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GRAFTING AS A STRATEGY FOR THE IMPROVEMENT OF CUCURBITS AND SOLANACEOUS VEGETABLES: A REVIEW

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Abstract

Grafting in today's world is recognized as an approachable technique with respect to modern horticulture area. It has become a popular technology among the vegetable growers and scientists and presently it is being widely utilised especially in solanaceous and cucurbitaceous vegetable crops which helps in eliminating various challenging environmental stresses. Under the present changing climatic conditions, grafting can play a significant role to improve vegetable productivity, provide resistance against soil borne diseases and insect pests, tolerance to abiotic stresses thereby improving the uptake of water and nutrients, increase the vigour of scion, fruit size and quality and extend the harvest period. The study in this review paper is generally engrossed around grafting the researches mostly done on grafting in certain vegetables.

Key words: Abiotic and Biotic Stress, Cucurbits, Grafting, Rootstock, Scion, Solanaceous vegetables

Introduction

Grafting is a friendly and innovative technique that was mostly used across the world as in continuous cropping systems (Aslam *et al*., 2020). In the world of horticulture industry, grafting has gained tremendous importance, and side by side the demand of grafted plants has dramatically increased because of increased resistance to biotic, abiotic stresses and its high yielding nature (Rouphael *et al*., 2017). Grafting has been employed to enhance resistance against several soil borne pathogens, stresses and depicted to increase fruit yield alongwith the uptake of nutrient content (Rouphael *et al*., 2010 & Miguel *et al*., 2004). The major role of grafting is to extend the production and yield of crops which further fulfils the increasing requirement of growing population (Condurso *et al*., 2012; Davis *et al*., 2008 & Liu *et al*., 2013).

Grafting method is considered as best one to be included in organic farming (Sen *et al*., 2018). Additionally, a combination of rootstock and scion has notable influence on the growth and ultimately yield of the plants (Voutsela *et al*., 2012). The selection of rootstock and scion should be appropriate because the rootstock may have an impact on the shape of fruits of the chosen scion (Tsaballa *et al*., 2013). In addition, grafting is preferred to combat against the adverse effects of soil borne diseases (Lee, 1994 & Rouphael *et al.,* 2017). Moreover, grafting helps in enhancing the uptake of nutrients and decreases the unfavourable effects of minerals like cadmium and toxicity of copper alongwith enhancing qualitative traits of fruits (Colla *et al*., 2010; Venema *et al*., 2008; Rouphael *et al*., 2008; Savvas *et al*., 2009 & Aloni *et al*., 2010).

In the Netherlands, grafted tomato transplants are utilised for all the tomato grown under soil less culture. In China, commercial nurseries over 1500 are developing grafted transplants. The international trading for transplanting of grafted vegetables is growing rapidly upward where Canada is exporting grafted vegetables transplants to Mexico, (Bie *et al*., 2017). The materials used for wrapping in grafting and the dates from when it was grafted had a remarkable influence on days to sprouting (50%), scion length, scion sprouted leaves and grafting success (Devkota *et al*., 2020).

Methods of grafting

Grafting method totally depends on the farmers experience, the crop, the person's choice, the number of grafts required, the motive of grafting, the access to work and the availability of infrastructure and machinery (Lee *et al*., 2010). For herbaceous grafting, DIMEAS (Department of Mechanical and Aerospace Engineering) of the Politecnico di Torino in collaboration with DISAFA *i.e.* Department of Agricultural Forest and Food Sciences

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from the Universitàdegli Studi di Torino developed innovative system of robotic basically controlled electro-pneumatically. This fully automated machine is quite preferable on the environment and also for cultivars quality because of minimal utilization of pesticides capable for picking, cutting, choosing, joining two plants so that to achieve grafted one (Belforte *et al*., 2017). There are also several other methods to perform grafting techniques including splice grafting or tube grafting, pin grafting, top insertion or hole insertion grafting, apical grafting, tongue or approach grafting, cleft grafting, post-graft healing environment (Abd AL-Razaq, 2019 & Maurya *et al*., 2019).

