fields to check biotic stress abandoned use of chemicals is observed in farms which leads to chemical toxicity in the final produce. Now-a-days netizens are more concerned towards their health so the demand for chemical free quality produce is increasing in the markets. So, to meet up the consumers demand with less no chemical toxicity use of resistant / tolerant planting materials is most important but at the same time it is time consuming and long term trail process. That is why, use of tolerant/ resistant rootstocks against abiotic and biotic stresses with wider compatibility can be possible to reduce chemical loads on crops with quality produce over conventional methods.

References

1. Arvanitoyannis IS, Khah EM, Christakou EC, Bletsos FA. Effect of grafting and modified atmosphere packaging on eggplant quality parameters during storage. International journal of food science & technology 2005;40(3):311-322.
2. Attia MF, Arafa AM, Moustafa MA, Mohamed MA. Pepper Grafting, a method of controlling soil borne diseases and enhancement of fruit yield: Improvement of Pepper Resistance to Fusarium Wilt. Egy. J of Phyto 2003;31(1-2):151-165.
3. Bletsos FA, Olympios CM. Rootstocks and grafting of tomatoes, peppers and eggplants for soil-borne disease resistance, improved yield and quality. The European Journal of Plant Science and Biotechnology 2008;2(1):62-73.
4. Colla G, Rouphael Y, Leonardi C, Bie Z. Role of grafting in vegetable crops grown under saline conditions. Scientia Horticulturae 2010;127(2):147-155.
5. Davis AR, Perkins-Veazie P, Hassell R, Levi A, King SR, Zhang X. Grafting Effects on Vegetable Quality. Hort. Sci 2008;43(6):1670-1672.
6. Flores FB, Sanchez-Bel P, Estañ MT, Martinez-Rodriguez MM., Moyano E, Morales B *et al.* The effectiveness of grafting to improve tomato fruit quality. Scientia horticulturae 2010;125(3):211-217.
7. Goldschmidt EE. Plant grafting: new mechanisms, evolutionary implications. Front. Plant Sci 2014;5:1-7.
8. Jang Y, Yang E, Cho M, Um Y, Ko K, Chun C. Effect of grafting on growth and incidence of *Phytophthora* blight and bacterial wilt of pepper (*Capsicum annuum* L.). Hort. Env. Biot 2012;53(1):9-19.
9. Johnson SJ, Kreider P, Miles CA. Vegetable Grafting: Eggplants and Tomatoes. Washington State University Extension 2011.
10. Kawaide T. Utilization of rootstocks in cucurbits production in Japan. Jpn. Agr. Res. Qrtly 1985;18:284-289.
11. King SR, Davis AR, Zhang X, Crosby K. Genetics, breeding and selection of rootstocks for Solanaceae and Cucurbitaceae. Sci. Hort 2010;127(2):106-111.
12. Lee JM. Cultivation of grafted vegetables: Current status, grafting methods and benefits. Hort. Sci 1994;29(4):235-239.
13. Lee JM, Oda M. Grafting of Herbaceous vegetables and Ornamental Crops. Hort. Revi 2003;28:61-124.
14. Lee JM, Kubota C, Tsao SJ, Bie Z, Echevarria PH, Morra L *et al.* Current status of vegetable grafting: diffusion, grafting techniques, automation. Sci. Hort 2010;127:93-105.
15. Leonardi C. Vegetable grafting tour introduction. University of Catania, Sicily, Italy 2016, 23.
16. Liao CT, Lin CH. Photosynthetic response of grafted bitter melon seedling to flood stress. Env. And Exp. Bot 1996;36:167-172.
17. Maurya D, Pandey AK, Kumar V, Dubey S, Prakash V. Grafting techniques in vegetable crops: A review. International Journal of Chemical Studies 2019;**7**(2):1664-1672.
18. Nicoletto C, Tosini F, Sambo P. Effect of grafting and ripening conditions on some qualitative traits of 'Cuore di bue'tomato fruits. Journal of the Science of Food and Agriculture 2013;93**(**6):1397-1403.
19. Nisini PT, Colla G, Granati E, Temperini O, Crino P, Saccardo F. Rootstock resistance to Fusarium wilt and effect on fruit yield and quality of two muskmelon cultivars. Sci. Hort 2002;93:281-288.
20. Oda M. New grafting methods for fruit–bearing vegetables in Japan. Japan Agricultural Research

Quarterly 1995;29:187-198.
21. Rivard CL, Louws FJ. Grafting to Manage Soil borne Diseases in Heirloom Tomato Production. Hort. Sci 2008;43(7):2104-2111.
22. Rouphael Y, Cardarelli M, Colla G, Rea E. Yield, mineral composition, water relations, and water use efficiency of grafted mini-watermelon plants under deficit irrigation. Hort Science 2008;43(3):730-736.
23. Schwarz D, Rouphael Y, Colla G, Venema JH. Grafting as a tool to improve tolerance of vegetables to abiotic stresses: Thermal stress, water stress and organic pollutants. Scientia Horticulturae 2010;127(2):162-171.
24. Tirupathamma TL, Ramana CV, Naidu LN, Sasikala K. Vegetable Grafting: A Multiple Crop Improvement Methodology. Current Journal of Applied Science and Technology 2019;33(3):1-10.
25. Venema JH, Dijk BE, Bax JM, Hasselt PR, Elzenga JTM. Grafting tomato (*Solanum lycopersicum*) onto the rootstock of a high-altitude accession of *Solanum habrochaites* improves suboptimal-temperature tolerance. Env. and Exp. Bot 2008;63:359-367.
26. Yamasaki A, Yamashita M, Furuya S. Mineral concentrations and cytokinin activity in the xylem exudate of grafted watermelons as affected by rootstocks and crop load. Journal of the Japanese Society for Horticultural Science 1994;62(4):817-826.
27. Zhou Y, Huang L, Zhang Y, Shi K, Yu J, Nogués S. Chill-induced decrease in capacity of RuBP carboxylation and associated H2O2 accumulation in cucumber leaves are alleviated by grafting onto fig leaf gourd. Annals of Botany 2007;100(4):839-848.