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Vegetable Grafting

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Abstract—*First literature report on vegetable grafting published by Korean scientist Hong in 17th century. However, it was not shaped in common practice until the 20th century in Asia. The development and utilization plastic films in agriculture creates new dimensions in middle of 20th century in japan and korea that helps to increase the production and distribution of grafted seedlings which results scientific investigations for ideal rootstocks. It has been gradually occupied unique role in the second half of the 20th century in various aspects in the manner of yield, fruit quality, stress resistance and ecofriendlynature. In 21st century it plays significant role in précised resource management in agriculture. Grafting is a method of asexual propagation where two living plant parts (the rootstock and scion) are united together to grow as a single plant. Grafting of a scion cultivar which is agronomically superior but lacking one or few characters onto a suitable rootstock facilitates the easy combining of characters. Grafting in vegetable crops provides ample of advantages viz.,eliminates incompatible barriers in distant hybridization, manage soil-borne diseases, improve fruit quality[appearance, size, shape, color, firmness, texture, pH, carotenoid content, flavour(sugar, acids, and aroma volatiles)], improve crop response to abiotic stresses such as salinity, drought, flooding and tolerance against heat and cold stress. It is eco-friendly in nature due to reduction in utilization of agrochemicals for management against pests, pathogens and paving paths towards organic farming of vegetables. This article provides detail information on grafting methods and applications in different vegetable crops.*

1. INTRODUCTION

Grafting is an ancient technique, in vegetables first literature reports available in 17th century book written by Hong.The production of grafted vegetables first started in Japan and Korea in the beginning of 20th century **with watermelon (*Citrulluslanatus*) grafted onto pumpkin(*Cucurbitamoschata*)rootstock. Eggplant (Solanummelongena) was grafted onto scarlet eggplant (*SolanumintegrifoliumPoir*.) middle of 20th century Later, grafting was introduced in Asia, parts of Europe and the Middle East in late 20th century.**Vegetable grafting is a process involves joining together two parts (a rootstock and scion) from different plants to form a single, living plant. Rootstock is a plant already has an established, healthy root system and is selected for their ability to resist under abiotic and biotic stress condition or their ability to increase vigour, precocity and enhanced yield and quality. The scion of the grafted represents the upper portion of the plant and is selected for its fruit quality characteristics. Grafting may affect the vegetative growth, flowering, flower modification due to regulating the growth hormone, increase the vigor of the crop, resulting in earlier or higher yields and superior quality. Grafting in vegetable crops provides ample of advantages viz.,eliminates incompatible barriers in distant hybridization, manage soil-borne diseases, improve fruit quality[appearance, size, shape, color, firmness, texture, pH, carotenoid content, flavour(sugar, acids, and aroma volatiles)], improve crop response to abiotic stresses such as salinity, drought, flooding and tolerance against heat and cold stress. In the past, vegetable growers commonly used fumigation by using methyl bromide to control many of the most problematic soil-borne disease and nematode problems. Now a days grafting is an alternative to pesticides also fits in with the growing interest in organic or pesticide free production.The use of this technique is mainly carried out for intensive cropping systems like greenhouse production. It is ecofriendly in nature and imparting the resistance, reduces the need of soil disinfectants and provides opportunity to produce vegetables in biotic and abiotic stress condition without use of chemicals and has new vista in organic farming of vegetables.

2. IMPORTANCE OF VEGETABLE GRAFTING

1. **Achieve soil borne disease and pest resistances/tolerances**:-*Solanumtorvum* was more resistant than *S.sisymbriifolium* to *V.dahliae*, when grown on both fumigated and *Verticillium*-infested soil. Hybrid squashes (*Cucurbita maxima* Duchesne × *Cucurbitamoschata* Duchesne) are widely used as melon rootstocks are highly resistant to fusarium wilt and tolerant to verticillium wilt, monosporascus suddenwilt, and gummy stem blight [5].*Cucurbita maxima* were highly resistant and resistant to *M. incognita* in soil infested with nematode.
2. **Acquire tolerance to abiotic stresses**:-[10] investigated the effects of grafting a commercial tomato hybrid onto three new commercial tomato rootstocks – 'Beaufort','He-Man', and 'Resistar' – with respect to plant growth, yield, and fruit quality, under low to moderate salt-stress conditions.Grafted watermelons had a greater tolerance when watered with saline water than did the non-grafted plants and also resistant to flood [1].