Cucurbits

The first vegetable seedlings that were grafted were used to overcome the *Fusarium* wilt disease for *Citrullus lanatus* L. plants being grafted on rootstock of bottle gourd (*Lagenaria siceraria* L.) (Gaion *et al*., 2018). The grafting increases disease resistance, affinity, stress tolerance, quality and yield of cucurbitaceae plants (Chen *et al*., 2012). The grafting of watermelon onto bottle gourd rootstock enhances tolerance from flood in loamy or heavy loamy soils (Gaion *et al*., 2018). Cucurbits grafted in sandy soils on pumpkin rootstock provide tolerance from conditions of drought (Anonymous, 2018). The assumption of grafting in a way to secure productivity and crop stand of watermelon, especially against biotic stress type conditions, by far surpasses from some other fruit crops that can be from other annually open cultivated one (FAO, 2012).

According to analysis based upon economic factor, the production of grafted cucumber showed higher benefit-cost ratio and net returns in comparison with the system of production for hybrids of cucumber which are authentically rooted and assumed as beneficial practice. Rootstocks which have higher compatibility with cucumber hybrid "Kalam F_1" scion showed noticeable comparable performance with respect to yield, vegetative growth or storage excluding pumpkin during all seasons with hybrid rootstock. The rootstock of plant bottle gourd (*Lagenaria siceraria*) observed as the highest rate of survival *i.e.,* 94%, 98% and 93%, respectively during three seasons as compared to all other hybrid rootstocks and cucurbitaceous (Aslam *et al*., 2020). Chuang *et al*. (2010) studied tissue culture and vegetable grafting in seedless watermelon carried out through use of chlorine dioxide (250 mg/l) disinfector which was used to treat embryo of watermelon, had many advantages in watermelon embryo germination.

Balkaya *et al*., (2016) cited that genotypes of cucurb it rootstock evaluated as having large scale of variation in context to tolerance for salt stress. Seven inbred lines from pumpkin, three inbred lines from winter squash and three hybrids (interspecific) of *C. maxima* × *C. moschata* were promising for salt stress, rootstock was purely recommended for seedling production from grafted melon, watermelon and cucumber. Ulas *et al*., (2019) concluded the selection of hybrid rootstocks *Cucurbita maxima* × *C. moschata i.e.* salt tolerant improves the performance of melons under any conditions of salt stress, on the contrary the combinations of appropriate rootstock/scion need to be investigated in further studies under saline type conditions for quality parameters and fruit productivity. Marsic and Jakse (2010) examined growth attributes and yield factors for grafted cucumber in several different soilless substrates displaying significant grafted plants were produced forming longer root systems and larger stems leading to increased yield (24%).

Cucumber when grafted on *Cucurbita pepo* rootstock performed well as compared to other grafts which might be because of improved phytohormones, non-photochemical quenching status and active enzymatic ROS (reactive oxygen species). The free radical scavenging activity increased in grafted cucumber under the conditions of salinity stress (Elsheery *et al*., 2020). Poor (2015) concluded that grafted watermelon (Charleston Gray) plants onto pumpkin (*Cucurbita pepo*) were drought tolerant and length of roots, number of leaves were significant attributes whereas wet, dry weight were insignificant. The most favoured commercial rootstock for vegetable cucumber belonging to genus *Cucurbita* is the interspecific cross *C. maxima* × *C. moschata* which has been utilized as an adaptable source of rootstocks (Lee *et al*., 2010).