3. **Increase vigor and yields**- Grafting eggplant onto interspecific eggplant hybrids, especially the *Solanumincanum* (SI) ×*Solanummelongena* (SM) with, has proved advantageous for eggplant production, because the high vigor and good rootstock/scion compatibility resulted in improved early and total yields, without apparently impairing fruit quality or composition. In tomato rootstock like Efialto', 'Heman' and 'Maxifort increase the marketable yield and enhance the lycopene content.The average yield of melon(44%) and watermelon(84%) plants grafted on different Cucurbita hybrids (*C. maxima* x *C. moschata*) as rootstocks were much higher than the yields of the non-grafted plants.By grafting watermelons on to different rootstocks, the quality of the fruit has been known to increase fruit firmness and thus increase shelf life
4. **Minimizing the autotoxic effect:** -Phenolic acid of root tissue and root exudates act as toxin in cucurbits Resistant (*Cucurbitaficifolia*).
5. **Survival of graftage under excessive moisture**:- Intergeneric grafting imparts the attributes of flood tolerance in cucurbits. Generally flooding reduces photosynthetic rate, stomatal conductance, transpiration, soluble protein. But these reaction minimized by intergeneric grafting of flood in tolerant bitter melon onto flood tolerance.
6. **Improving quality traits**:-Flavor, p^H, sugar, colour, carotenoid concentration, texture can be affected by type of rootstock used in watermelon stated by [2].[7] observed thatdifferent rootstocks affect graftedcucumber quality characteristics such as fruit shape,skin and flesh colour and texture, skin smoothness,firmness, rind thickness, and soluble solids content.
7. **Effect of grafting on flowering and harvest**:-Influence early flowering:[8]state that compared with other rootstocks, watermelon grafted onto bottle gourd causes early formation of female flower.Cucumber varieties grafted onto a squash interspecific hybrid rootstock inhibited flowering [9].
8. **High and low temperature Tolerance:-** Brinjal grafted on heat tolerant rootstock of brinjal seemed promising and resulted in prolonged growth stage and yield increase upto 10%. In low temperature cucurbit crops are not germinate so use of grafting for off season crop. Grafted watermelon seedlings under low temperature stress have higher antioxidants and antioxidative enzymeactivities in leaves than self-rooted watermelon seedlings [4].

3. GRAFTING TECHNIQUES

Different grafting techniques were adopted for different scions and rootstocks; they depend on grafting objectives, farmers' experience, and post grafting management conditions; and moreover, the survival rate of grafted plants depends on compatibility between scion and rootstock, quality and age of seedlings, quality of the joined section, and post-grafting management.

The initial grafting method used for melon was cleft grafting but after the introduction of the tongue approach grafting method, its use diminished greatly. The tongue approach method became widespread in Asia because of its higher success rate and the uniform growth of grafted seedlings. In Spain, high proportions (more than 90%) of watermelon plants are grafted using the one cotyledon method.

Choice of Rootstock:Root system more vigorous than scion.Overcome to low soil moisture. Overcome low fertility stress and salt stress.Hardiness in low and high temperature.Resistant to soil borne pathogen, pest and nematode. Increase vigor and precocity.

Choice of scion: Ability to produce higher yield and quality fruit.

1. **Tongue approach grafting (TAG)**:-It is easy to use and has a high success rate and the grafted seedlings have uniform growth rate shown in Fig. 1. The scions and rootstocks should be approximately the same diameter in the TAG method. This is usually the case after the rootstock has fully developed cotyledons and the scion has cotyledons and the first true leaf. Cut 45 degree downward slit halfway through the stem below the cotyledons, and cut an identically angled upward slit in the scion stem. The angle and location of the cuts must be relatively precise so the scion can be placed on top of the rootstock. Bring the two cut stems together so they overlap, then attach a clip or securely wrap the joined stems in plastic wrap, foil, or parafilm.

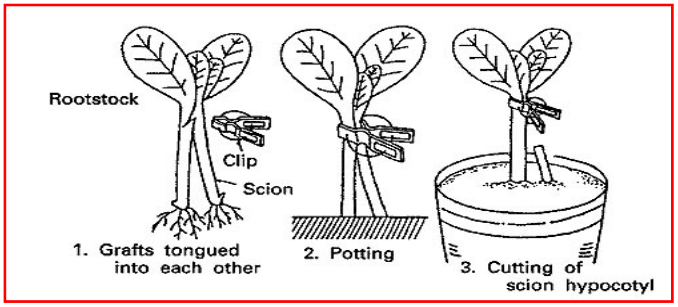

Fig. 1: Tongue Approach Grafting (TAG)

Place the joined plant in a transplant tray or small pot. Mist the plant with water and place it on a greenhouse bench. Water the plant as needed. Cut off the top of the rootstock 5 days after grafting. Wait 7 days, and then cut off the bottom portion of the scion. Advantages of TAG are relatively simple techniquefavoured by lessexperienced farmers, grafting clip is not essential and high humidity and low light environment is not required for successful healing of the graft union; a normal greenhouse environment is sufficient. Approach grafting is slowly losing popularity among commercial growers because of the extra labour and time involved in cutting the rootstock

twice, larger space demand compared to other methods, and a generally weaker graft union more prone to breaking or scion rooting after transplanting [3]. [6] reported that, tongue approach grafting (TAG) of significantly enhanced watermelon yield. In watermelons, cucumbers, and melons this technique is used.

2. Cleft grafting:-Cleft grafting (Fig. 2) in herbaceous plants may be some-what different from those of woody plants. This methodis simple and easy to learn, and is suitable for preventing soil borne diseases since the grafting junction is high on the hypocotyl. When cotyledons and the first true leaf start to develop (about 7 to 10 days after sowing) the rootstock is ready to graft. The rootstock seedlings are decapitated and longitudinal cut is made in a downward direction, 1–1.5 cm long and 3/4 depth of the stem diameter. The scion is pruned to have 1–3 true leaves and the lower stem is cut to slant angle to make a tapered wedge. After placing the scion into the split made on the rootstock, a clip is placed to hold in position until the union. Various types of grafting clips, differing in material, size, shape, and others, have been developed for cleft grafting. Plants should be maintained in the greenhouse until the junction is healed, and should not be more than 33 days old before transplanting. Cleft grafting had been used in cucurbits for a while in several countries, but the use is usually confined to solanaceous crops these days. In contrast, tongue approach and clefttechniques, which have high survival rates, are oftenchosen by the farmers who have plenty of space andadequate labour.