The deteriorated quality of fruits in the grafted plants is chiefiy due to reduction in the level of acidity and sweetness and is particularly a common difficulty with hybrids from *Cucurbita* that are observed frequently in interaction of scion and rootstock, further aggravated by practices of crop management (Davis *et al*., 2008 & Rouphael *et al*., 2010). Kyriacao *et al*. (2017) investigated the suggestion of grafting for quality of watermelon fruit, involving mostly interspecific hybrids such as (*Cucurbita maxima* (Duchesne) × *C. moschata* (Duchesne ex Poir) and bottle gourd rootstocks like [*Lagenaria siceraria* (Molina) Standl]. Grafting increases enzymes of anaerobic respiration in adventitious and tap root system of bitter melon by improving bitter melon tolerance to water logging conditions, expanding bitter melon parenchyma adventitious roots (Peng *et al*., 2020).

Solanaceous vegetables

In solanaceous vegetables *viz*. tomato, grafting improves characteristics of fruit such as its firmness,

lycopene content, total soluble solids, pH, vitamin C and commercial rootstocks around 33% showed promising outcomes against soil-borne pathogens (Grieneisen *et al*. 2018). Semiz and Suarez (2015) observedthat when cultivar Big Dena was grafted on tomato cultivar rootstock 'Maxifort', it displayed increase in range of yield under favourable saline conditions when differentiated with the plants that were non-grafted. The environmental conditions like salt stress can be overcome by grafting salt-susceptible cultivars of tomato onto salt-tolerant or resistant rootstocks which is known as sustainable strategy, and further it also enhances the yield of tomato fruits (Singh *et al*., 2020).

The grafted fruit plants obtained were subjected to 100 mM sodium chloride which demonstrated the highest content of vitamin C and total phenols. The treatments that were without any salt stress had higher range of lycopene content as well as higher yield whereas the activity of Superoxide dismutase increased with sodium chloride and grafting (Leon *et al*., 2020). Alzate *et al*., (2018) described that under the conditions of biotic and abiotic stress, grafted vegetables have the capability to better use chlorine and confer better regulation of photosynthesis in contrast to non-grafted vegetables. The photosynthetic regulation may be at high point because higher chlorine content decreases water loss from leaves. Gebologlu *et al*., (2011) reported that when plant material as cv. Yanký F_1 and *cv.* Esin $F_1$and rootstocks *viz.* Spirit F_1, Groundforce, ES30501, 8411, Beaufort, ES30502, Titron, K8 and R801 were utilized as treatment in accordance to self-grafted and non-grafted plants, marketable yield was increased from 13.85% to 32.73%. Similarly, titrable acidity, ascorbic acid, water solubilisable dry matter was unaffected by these rootstocks and grafted plants used did not significantly affected tomato fruits nutrient content.

Urlic *et al.,* (2020) studied about tomato cultivars 'Clarabella' and 'Belle' ungrafted, graftedand self-grafted on'He-man' the rootstock which further were cultivated undergoing two different regimes of irrigation; first one was partial-root zone drying and second one was fully irrigated. The regime of partial rooted zone in ungrafted plants fruit juice had the highest acidity and brix level; on the other side the grafted seedlings had outstandingly higher efficiency of using water. Grafting when considered in the production of tomato as a cultivation practice reduced sugar content while uptake of some micro, macro elements was increased. This led to less elastic and firmer skin of tomato fruits which further increased its marketability (Milenkovic *et al*., 2020). Application of grafting techniques in tomato leads to the formation of more flowers specifically for outdoor cultivation however for indoor cultivation remarkable effects were noticed on both total number of fruits and total fruit weight (Voutsela *et al*., 2012).

Cayenne pepper, sticky nightshade and Jerusalem cherry were not utilized in terms of rootstocks for the scions of Santa Cruz Kada which is from tomato cultivar. The mini-tomato cultivar accession called as RVTC-66 analysed as high efficiency of photosynthesis, low incompatibility grafting when compared to the production of same fruit in self-grafting yet with raised index value of plant health regarding bacterial wilt disease (Zeist *et al*., 2018). The interaction between grafting and rootstock had influence on the rate of plant development and graft-taken. S*olanum pennellii* and 6889-50 mini-tomato (*S. lycopersicum* L.) should not be recommended as rootstock whereas full type of cleft grafting were mostly adoptable for *Physalis* and *Cocona* whereas approachable method depicts better results for mini-tomato cultivar accessions RVTC 20, 0224-53 and RVTC 57, even for *S. habrochaites* (Zeist *et al*., 2017). Intergeneric grafting in solanaceae and cucurbitaceae family was recorded between tomatoes and goji plants in which at the rate of fruit ripening content of chlorophyll and net photosynthetic rate were at higher level (Huang *et al*., 2015).

Brinjal cultivars when was grafted onto 'Beaufort' F_1 shows improvement in terms of fruit quality and yield, which was then attributed to greater grafted plants vigor (Maršiæ *et al*., 2014). 'Beaufort' F_1 is the rootstock in grafted eggplant cultivar Epic that helps in inducing resistance to *Verticillium* wilt (Johnson *et al*., 2014 & Miles *et al*., 2015). N dereyimana *et al*., 2013 reported the production of grafting done in eggplant through drip fertigation by opting spacing of 1 × 1 m along with 100% RDF is recommended because the outcome involves high marketability, earliness and superiority of the crop. Egg plant genotypes named as 'Mardin Kýzýltepe' and 'Burdur Merkez' that are salt-tolerant and 'Artvin Hopa' and 'Kemer' that are salt-sensitive were selected as scions. The seedlings followed by grafting induced salt tolerance registered lower peroxidation of lipids ,lesser Na^+ and Cl^- concentration and enzyme activities that are antioxidative. The bacterial inoculation significantly counteracted the adverse effects of induced salt stress on characteristics of growth, leaf chlorine, sodium content and anti-oxidative enzymatic activities. Grafting and inoculation with bacteria *Serratiam arcescens* were mainly effective in improving the growth and some important physiological processes in eggplant (Turhan *et al*., 2020). Villeneuve *et al*. (2016) reported grafting on

resistant rootstock as an alternative technique to disinfect the soil status. Solanaceous vegetables offer a wide choice for candidate species as rootstock. The goal of several species of *Solanum* with brinjal presented a fine graft affinity.

Innovations in grafting technology

Grafting techniques should have minimally two well defined functions: first having healthy rootstocks that are resistant to any diseases should be employed to reduce crop losses. Secondly, hybrid lines of rootstock should be identified in absence of disease pressure for increased crop yield and plant vigority (Yassin and Hussen, 2015). Moreover, for growers, the grafting technique for IPM (integrated pest management) is an effective tool that faces pressure of heavy diseases like pathogens generally soil borne (Rivard and Louws, 2008). With the help of cleft grafting, double grafted and single grafted tomato i.e. Pomato was produced. In Netherlands, grafting Robots which is fully automated model was developed that can graft thousand seedlings of tomato or eggplant per hour thereby increasing the success rate of crop productivity (Maurya *et al*., 2019). The capability of grafting robot is usually greater than the mode of one-operator's feeding speed yet lower (Xie *et al*., 2020).

Micro-grafting done in herbaceous plants by using micro explants from meristematic tissues to analyze grafting physiology and to eliminate the viruses from infected plants. This method of grafting is expensive providing very fast virus free plants propagation (Maurya *et al*., 2019). The automatic robot grafting performed using technique known for image recognition was superior with the success rates of grafting done in cucumber and tomato as 96±3.2 96±3.2 and 95±4 95±4, respectively (Kang *et al*., 2019).

Conclusion

Grafting being well established technique triggers the plant production as well as yield so the adoption of this method should be enhanced as consumers can take maximum benefit from this methodology. Proper selection and use of highly compatible scion and rootstock is quite important for obtaining higher fruit yield and better quality characteristics in the resultant grafted plant. Therefore, there is a need to identify, evaluate and screen new genotypes for developing tolerant rootstocks for various biotic and abiotic stresses by exploiting the wild and elite germplasm. Further studies should be emphasized in breeding aspects for identify regulations in genes and signalling factors across grafting.

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