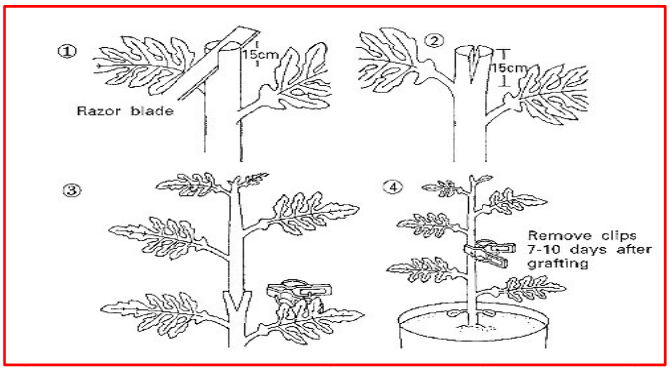

Fig. 2: Cleft Grafting (CG) fftc.agnet.org

3. Hole insertion grafting (HIG):-For watermelons, hole insertion hypocotyl grafting (Fig. 3) is favoured by many farmers in many areas because of the smaller seedling size of watermelon as compared to the size of the rootstock, which is usually squash or bottle gourd.There is a high success rate on rootstocks that are compatible with *Lagenaria*; however, a great concern lies within the high rate of remaining meristematic tissue since which will necessitate future re-growth removal and increasing grafting cost. First, true leaves and meristem tissue are removed at the growing tip of the rootstock. This method is easy, has high survival rate, and the grafted plants have fewer incidence of soil borne disease because of the high graft union. One person can produce 1,500 or more grafts/day and post-grafting acclimatization is simple. Next, a slit is made across the growing point from the bottom of one cotyledon to the other side of the hypocotyl. A shaved stick such as a toothpick or bamboo barbecue skewer can be used as the insertion tool. Leave the stick inserted in the growing point, while cutting the scion hypocotyl at both sides into a V shape. The scion is then inserted into the slit while the stick is removed. Hole insertion grafting produces high-quality grafted transplants because it maximizes the contacting surface area between rootstock and scion and affords protection of the graft union with both rootstock cotyledons. Another advantage of this method is that it does not require grafting clips, which reduces the grafting cost as well as the labour involved in collecting clips after healing.

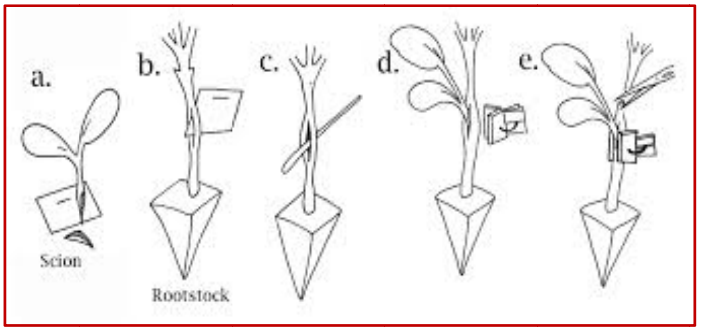

Fig. 3: Hole insertion grafting (HIG)

4. One Cotyledon Graft: The “one cotyledon graft” is also known as “splice” or “slant” grafting (Fig. 4).This graft is moderately simple being less labour intensive than approach grafting.The process of splice grafting is simpler than that of hole insertion grafting. First, the rootstock growing tip is cut at a 45-degree angle. The cut removes true leaves, meristem tissue, and one of the cotyledons. Next, the hypocotyl of the scion is cut at the same angle as the rootstock.

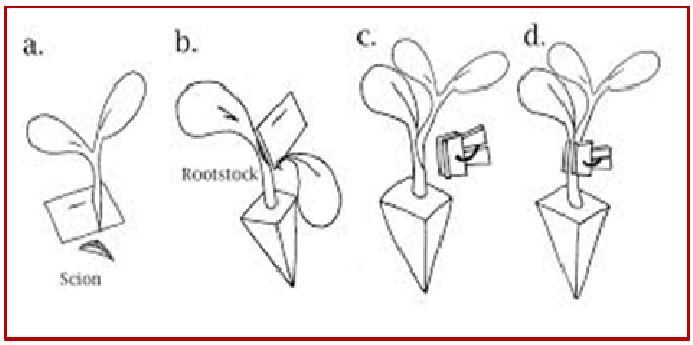

Fig. 4: One Cotyledon Grafting

The scion is then attached to the rootstock with a grafting clip. This method is most suitable for melon rootstocks, as it works best when the rootstock and scion have similar hypocotyl diameters. Hybrid squash rootstocks also are grafted with this method because it is simple to perform. The grafting technique

influenced the graft survival rate, with higher values recorded with splice grafting (78%) resulted by[10]. This is a simple technique that is relatively quick and easy to perform. The only task after grafting is to remove the clip. There is no trimming of unwanted plant parts after healing of the graft union

5. Tube grafting:-In tube grafting, a 45-degree diagonal cut is made through the entire stem in both the rootstock and the scion. Ideally, both cuts are made below the cotyledon, as this reduces the chance of the rootstock suckering after the graft has healed The two pieces are joined together and the graft union is covered by either a grafting clip or plastic parafilm. Newly grafted plants are immediately brought into a 'healing chamber'- a low light environment with high relative humidity and a minimum of 18 degrees C at all times. After approximately seven days the plants can be removed from the chamber. Tomato seedlings are almost always grafted using 'tube grafting' method in commercial propagation. This grafting method is also called 'Japanese Grafting Method'.

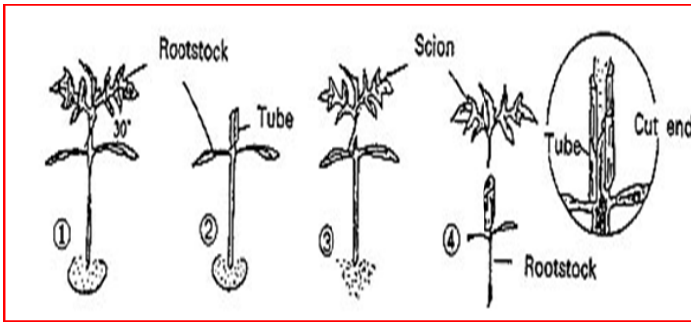

Fig. 5: Tube Grafting

6. Pin grafting (PG):-This method is similar to One Cotyledon Grafting, except that specially designed pins are used instead of grafting clips to secure the graft union. The cotyledons of the rootstock and scion are cuthorizontally, and a ceramic pin is inserted into the cut surface this helps align and secure the joined sections. This method's limiting factor is that the scion and rootstock should be approximately the same diameter so the cambial regions are in close contact. This method is easy, reducing labour cost, but ceramic pins add expense, and a special environmentally-controlled chamber is needed to acclimatize the grafted plants Fig. 6.

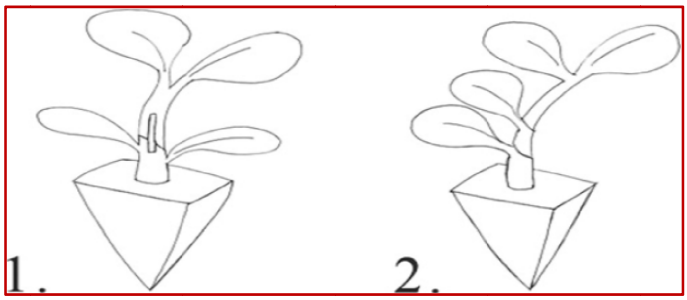

Fig. 6: (1) Pin grafting and, Fig. 7: (2) Double grafting

7. Double grafting (DG):-Double grafting (Fig. 7) is used when a perfect rootstock for a specific scion is unavailable. For example, if the rootstock is too large and an intermediate sized stem is needed to bridgethe rootstock and scion. The scion is first grafted onto a middle rootstock.The middle rootstock is then grafted onto another rootstock, which has goodresistance to soil borne diseases. Unfortunately this method increases labour and cost while decreasing survival rate.

Problem of vegetable grafting:-Labour for grafting operation,specially designed knives and grafting operating machine. Various problems are commonly associated with grafting and cultivating grafted seedlings. Major problems are the labour and techniques required for the grafting operation and post graft handling of grafted seedlings for rapid healing for 7 to 10 days. An expert can graft 1200 seedlings per day (150 seedlings per hour), but the numbers very with the grafting method. Similarly, the post graft handling method depends mostly on the grafting methods. Also improper management of post-grafting environment (High temperature, high humidity, direct overhead water, excessive light and insufficient light). Excessive light in the post grafting environment that force newly grafted plant to perform activities, such as photosynthetic that are difficult to heal and insufficient during hardening. Excessive vegetative growth.Uneven senescence.In sufficient sanitation at any stage from seed sowing through grafted plant healing,can promote the onset and transmission of the disease.

Key for success:-Selection of idealsize of scion and rootstock is an importantcriteria.Grafting clips should also be selected according to the size. Too big clips cannot hold the grafted union or too small clips gives too much pressure and may deform the union.

Rootstocks for grafting of vegetable

Crop	Rootstocks	Purpose
Cucumber	Fig. leaf (Cucurbitaficifolia), F_1 (C.maxima x C. Moschata), Cucumber (Cucumissativus) Sicyosangulatus	1,2,3 1,2,3 1,2 2,5
Melons (for open field)	Cucurbita spp. C. moschatax C. maxima Cucumismelo	1,2 1,2,3,8 1
Melons (for greenhouse)	Cucumismelo Benincasahispida C. moschatax C. maxima	1 1,2 1,2,3
Watermelon	Bottle gourd (Lagenariasiceraria) Interspecifi c hybri ds F_1 (C.maxima x C. Moschata), Cucumber (Cucumismelo) Wax gourd (Benincasahispida), Pumpkin (Cucurbi ta moschatus), Squash (Cucurbitapepo), Sicyosangulatus	1,2 1,2,3 1,2 1,2,3 1,2,3 1,2 5
Tomato	Lycopersiconpimpinellifolium L. esculentum Solanumnigrum	5 1,2 6

Eggplant	Solanumtorvum Solanumintegrifolium Solanummelongena Solanumnigrum	1,5,6,7 1,6 6 6,7
1: Fusarium wilts, 2: growth promotion, 3: low temperature, 4, growth period extension, 5: nematodes resistance, 6: Bacterial wilt, 7: Verticillium wilt 8: Charcoal rot		

4. CONCLUSION

Grafting can affect various quality aspects of vegetables. Rootstock/scion combinations should be carefully selected for specific climatic and geographic conditions. Appropriate selection can help control biotic and abiotic stress ultimately increase yield and quality.

REFERENCES

[1] Cohen, R., Burger, Y., Horev, C., Porat, A.and Edelstein,M., "Peformance of Galia-type melons grafted on to Curcurbita rootstock in *Monosporascuscannonballus*-infested and noinfested soils",*Ann. Appl.Biol*,2005, pp. 381-387.

[2] Davis, A.R., Perkins-Veazie, P., Hassell, R. L., King, S.R., "Grafting effects on vegetable quality". *Hort Science*, 43(6), 2008, pp. 1670-1672.

[3] Lee, J.M. and Oda,M., "Grafting of herbaceous vegetable and ornamental crops". *Horticultural reviews*, 2003, pp. 61-124.

[4] Liu, H.Y., Zhu, Z.J., Lu G.H., and Qian Q. Q.,"Study On Relationship Between Physiological Changes And Chilling Tolerance In Grafted Watermelon Seedlings Under Low Temperature Stress", *ScientiaAgriculturaeSinica,* 36, 2003, pp. 1325–1329.

[5] Louws, F. J., Rivard, C. L. and Kubota,C., "Grafting Fruiting Vegetables To Manage Soilborne Pathogens, Foliar Pathogens, Arthropods And Weeds," *ScientiaHorticulturae*,127, 2010, pp. 127–146.

[6] Mohamed, F.H., Abd El-Hamed, K.E., Elwan, M.W.M., Hussien M.N.E., "Evaluation Of Different Grafting Methods And Rootstocks In Watermelon Grown In Egypt",*Sci. Hort.*, 168,2014, pp. 145-150.

[7] Robinson, R.W., and Decker-Walters D.S., "Cultural Requirements, In: *Cucurbits"*, R.W. Robinsonand D.S. Decker-Walters, Eds., *CAB International*, Wallingford, UK, 1997, pp. 113–143.

[8] Sakata, Y., Takayoshi, O., and Mitsuhiro,S., The History And Present State Of The Grafting Of Cucurbitaceous Vegetables In Japan,*Acta Hort*. 731, 2007, pp. 159–170.

[9] Satoh, S.,"Inhibition of flowering of cucumber grafted on rooted squash stocks",*Physiol. Plant.* 97, 1996 pp. 440–444.

[10] Savvas D., Savva A., Ntatsi G., Ropokis A., Karapanos I., Krumbein A., Olympios C., "Effects of three commercial rootstocks on mineral nutrition, fruit yield, and quality of salinized tomato",*J. Plant Nutr. Soil Sci*. 174, 2011, pp. 154-162.